CORA Cork Open Research Archive
Cartlann Taighde Oscailte Chorcaí

Title	Worldwide trends in diabetes since 1980: a pooled analysis of 751 population-based studies with 4·4 million participants
Authors	NCD Risk Factor Collaboration (NCD-RisC);Walton, Janette
Publication date	2016-04-09
Original Citation	NCD Risk Factor Collaboration (2016) 'Worldwide trends in diabetes since 1980: a pooled analysis of 751 population-based studies with 4·4 million participants', The Lancet, 387 (10027), pp. 1513-1530. doi:10.1016/S0140-6736(16)00618-8
Type of publication	Article (peer-reviewed)
Link to publisher's version	10.1016/S0140-6736(16)00618-8
Rights	© 2016, NCD Risk Factor Collaboration. Open Access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY 4.0) - https://creativecommons.org/licenses/by/4.0/
Download date	2026-11-07 03:26:35
Item downloaded from	https://hdl.handle.net/10468/3351

UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Worldwide trends in diabetes since 1980: a pooled analysis of 751 population-based studies with 4·4 million participants

*NCD Risk Factor Collaboration (NCD-RisC)**

Lancet 2016; 387: 1513–30

Published Online
April 6, 2016
http://dx.doi.org/10.1016/S0140-6736(16)00618-8

This online publication has been corrected. The corrected version first appeared at thelancet.com on October 26, 2016

See Comment page 1485

See Perspectives page 1505

*NCD Risk Factor Collaboration members are listed at the end of the paper

Correspondence to:
Prof Majid Ezzati, School of Public Health, Imperial College London, London W2 1PG, UK
majid.ezzati@imperial.ac.uk

Summary

Background One of the global targets for non-communicable diseases is to halt, by 2025, the rise in the age-standardised adult prevalence of diabetes at its 2010 levels. We aimed to estimate worldwide trends in diabetes, how likely it is for countries to achieve the global target, and how changes in prevalence, together with population growth and ageing, are affecting the number of adults with diabetes.

Methods We pooled data from population-based studies that had collected data on diabetes through measurement of its biomarkers. We used a Bayesian hierarchical model to estimate trends in diabetes prevalence—defined as fasting plasma glucose of 7·0 mmol/L or higher, or history of diagnosis with diabetes, or use of insulin or oral hypoglycaemic drugs—in 200 countries and territories in 21 regions, by sex and from 1980 to 2014. We also calculated the posterior probability of meeting the global diabetes target if post-2000 trends continue.

Findings We used data from 751 studies including 4 372 000 adults from 146 of the 200 countries we make estimates for. Global age-standardised diabetes prevalence increased from 4·3% (95% credible interval 2·4–7·0) in 1980 to 9·0% (7·2–11·1) in 2014 in men, and from 5·0% (2·9–7·9) to 7·9% (6·4–9·7) in women. The number of adults with diabetes in the world increased from 108 million in 1980 to 422 million in 2014 (28·5% due to the rise in prevalence, 39·7% due to population growth and ageing, and 31·8% due to interaction of these two factors). Age-standardised adult diabetes prevalence in 2014 was lowest in northwestern Europe, and highest in Polynesia and Micronesia, at nearly 25%, followed by Melanesia and the Middle East and north Africa. Between 1980 and 2014 there was little change in age-standardised diabetes prevalence in adult women in continental western Europe, although crude prevalence rose because of ageing of the population. By contrast, age-standardised adult prevalence rose by 15 percentage points in men and women in Polynesia and Micronesia. In 2014, American Samoa had the highest national prevalence of diabetes (>30% in both sexes), with age-standardised adult prevalence also higher than 25% in some other islands in Polynesia and Micronesia. If post-2000 trends continue, the probability of meeting the global target of halting the rise in the prevalence of diabetes by 2025 at the 2010 level worldwide is lower than 1% for men and is 1% for women. Only nine countries for men and 29 countries for women, mostly in western Europe, have a 50% or higher probability of meeting the global target.

Interpretation Since 1980, age-standardised diabetes prevalence in adults has increased, or at best remained unchanged, in every country. Together with population growth and ageing, this rise has led to a near quadrupling of the number of adults with diabetes worldwide. The burden of diabetes, both in terms of prevalence and number of adults affected, has increased faster in low-income and middle-income countries than in high-income countries.

Funding Wellcome Trust.

Copyright © NCD Risk Factor Collaboration. Open Access article distributed under the terms of CC BY.

Introduction

Diabetes is an important cause of mortality, morbidity, and health-system costs in the world.[1,2] Therefore, there is an urgent need to implement population-based interventions that prevent diabetes, enhance its early detection, and use lifestyle and pharmacological interventions to prevent or delay its progression to complications. To motivate such actions, one of the global targets set after the 2011 UN High-Level Meeting on Non-Communicable Diseases (NCDs) is to halt, by 2025, the rise in the age-standardised adult prevalence of diabetes at its 2010 levels.[3] Valid and consistent estimates of diabetes prevalence over time are needed to evaluate the effect of interventions, compare trends in different countries, and measure progress towards the agreed target.

A previous study estimated trends in mean fasting plasma glucose from 1980 to 2008 and reported diabetes prevalence, but only as a secondary outcome and estimated based on mean fasting plasma glucose.[4] The International Diabetes Federation (IDF) periodically reports diabetes prevalence,[5,6] but does not analyse trends; uses some sources that are based solely on self-reported diabetes; and does not fully account for differences in diabetes definitions in different data sources,[7] even though diabetes prevalence varies depending on whether it is defined based on fasting plasma glucose, 2 h plasma glucose in an oral glucose tolerance test (2hOGTT), or haemoglobin A1c (HbA_{1c}).[8] Furthermore, it is not known how trends in prevalence, together with population growth and ageing, have affected the number of adults with diabetes. Our aim

Research in context

Evidence before this study

We searched MEDLINE (via PubMed) for articles published between Jan 1, 1950, and Dec 11, 2013, with the search terms ("Blood Glucose"[MAJR] OR "Diabetes Mellitus"[MAJR:NoExp] OR "Diabetes Mellitus, Type 2"[MAJR:NoExp] OR "Diabetes Mellitus, Type 1"[MAJR:NoExp] OR "Prediabetic state"[MAJR] OR "Hyperglycemia"[MAJR] OR "Hemoglobin A, Glycosylated"[MAJR]) AND ("Humans"[Mesh]). Articles were screened according to the inclusion and exclusion criteria described in the appendix (pp 2–6).

A few studies have reported diabetes trends in one or a few countries. A previous study reported diabetes prevalence trends to 2008 as a secondary outcome, which was estimated from mean fasting plasma glucose. This study was done before the global target on diabetes was agreed, hence there are no recent data. The International Diabetes Federation periodically reports diabetes prevalence but does not analyse trends, uses some sources that are only based on self-reported diabetes, and does not fully account for differences in diabetes definitions in different data sources.

Added value of this study

This study provides the lengthiest and most complete estimates of trends in adult diabetes prevalence worldwide. We achieved this level of detail by reanalysing and pooling hundreds of population-based sources with actual measurements of at least one diabetes biomarker and systematically converting all data sources to a common definition of diabetes. We also systematically projected recent trends into the future, and assessed the probability of achieving the global diabetes target.

Implications of all the available evidence

Since 1980, age-standardised diabetes prevalence in adults increased or at best remained unchanged in every country. The burden of diabetes, in terms of both prevalence and number of adults affected, has increased faster in low-income and middle-income countries than in high-income countries. If post-2000 trends continue, the probability of meeting the global diabetes target is lower than 1% for men and is 1% for women worldwide.

was to estimate worldwide trends in the prevalence and number of adults with diabetes. We also estimated the probability of achieving the global diabetes target.

Methods

Study design and definitions

We estimated trends in diabetes prevalence from 1980 to 2014, in 200 countries and territories organised into 21 regions, mostly on the basis of geography and national income (appendix pp 11–12). The exception was a region consisting of high-income English-speaking countries because cardiometabolic risk factors, especially body-mass index (BMI), an important risk factor for diabetes, have similar trends in these countries, which can be distinct from other countries in their geographical region. As the primary outcome, diabetes was defined as fasting plasma glucose of 7·0 mmol/L or higher, history of diagnosis with diabetes, or use of insulin or oral hypoglycaemic drugs. This definition of diabetes is used in the Global Monitoring Framework for NCDs;[3] it also relies more directly on data from population-based health-examination surveys, which, for logistical reasons, are more likely to measure fasting plasma glucose than 2hOGTT. Our analysis covered men and women aged 18 years or older, consistent with the Global Monitoring Framework for NCDs.[3]

See Online for appendix

Our study had three stages, each described in detail below and in the appendix (pp 2–8). First, we identified, accessed, and reanalysed population-based health-examination surveys that had measured at least one diabetes biomarker. We then converted diabetes prevalence in sources that had defined diabetes through 2hOGTT or HbA_{1c} or used a cutoff other than 7·0 mmol/L for fasting plasma glucose, to a corresponding prevalence based on the primary outcome as defined above. Finally, we applied a statistical model to the pooled data to estimate trends for all countries and years.

Data sources

We included data sources that were representative of a national, subnational, or community population and that had measured at least one of the following diabetes biomarkers: fasting plasma glucose, 2hOGTT, and HbA_{1c}. We did not use data from sources that relied entirely on self-reported history of diagnosis because this approach would miss undiagnosed diabetes, which forms a substantial share of all people with diabetes, especially in communities with little access to health care.[9–11] Our methods for identifying and accessing data sources are described in the appendix (pp 2–6).

History of diabetes diagnosis was established with survey-specific questions, such as "have you ever been told by a doctor or other health professional that you have diabetes?" or the combination of "do you now have, or have you ever had diabetes?" and "were you told by a doctor that you had diabetes?" Similarly, the use of diabetes drugs was established with survey-specific questions, such as "are you currently taking medication for diabetes or high blood sugar?" or the combination of "do you currently inject insulin for diabetes?" and "are you currently taking any medicines, tablets, or pills for diabetes?" Some surveys also verified medications with use of visual inspection or medical records, or had used these approaches to establish the use of diabetes drugs.

Conversion to a consistent definition of diabetes

9% of our data were from sources that had reported the prevalence of diabetes based on 2hOGTT or HbA_{1c} but not

fasting plasma glucose. Another 29% of data were from a previous global pooling study[4] or extracted from published reports and papers, and had used fasting plasma glucose but reported only mean plasma concentrations or a prevalence based on a cutoff other than 7·0 mmol/L (eg, ≥7·8 mmol/L). To correct for incomparability of definitions of diabetes, we used regressions that converted prevalence from these sources to our primary outcome. The dependent variable in each of these regressions, which are described in detail elsewhere[8] and presented in the appendix (pp 7–8 and 30–79), was the primary outcome (prevalence of fasting plasma glucose ≥7·0 mmol/L or history of diabetes diagnosis or use of diabetes drugs), and the main independent variable was a prevalence based on the definitions in at least one study that did not report the primary outcome but had some form of data on diabetes and glycaemia. The coefficients of these regressions were estimated from data sources with individual-level data, which could be used to calculate prevalence with both definitions. Details of conversion (or cross-walking) regressions, and their specification and coefficients, are presented in the appendix (pp 30–79). Datapoints based on fewer than 25 people were excluded. All regressions included terms for age, sex, country, income (natural logarithm of per-capita gross domestic product adjusted for purchasing power and inflation), and the year of study. When we used more than 400 datapoints to estimate the regression coefficients, the regressions also included regional random effects. Finally, we included interaction terms in the regressions if the interaction terms provided a better fit to the data as determined by the Bayesian Information Criterion.

Statistical analysis

The statistical model used to estimate diabetes prevalence by country, year, age, and sex is described in detail in a statistical paper and in related substantive papers.[12–14] In summary, we used a hierarchical probit model in which diabetes levels and trends in countries were nested in regional levels and trends, which were in turn nested in those of super-regions and worldwide. In this structure, estimates of diabetes levels and trends for each country and year were informed by the country's own data, if available, and by data from other years in the same country and in other countries, especially those in the same region, with data for similar time periods. The hierarchical structure borrows information to a greater degree when data are non-existent or weakly informative (eg, because they have a small sample size or are not national), and to a lesser extent in data-rich countries and regions.

The model incorporated non-linear time trends and age patterns, allowing the age pattern of diabetes to vary across populations such that the rise in prevalence with age would be steeper where diabetes prevalence is higher.[15] The model accounted for the fact that prevalence in subnational and community studies might systematically differ from nationally representative surveys, and also tends to have larger variation relative to the true values than national studies do. These features were implemented by including data-driven fixed-effect and random-effect terms for subnational and community data. The fixed effects adjust for systematic differences between subnational or community studies and national studies. The random effects allow national data to have larger influence on the estimates than subnational or community data with similar sample sizes. The model also accounted for rural–urban differences in diabetes prevalence, through the use of data-driven fixed effects for rural-only and urban-only studies. These rural and urban effects were weighted by the difference between study-level and country-level urbanisation. The statistical model also included country-level covariates that help predict diabetes prevalence, including average number of years of education, proportion of national population living in urban areas, a summary measure of availability of different food types for human consumption, and age-standardised adult mean BMI.[16] The covariate on food availability was constructed from the food balance sheets of the Food and Agriculture Organization of the UN, with use of principal component analysis. Details of the variables, data, and methods are provided elsewhere.[13,17]

We fitted this Bayesian model with the Markov chain Monte Carlo (MCMC) algorithm. Convergence was monitored and 5000 post-burn-in samples were obtained from the posterior distribution of model parameters, which were then used to obtain the posterior distributions of diabetes prevalence. The reported credible intervals (CrI) represent the 2·5–97·5 percentiles of the posterior distributions.

We report the posterior probability that an estimated increase or decrease represents a truly increasing or decreasing trend. Posterior probability would be 0·50 in a country or region in which an increase is statistically indistinguishable from a decrease; a larger posterior probability indicates more certainty in a change in prevalence. Additionally, we calculated the posterior probability of meeting the global target of no increase in diabetes prevalence if post-2000 trends continue. All analyses were done separately by sex. We used the WHO standard population for age standardisation.

We examined how well our model estimates diabetes prevalence in countries and years without data by withholding some of the data from the model and calculating the differences between the held-out data and the estimates—ie, the error in estimates (appendix pp 9–10). This validation test shows that our model performed very well; the median errors were close to zero globally, and the median absolute errors were small (appendix pp 80–84).

Role of funding source

The funder of the study had no role in study design, data collection, analysis, interpretation, or writing of the report. Country and Regional Data Group

members, BZ, JB, and MDC had full access to the data in the study and the corresponding author had final responsibility for the decision to submit for publication.

Results

We used data from 751 population-based measurement surveys and studies, which included 4 372 000 participants aged 18 years or older. The studies covered 146 (73%) of the 200 countries and territories for which estimates were made (appendix pp 97–98). These 146 countries contained 90% of the world's adult population in 2014. Regionally, the average number of data sources per country ranged from less than one in central Africa to 24 in the high-income Asia Pacific region. 21 (39%) of the 54 countries without data were in sub-Saharan Africa, 11 (20%) in the Caribbean, seven (13%) in central Europe, four (7%) in central Asia, and the remaining 11 (20%) in other regions. Nearly a third of surveys and studies (242) were from years before 2000, and the other two-thirds (509) for 2000 and later.

From 1980 to 2014, worldwide age-standardised adult diabetes prevalence increased from 4·3% (95% CrI 2·4–7·0) to 9·0% (7·2–11·1) in men (figure 1) and from 5·0% (2·9–7·9) to 7·9% (6·4–9·7) in women (figure 2); the posterior probabilities that these were true increases were 0·994 and 0·954, respectively. Over these years, crude adult prevalence increased from 3·6% (2·0–5·9) to 8·8% (7·0–10·8) in men, and from 4·7% (2·7–7·4) to 8·2% (6·6–9·9) in women (figures 1, 2).

Age-standardised diabetes prevalence in women in 2014 was lowest in northwestern and southwestern Europe, which each had a prevalence of less than 5% (figure 2). The lowest prevalence in adult men was also in northwestern Europe, at 5·8% (95% CrI 3·6–8·7). Crude adult prevalence in northwestern Europe was 5·9% (3·8–8·6) for women and 7·9% (5·1–11·5) for men in 2014. At the other extreme, age-standardised diabetes prevalence was higher than 20% in adult men and women in Polynesia and Micronesia, and around 15% in Melanesia and in the Middle East and north Africa.

Over the 35 years of analysis, there was almost no change in age-standardised diabetes prevalence in women in northwestern and southwestern Europe, and only a small non-significant increase in central and eastern Europe (figure 2). Adult men in northwestern Europe also had a smaller rise in prevalence than did other regions (figure 1). By contrast, age-standardised prevalence in Polynesia and Micronesia rose by 15·0 (95% CrI 5·5–25·9) percentage points in adult men (posterior probability >0·999) and by 14·9 (4·5–26·2) percentage points in adult women (posterior probability 0·998). Crude adult prevalence increased more than age-standardised prevalence in regions that had substantial ageing—eg, in high-income regions.

In 1980, age-standardised adult diabetes prevalence was lower than 3% in men in 32 countries and in women in 23 countries (figures 3, 4). In the same year, age-standardised prevalence was higher than 12% in adult men and women in a few islands in Polynesia and Micronesia and women in Kuwait, reaching 25% in men and women in Nauru. By 2014, women in only one country had an age-standardised adult prevalence lower than 3% and women in only nine countries had one lower than 4%, with the lowest prevalence estimated in some countries in northwestern Europe such as Switzerland, Austria, Denmark, Belgium, and the Netherlands (figure 4). In the same year, age-standardised prevalence in adult men was higher than 4% in every country (figure 3); the lowest estimated prevalences were in the same northwestern European countries as those for women and in a few countries in east Africa and southeast Asia. At the other extreme, age-standardised adult diabetes prevalence in 2014 was 31% (95% CrI 19–44) in men and 33% (21–47) in women in American Samoa, and was also higher than 25% in men and women in some other islands in Polynesia and Micronesia (figures 3, 4; appendix pp 85–94).

No country had a statistically significant decrease in diabetes prevalence from 1980 to 2014 (figure 5), although the relative increase over these 35 years was lower than 20% in nine countries for men, mostly in northwestern Europe, and in 39 countries for women. Over the same period, age-standardised adult prevalence of diabetes at least doubled for men in 120 countries and for women in 87 countries, with a posterior probability of 0·887 or higher. The largest absolute increases in age-standardised adult prevalence were in Oceania, exceeding 15 percentage points in some countries, followed by the Middle East and north Africa (figure 5).

Worldwide, if post-2000 trends continue, the probability of meeting the global diabetes target for men is lower than 1%; for women it is 1%. Only nine countries, mostly in northwestern Europe, had a 50% or higher probability of meeting the global target for men, as did 29 countries for women (figure 6). Rather, if post-2000 trends continue, age-standardised prevalence of diabetes in 2025 will be 12·8% (95% CrI 8·3–19·6) in men and 10·4% (7·1–15·1) in women. The number of adults with diabetes will surpass 700 million.

The number of adults with diabetes in the world increased from 108 million in 1980, to 422 million in 2014 (figure 7). East Asia and south Asia had the largest rises of absolute numbers, and had the largest number of people with diabetes in 2014: 106 million and 86 million, respectively. 39·7% (n=124·8 million) of the rise in the number of people with diabetes was due to population growth and ageing, 28·5% (n=89·7 million) due to the rise in age-specific prevalences, and the remaining 31·8% (n=99·9 million) due to the interaction of the two—ie, an older and larger population with higher age-specific prevalences (figure 7).

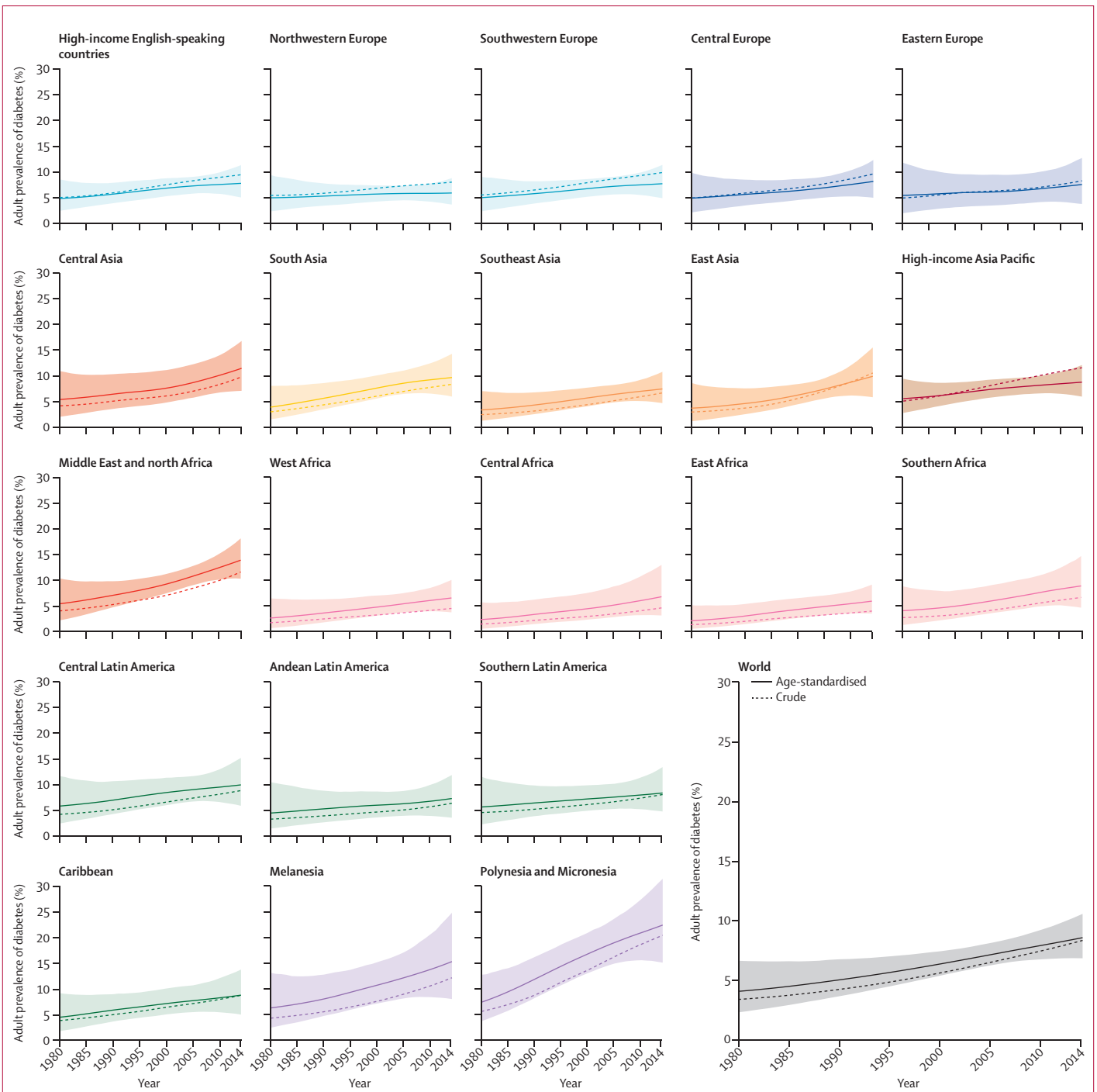


Figure 1: **Trends in age-standardised and crude prevalence of diabetes for men by region**
The lines (solid for age-standardised and dashed for crude) show the posterior mean estimates; the shaded area shows the 95% credible intervals for age-standardised prevalence. For trends and numerical results by country see appendix pp 85–94, 103–170.

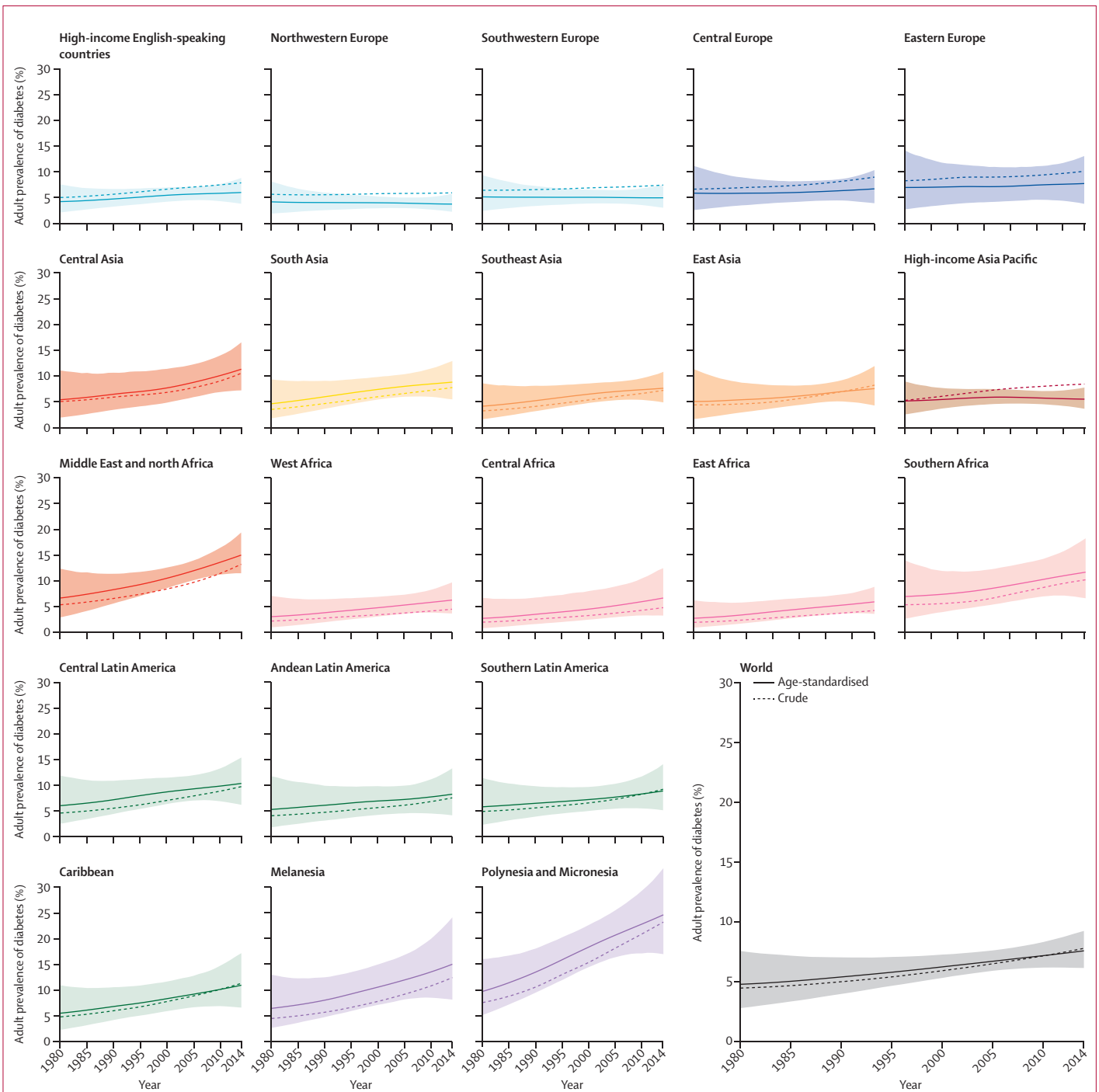


Figure 2: **Trends in age-standardised and crude prevalence of diabetes for women by region**
The lines (solid for age-standardised and dashed for crude) show the posterior mean estimates; the shaded area shows the 95% credible intervals for age-standardised prevalence. For trends and numerical results by country see appendix pp 85–94, 103–170.

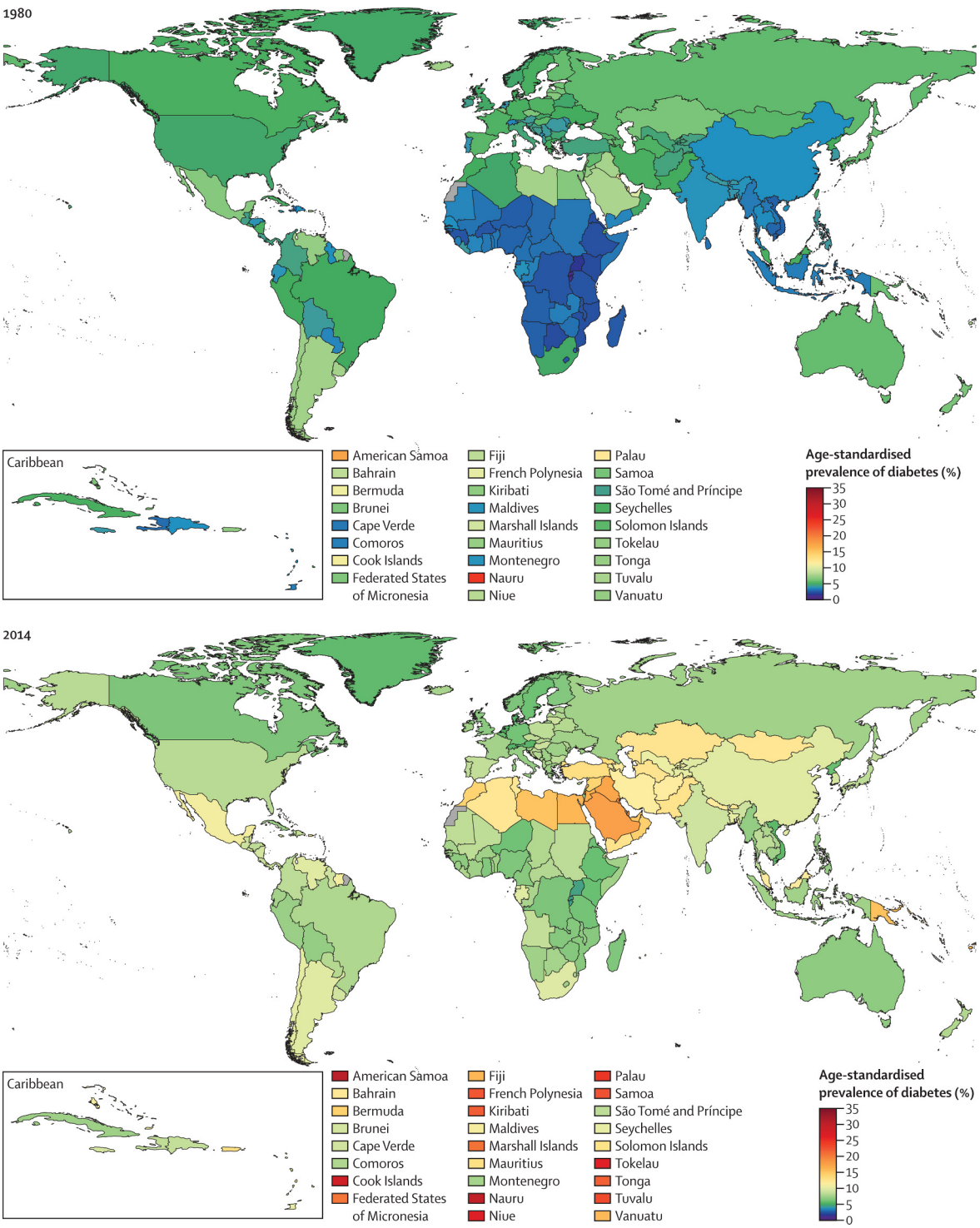


***Figure* 3 : Age-standardised prevalence of diabetes in adult men by country in 1980 and 2014**

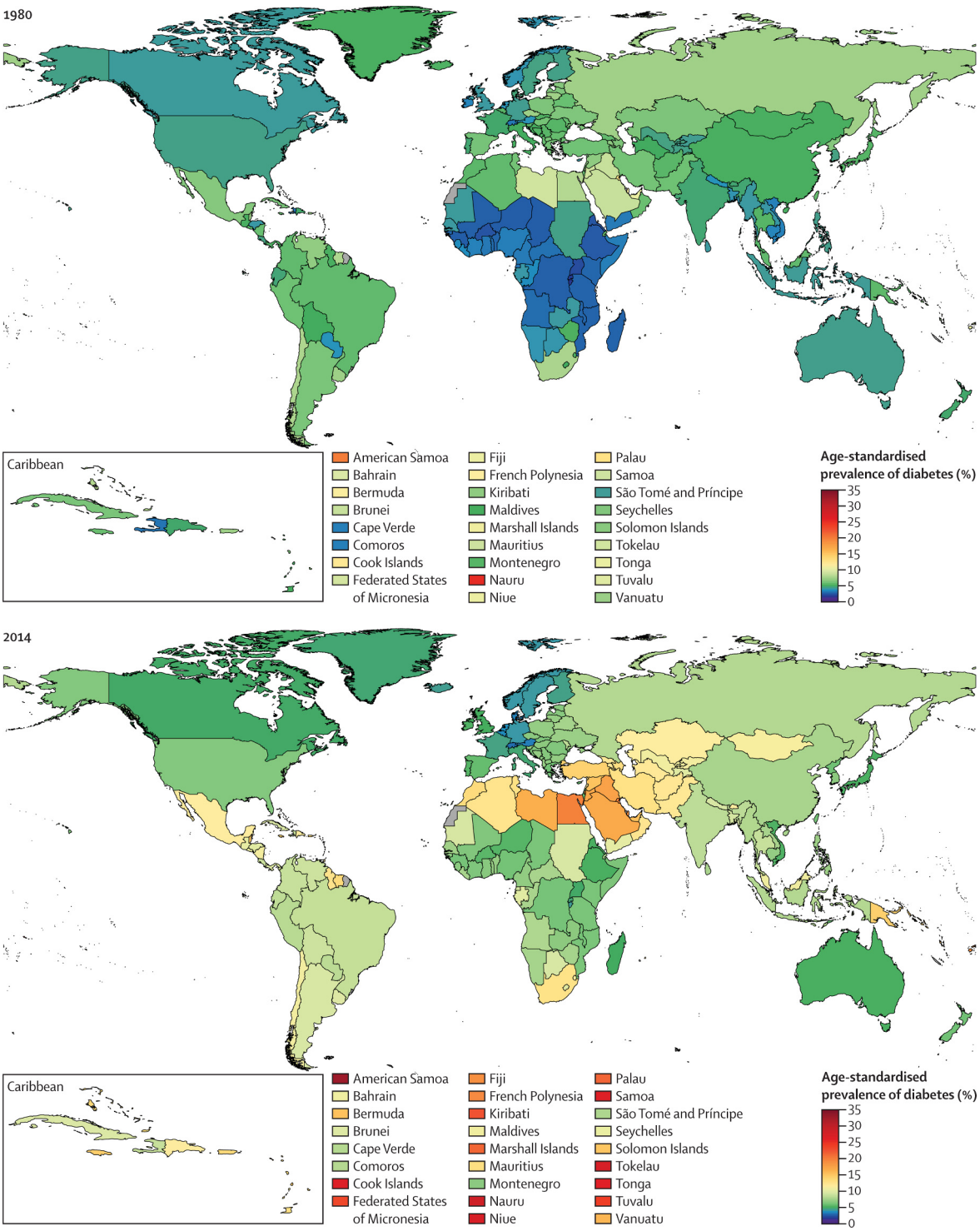


Figure 4: **Age-standardised prevalence of diabetes in adult women by country in 1980 and 2014**

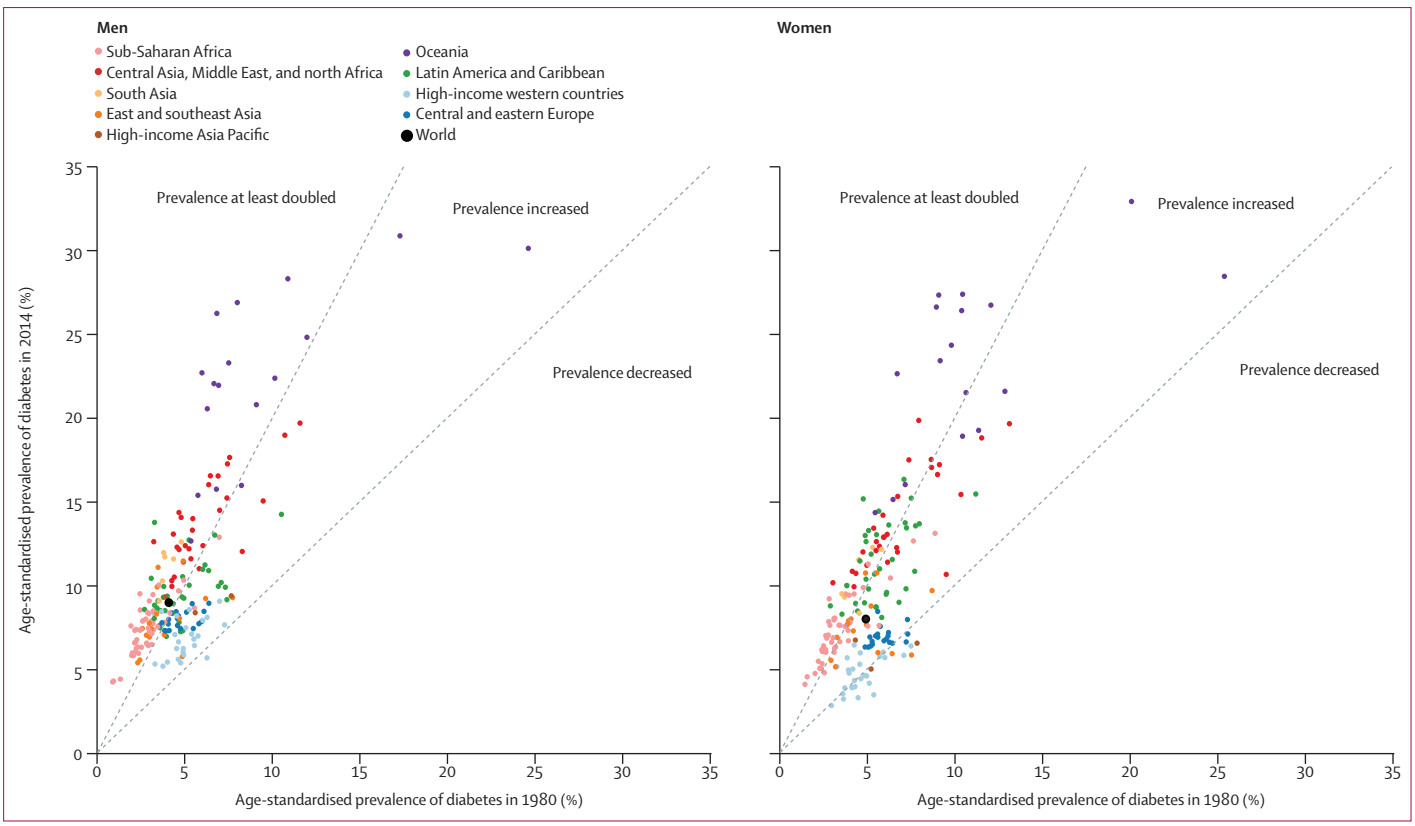


Figure 5: **Comparison of age-standardised prevalence of diabetes in adults in 1980 and 2014**

Half of adults with diabetes in 2014 lived in five countries: China, India, the USA, Brazil, and Indonesia (figure 8). These countries also accounted for one half of the world's adult population in 2014. Although the top three countries on this list remained unchanged from 1980 to 2014, the global share of adults with diabetes who live in China and India increased, by contrast with the USA, where the share decreased. The changes in the share of adults with diabetes from India and the USA might be partly because of the changes in their shares. However, the share of the adult population of China remained virtually unchanged, while its share of the adult population with diabetes increased. Low-income and middle-income countries, including Indonesia, Pakistan, Mexico, and Egypt, replaced European countries, including Germany, Ukraine, Italy, and the UK, on the list of the top ten countries with most adults with diabetes (figure 8).

Discussion

We used population-based data to document the global diabetes epidemic since 1980. Over this period, age-standardised diabetes prevalence in adults increased or at best remained unchanged in every country. It more than doubled in men and increased by 60% in women worldwide, shifting from an excess prevalence in women in 1980, to a higher male prevalence in 2014.[18,19] This rise in prevalence has been compounded by population growth and ageing, nearly quadrupling the number of adults with diabetes over these 35 years. The burden of diabetes, both in terms of prevalence and number of adults with diabetes, increased at a greater rate in low-income and middle-income countries than in high-income countries. The highest national prevalences—generally those in Oceania, and the Middle East and north Africa—are now five to ten times greater than the lowest prevalences, which are in some western European countries.

Our estimates of diabetes prevalence for 2013 for the world as a whole are similar to those by the IDF for the same year,[5,6] but there were differences between our estimates and those from the IDF in some countries and regions. In particular, we estimated a higher age-standardised prevalence of diabetes in most countries in the Middle East and north Africa than the IDF. The IDF does not estimate trends, hence we could not compare trend estimates. Our finding that diabetes prevalence was low in much of Asia and sub-Saharan Africa in the 1980s and 1990s is consistent with other studies that found low prevalences in these regions in those decades.[20,21] Our finding that diabetes prevalence did not increase in continental western Europe (especially in

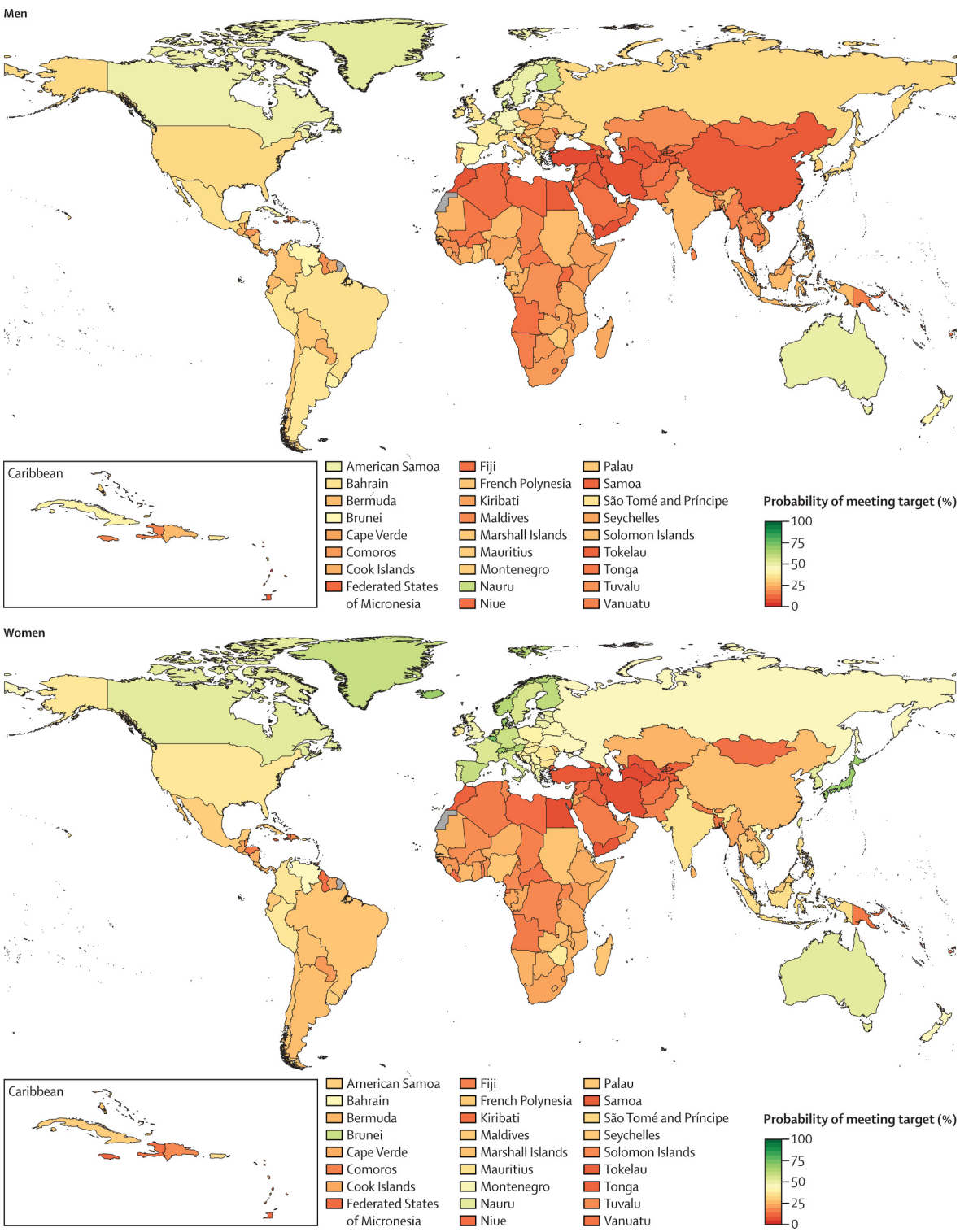


Figure 6: **Probability of achieving the target of halting the rise of diabetes in adults by 2025 at its 2010 levels by sex and country if post-2000 trends continue**

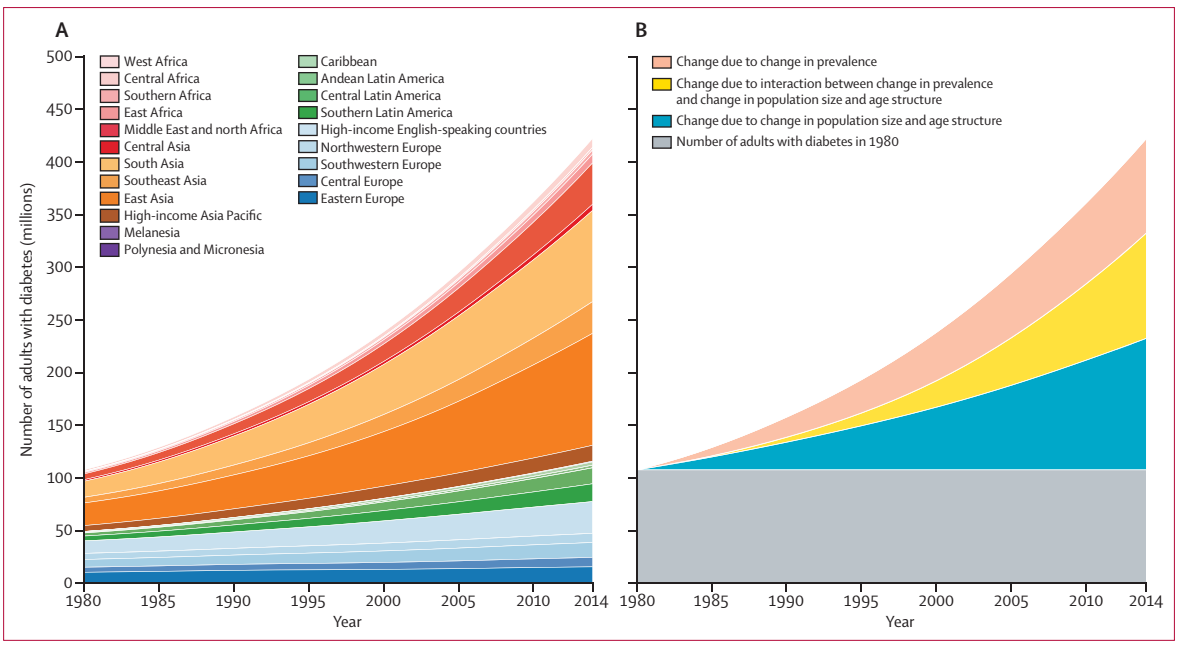


***Figure 7*: Trends in the number of adults with diabetes by region (A) and decomposed into the contributions of population growth and ageing, rise in prevalence, and interaction between the two (B)**
For results by region see appendix pp 101–102.

northwestern Europe) is also consistent with reports from Sweden,[22] Germany,[23] and Switzerland[24] that covered a subset of our analysis years. Similarly, our estimated increases for high-income English-speaking countries are consistent with studies that had analysed repeated population-based surveys in the USA[25] and the UK.[26,27] A meta-analysis of 15 studies in Japan reported no increase in diabetes prevalence,[28] as observed in our analysis. Several recent reports have also documented similar increases in diabetes prevalence to those observed in our analysis in China,[29,30] India,[31–34] Iran,[35] Turkey,[36] and Saudi Arabia.[37] Finally, our finding of the slower rise in diabetes prevalence in women compared with men is consistent with historical data in a few high-income countries.[18,19]

The larger rise in diabetes prevalence in low-income and middle-income countries than in high-income countries, and the mostly flat trends in Europe (especially in northwestern Europe), might be caused by several factors. First, adiposity, which is an important risk factor for diabetes, has increased substantially more, and is now higher, in many low-income and middle-income countries than in continental Europe and high-income Asia Pacific countries, especially in women.[16] Second, regional differences in diabetes could be due in part to differences in genetic susceptibility or phenotypic variations arising from inadequate fetal and childhood nutrition and growth; earlier onset of β-cell dysfunction might be one differentiating characteristic of Asian populations compared with European populations.[38–42] Third, better-resourced health systems in Europe and other high-income countries might identify people at high risk of diabetes at an earlier stage, and use lifestyle and dietary modification or drugs to prevent or delay its onset.[43–45] At the moment, information on the proportion of people with, or at risk of, diabetes who are diagnosed and receive treatment is limited to a few countries. Consistent information on diagnosis and treatment coverage will become increasingly important as universal health coverage becomes a central theme of global health efforts, and should be a focus of future analyses. Finally, in addition to total caloric intake and adiposity, dietary composition and physical activity might affect diabetes risk and contribute to differences in regional trends.[46] These and other potential reasons for the divergent trends in diabetes prevalence should be investigated. Furthermore, the shift in diabetes burden from women towards men might be due to men having higher prevalences of some risk factors for diabetes, such as smoking, or being at risk of diabetes at lower BMI levels than are women.[18,19]

The strengths of our study include its scope of making consistent and comparable estimates of trends in diabetes prevalence and of the probabilities of meeting the global diabetes target. We used an unprecedented amount of population-based data, which came from countries in which 90% of the global adult population lives. We used only data from studies that had measured a diabetes biomarker to avoid bias in self-reported data. Data were analysed according to a common protocol, and the characteristics and quality of data sources were rigorously verified through repeated checks by Collaborating Group members from each country. We pooled data using a statistical model that took into account the epidemiological features of diabetes, including non-linear time trends and age associations, and used all available data while giving

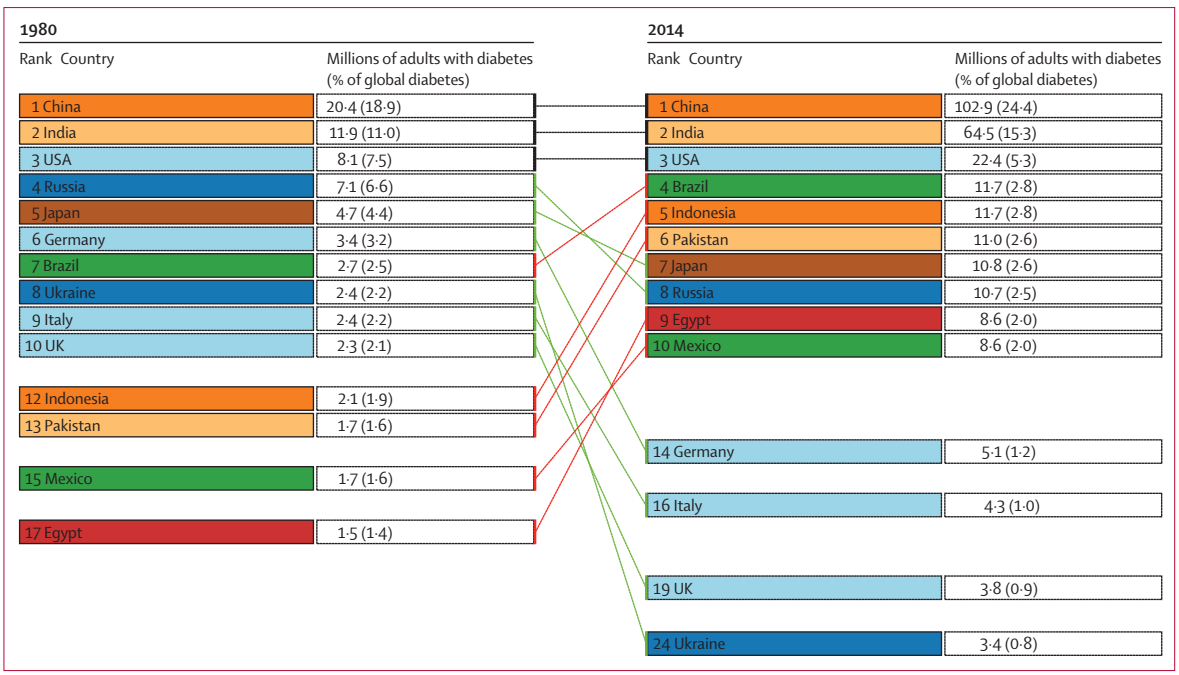


Figure 8: **Ten countries with the largest number of adults with diabetes in 1980 and 2014**
Colours for each country indicate its region.

more weight to national data than to subnational and community sources.

Despite our extensive efforts to identify and access worldwide population-based data, some countries had no or few data sources, especially those in sub-Saharan Africa, the Caribbean, central Asia, and central Europe. Estimates for these countries relied mostly or entirely on the statistical model, which shares information across countries and regions through its hierarchy and through predictive covariates. The absence or scarcity of data is reflected in wider uncertainty intervals of our estimates for these countries and regions (figures 1, 2; appendix pp 103–170). Diabetes was reported using a definition other than our primary outcome in some data sources, either because fasting plasma glucose was not measured or because individual-level data could not be accessed. To overcome this issue, we systematically used the reported metrics to estimate our primary outcome; the cross-walking regressions used for this purpose had good predictive accuracy. The share of studies that used a portable device (instead of laboratory analysis) for measuring diabetes biomarkers has increased over time. We do not expect the rise in the use of portable devices to affect the estimated levels and trends because their higher use in population-based research is partly due to increasing similarity between their measurements and those in laboratory-based tests,[47,48] facilitated by more advanced technologies and better standardisation. Further, although our primary outcome is consistent with the NCD Global Monitoring Framework, diabetes prevalence based on fasting plasma glucose alone is lower than that based on the combination of fasting plasma glucose and 2hOGTT.[8] Age-standardised adult diabetes prevalence would be 10·0% (95% CrI 8·0–12·5) for men and 8·8% (7·2–10·7) for women, worldwide, if we applied the cross-walking regression (similar to those in appendix pp 34–79) to convert our estimates to prevalence of diabetes defined as fasting plasma glucose of 7·0 mmol/L or higher, or 2hOGTT of 11·1 mmol/L or higher, or history of diagnosis with diabetes or use of insulin or oral hypoglycaemic drugs. Finally, the survey data did not separate type 1 and type 2 diabetes because distinguishing between these disorders is difficult in adults.[49–51] However, most (85–95%) cases of diabetes in adults are type 2,[50,52] so the observed rise in diabetes prevalence in adults is quite likely due to increases in type 2 diabetes.

Diabetes and its macrovascular and microvascular complications account for more than 2 million deaths every year,[1] and are the seventh leading cause of disability worldwide.[53] Diabetes is also a risk factor for tuberculosis, another disease with large burden in low-income and middle-income countries.[54] Diabetes and its complications impose substantial economic costs on patients, their families, health systems, and national economies because of direct costs of treatment and loss of work and wages.[2] On the basis of estimates for the number of people with diabetes in 2014 in this study, and cost estimates from a systematic review,[2] the direct annual cost of diabetes in the world is Intl$825 billion, with China ($170 billion), the USA ($105 billion), India ($73 billion), and Japan ($37 billion) having the largest

costs. Nearly 60% of the global costs are borne by low-income and middle-income countries, where substantial parts of treatment costs are paid out-of-pocket,[2] which affects treatment utilisation and adherence and leads to financial hardship for patients and their families.

Glucose reduction with lifestyle modification and drugs in people with diabetes, especially if started early, can delay progression to microvascular complications.[55–57] Although evidence is mixed from trials on the macrovascular benefits of intensive glucose lowering,[55,58–60] long-term glycaemic control and lowering blood pressure and serum cholesterol also reduce the risk of adverse cardiovascular outcomes.[61,62] However, the effectiveness of these interventions at the population level has been slight, both because many diabetes cases remain undiagnosed[9–11] and because adherence to treatment is typically lower in general populations than in those enrolled in clinical trials.[63–65]

Efforts to reduce the global health and economic burden of diabetes should emphasise prevention of diabetes or delaying its onset, through enhancing healthy behaviours and diets at the population level, and early detection and management of high-risk individuals. There has been little success in preventing obesity,[16] the most important risk factor for diabetes, at the population level although the global target on obesity could engender new efforts and policy innovations. As these policies are implemented, identifying people at high risk of diabetes—especially those with impaired glucose tolerance—through the primary care system, using advice and support to induce and maintain lifestyle change, possibly together with drugs such as metformin, might be the only short-term approach for global diabetes prevention.[44,64,66,67] Such programmes have been implemented in a few high-income and middle-income countries,[45,68,69] but their success elsewhere requires a financially accessible primary care system that prioritises diabetes prevention and management and is staffed and resourced to support lifestyle change and improve access to and adherence to medication.[10,43,45,64,68,70]

Contributors

ME and GD designed the study and oversaw research. Members of the Country and Regional Data Group collected and reanalysed data, and checked pooled data for accuracy of information about their study and other studies in their country. BZ, YL, KH, and MDC led data collection. BZ, JB, and YL led the statistical analysis and prepared results. Members of the Pooled Analysis and Writing Group collated data, checked all data sources in consultation with the Country and Regional Data Group, analysed pooled data, and prepared results. ME wrote the first draft of the report with input from other members of Pooled Analysis and Writing Group. Members of Country and Regional Data Group commented on the draft report.

NCD Risk Factor Collaboration

*Pooled Analysis and Writing (*equal contribution)*—Bin Zhou (Imperial College London, UK)*; Yuan Lu (Harvard T H Chan School of Public Health, USA)*; Kaveh Hajifathalian (Harvard T H Chan School of Public Health, USA)*; James Bentham (Imperial College London, UK)*; Mariachiara Di Cesare (Imperial College London, UK; Middlesex University, UK)*; Goodarz Danaei (Harvard T H Chan School of Public Health, USA)*; Honor Bixby (Imperial College London, UK); Melanie J Cowan (World Health Organization, Switzerland); Mohammed K Ali (Emory University, USA); Cristina Taddei (University of Florence, Italy); Wei-Cheng Lo (National Taiwan University, Taiwan); Barbara Reis-Santos (Universidade Federal de Pelotas, Brazil); Gretchen A Stevens (World Health Organization, Switzerland); Leanne M Riley (World Health Organization, Switzerland); J Jaime Miranda (Universidad Peruana Cayetano Heredia, Peru); Prof Peter Bjerregaard (University of Southern Denmark, Denmark; University of Greenland, Greenland); Prof Juan A Rivera (Instituto Nacional de Salud Pública, Mexico); Heba M Fouad (World Health Organization Regional Office for the Eastern Mediterranean, Egypt); Prof Guansheng Ma (Peking University, China); Prof Jean Claude N Mbanya (University of Yaoundé 1, Cameroon); Prof Stephen T McGarvey (Brown University, USA); Viswanathan Mohan (Madras Diabetes Research Foundation, India); Prof Altan Onat (Istanbul University, Turkey); Aida Pilav (Federal Ministry of Health, Bosnia and Herzegovina); Prof Ambady Ramachandran (India Diabetes Research Foundation, India); Prof Habiba Ben Romdhane (University Tunis El Manar, Tunisia); Christopher J Paciorek (University of California, Berkeley, USA); James E Bennett (Imperial College London, UK); Prof Majid Ezzati (Imperial College London, UK).

*Country and Regional Data (*equal contribution; listed alphabetically)*—Ziad A Abdeen (Al-Quds University, Palestine)*; Khalid Abdul Kadir (Monash University Malaysia, Malaysia)*; Niveen M Abu-Rmeileh (Birzeit University, Palestine)*; Benjamin Acosta-Cazares (Instituto Mexicano del Seguro Social, Mexico)*; Robert Adams (The University of Adelaide, Australia)*; Wichai Aekplakorn (Mahidol University, Thailand)*; Carlos A Aguilar-Salinas (Instituto Nacional de Ciencias Médicas y Nutricion, Mexico)*; Charles Agyemang (University of Amsterdam, Netherlands)*; Alireza Ahmadvand (Non-Communicable Diseases Research Center, Iran)*; Amani Rashed Al-Othman (Kuwait Institute for Scientific Research, Kuwait)*; Ala'a Alkerwi (Luxembourg Institute of Health, Luxembourg)*; Philippe Amouyel (Lille University and Hospital, France)*; Antoinette Amuzu (London School of Hygiene & Tropical Medicine, UK)*; Lars Bo Andersen (University of Southern Denmark, Denmark)*; Sigmund A Anderssen (Norwegian School of Sport Sciences, Norway)*; Ranjit Mohan Anjana (Madras Diabetes Research Foundation, India)*; Hajer Aounallah-Skhiri (National Institute of Public Health, Tunisia)*; Tahir Aris (Ministry of Health Malaysia, Malaysia)*; Nimmathota Arlappa (Indian Council of Medical Research, India)*; Dominique Arveiler (Strasbourg University and Hospital, France)*; Felix K Assah (University of Yaoundé 1, Cameroon)*; Mária Avdicová (Regional Authority of Public Health, Banska Bystrica, Slovakia)*; Fereidoun Azizi (Shahid Beheshti University of Medical Sciences, Iran)*; Nagalla Balakrishna (Indian Council of Medical Research, India)*; Piotr Bandosz (Medical University of Gdansk, Poland)*; Carlo M Barbagallo (University of Palermo, Italy)*; Alberto Barceló (Pan American Health Organization, USA)*; Anwar M Batieha (Jordan University of Science and Technology, Jordan)*; Louise A Baur (University of Sydney, Australia)*; Habiba Ben Romdhane (University Tunis El Manar, Tunisia)*; Mikhail Benet (University Medical Science, Cuba)*; Antonio Bernabe-Ortiz (Universidad Peruana Cayetano Heredia, Peru)*; Sumit Bharadwaj (Chirayu Medical College, India)*; Santosh K Bhargava (Sunder Lal Jain Hospital, India)*; Yufang Bi (Shanghai Jiao-Tong University School of Medicine, China)*; Peter Bjerregaard (University of Southern Denmark, Denmark; University of Greenland, Greenland)*; Espen Bjertness (University of Oslo, Norway)*; Marius B Bjertness (University of Oslo, Norway)*; Cecilia Björkelund (University of Gothenburg, Sweden)*; Anneke Blokstra (National Institute for Public Health and the Environment, Netherlands)*; Simona Bo (University of Turin, Italy)*; Bernhard O Boehm (Nanyang Technological University, Singapore)*; Carlos P Boissonnet (Centro de Educación Médica e Investigaciones Clínicas, Argentina)*; Pascal Bovet (Ministry of Health, Seychelles; University of Lausanne, Switzerland)*; Imperia Brajkovich (Universidad Central de Venezuela, Venezuela)*; Juergen Breckenkamp (Bielefeld University, Germany)*; Hermann Brenner (German Cancer Research Center, Germany)*; Lizzy M Brewster (University of Amsterdam, Netherlands)*; Garry R Brian (The Fred Hollows Foundation New Zealand, New Zealand)*; Graziella Bruno (University of Turin, Italy)*; Anna Bugge (University of Southern Denmark,

Denmark)*; Antonio Cabrera de León (University La Laguna, Spain)*; Günay Can (Istanbul University, Turkey)*; Ana Paula C Cândido (Universidade Federal de Juiz de Fora, Brazil)*; Vincenzo Capuano (Cardiologia di Mercato S Severino, Italy)*; Axel C Carlsson (Karolinska Institutet, Sweden)*; Maria J Carvalho (University of Porto, Portugal)*; Felipe F Casanueva (Santiago de Compostela University, Spain)*; Juan-Pablo Casas (University College London, UK)*; Carmelo A Caserta (Associazione Calabrese di Epatologia, Italy)*; Katia Castetbon (French Institute for Health Surveillance, France)*; Snehalatha Chamukuttan (India Diabetes Research Foundation, India)*; Nishi Chaturvedi (University College London, UK)*; Chien-Jen Chen (Academia Sinica, Taiwan)*; Fangfang Chen (Capital Institute of Pediatrics, China)*; Shuohua Chen (Kailuan General Hospital, China)*; Ching-Yu Cheng (Duke-NUS Graduate Medical School, Singapore)*; Angela Chetrit (The Gertner Institute for Epidemiology and Health Policy Research, Israel)*; Shu-Ti Chiou (Ministry of Health and Welfare, Taiwan)*; Yumi Cho (Korea Centers for Disease Control and Prevention, Republic of Korea)*; Jerzy Chudek (Medical University of Silesia, Poland)*; Renata Cifkova (Charles University in Prague, Czech Republic)*; Frank Claessens (Katholieke Universiteit Leuven, Belgium)*; Hans Concin (Agency for Preventive and Social Medicine, Austria)*; Cyrus Cooper (University of Southampton, UK)*; Rachel Cooper (University College London, UK)*; Simona Costanzo (IRCCS Istituto Neurologico Mediterraneo Neuromed, Italy)*; Dominique Cottel (Institut Pasteur de Lille, France)*; Chris Cowell (Westmead University of Sydney, Australia)*; Ana B Crujeiras (CIBEROBN, Spain)*; Graziella D'Arrigo (National Council of Research, Italy)*; Jean Dallongeville (Institut Pasteur de Lille, France)*; Rachel Dankner (The Gertner Institute for Epidemiology and Health Policy Research, Israel)*; Luc Dauchet (Lille University Hospital, France)*; Giovanni de Gaetano (IRCCS Istituto Neurologico Mediterraneo Neuromed, Italy)*; Stefaan De Henauw (Ghent University, Belgium)*; Mohan Deepa (Madras Diabetes Research Foundation, India)*; Abbas Dehghan (Erasmus Medical Center Rotterdam, Netherlands)*; Valerie Deschamps (French Institute for Health Surveillance, France)*; Klodian Dhana (Erasmus Medical Center Rotterdam, Netherlands)*; Augusto F Di Castelnuovo (IRCCS Istituto Neurologico Mediterraneo Neuromed, Italy)*; Shirin Djalalinia (Non-Communicable Diseases Research Center, Iran)*; Kouamelan Doua (Ministère de la Santé et de la Lutte Contre le Sida, Côte d'Ivoire)*; Wojciech Drygas (The Cardinal Wyszynski Institute of Cardiology, Poland)*; Yong Du (Robert Koch Institute, Germany)*; Vilnis Dzerve (University of Latvia, Latvia)*; Eruke E Egbagbe (University of Benin, Nigeria)*; Robert Eggertsen (University of Gothenburg, Sweden)*; Jalila El Ati (National Institute of Nutrition and Food Technology, Tunisia)*; Roberto Elosua (Institut Hospital del Mar d'Investigacions Mèdiques, Spain)*; Rajiv T Erasmus (University of Stellenbosch, South Africa)*; Cihangir Erem (Karadeniz Technical University, Turkey)*; Gul Ergor (Dokuz Eylul University, Turkey)*; Louise Eriksen (University of Southern Denmark, Denmark)*; Jorge Escobedo-de la Peña (Instituto Mexicano del Seguro Social, Mexico)*; Caroline H Fall (University of Southampton, UK)*; Farshad Farzadfar (Tehran University of Medical Sciences, Iran)*; Francisco J Felix-Redondo (Centro de Salud Villanueva Norte, Spain)*; Trevor S Ferguson (The University of the West Indies, Jamaica)*; Daniel Fernández-Bergés (Hospital Don Benito-Villanueva de la Serena, Spain)*; Marika Ferrari (Council for Agricultural Research and Economics, Italy)*; Catterina Ferreccio (Pontificia Universidad Católica de Chile, Chile)*; Edith JM Feskens (Wageningen University, The Netherlands)*; Joseph D Finn (University of Manchester, UK)*; Bernhard Föger (Agency for Preventive and Social Medicine, Austria)*; Leng Huat Foo (Universiti Sains Malaysia, Malaysia)*; Ann-Sofie Forslund (Luleå University, Sweden)*; Heba M Fouad (World Health Organization Regional Office for the Eastern Mediterranean, Egypt)*; Damian K Francis (The University of the West Indies, Jamaica)*; Maria do Carmo Franco (Federal University of São Paulo, Brazil)*; Oscar H Franco (Erasmus Medical Center Rotterdam, Netherlands)*; Guillermo Frontera (Hospital Universitario Son Espases, Spain)*; Takuro Furusawa (Kyoto University, Japan)*; Zbigniew Gaciong (Medical University of Warsaw, Poland)*; Sarah P Garnett (University of Sydney, Australia)*; Jean-Michel Gaspoz (Geneva University Hospitals, Switzerland)*; Magda Gasull (CIBER en Epidemiología y Salud Pública, Spain)*; Louise Gates (Australian Bureau of Statistics, Australia)*; Johanna M Geleijnse (Wageningen University, Netherlands)*; Anoosheh Ghasemian (Non-Communicable Diseases Research Center, Iran)*; Anup Ghimire (B P Koirala Institute of Health Sciences, Nepal)*; Simona Giampaoli (Istituto Superiore di Sanità, Italy)*; Francesco Gianfagna (University of Insubria, Italy)*; Jonathan Giovannelli (Lille University Hospital, France)*; Aleksander Giwercman (Lund University, Sweden)*; Marcela Gonzalez Gross (Universidad Politécnica de Madrid, Spain)*; Juan P González Rivas (The Andes Clinic of Cardio-Metabolic Studies, Venezuela)*; Mariano Bonet Gorbea (National Institute of Hygiene, Epidemiology and Microbiology, Cuba)*; Frederic Gottrand (Université de Lille 2, France)*; Dušan Grafnetter (Institute for Clinical and Experimental Medicine, Czech Republic)*; Tomasz Grodzicki (Jagiellonian University Medical College, Poland)*; Anders Grøntved (University of Southern Denmark, Denmark)*; Grabriella Gruden (University of Turin, Italy)*; Dongfeng Gu (National Center of Cardiovascular Diseases, China)*; Ong Peng Guan (Singapore Eye Research Institute, Singapore)*; Ramiro Guerrero (Universidad Icesi, Colombia)*; Idris Guessous (Geneva University Hospitals, Switzerland)*; Andre L Guimaraes (State University of Montes Claros, Brazil)*; Laura Gutierrez (Institute for Clinical Effectiveness and Health Policy, Argentina)*; Ian R Hambleton (The University of the West Indies, Barbados)*; Rebecca Hardy (University College London, UK)*; Rachakulla Hari Kumar (Indian Council of Medical Research, India)*; Jun Hata (Kyushu University, Japan)*; Jiang He (Tulane University, USA)*; Christin Heidemann (Robert Koch Institute, Germany)*; Sauli Herrala (Oulu University Hospital, Finland)*; Ilpo Tapani Hihtaniemi (Imperial College London, UK)*; Sai Yin Ho (University of Hong Kong, China)*; Suzanne C Ho (The Chinese University of Hong Kong, China)*; Albert Hofman (Erasmus Medical Center Rotterdam, Netherlands)*; Claudia M Hormiga (Fundación Oftalmológica de Santander, Colombia)*; Bernardo L Horta (Universidade Federal de Pelotas, Brazil)*; Leila Houti (University of Oran 1, Algeria)*; Christina Howitt (The University of the West Indies, Barbados)*; Thein Thein Htay (Ministry of Health, Myanmar)*; Aung Soe Htet (University of Oslo, Norway)*; Maung Maung Than Htike (Ministry of Health, Myanmar)*; Yang Hu (Harvard T H Chan School of Public Health, USA)*; Abdullatif S Hussieni (Birzeit University, Palestine)*; Inge Huybrechts (International Agency for Research on Cancer, France)*; Nahla Hwalla (American University of Beirut, Lebanon)*; Licia Iacoviello (IRCCS Istituto Neurologico Mediterraneo Neuromed, Italy)*; Anna G Iannone (Cardiologia di Mercato S. Severino, Italy)*; M Mohsen Ibrahim (Cairo University, Egypt)*; Nayu Ikeda (National Institute of Health and Nutrition, Japan)*; M Arfan Ikram (Erasmus Medical Center Rotterdam, Netherlands)*; Vilma E Irazola (Institute for Clinical Effectiveness and Health Policy, Argentina)*; Muhammad Islam (Aga Khan University, Pakistan)*; Masanori Iwasaki (Niigata University, Japan)*; Jeremy M Jacobs (Hadassah University Medical Center, Israel)*; Tazeen Jafar (Duke-NUS Graduate Medical School, Singapore)*; Kazi M Jamil (Kuwait Institute for Scientific Research, Kuwait)*; Grazyna Jasienska (Jagiellonian University Medical College, Poland)*; Chao Qiang Jiang (University of Hong Kong, China)*; Jost B Jonas (Ruprecht-Karls-University of Heidelberg, Germany)*; Pradeep Joshi (World Health Organization Country Office, India)*; Anthony Kafatos (University of Crete, Greece)*; Ofra Kalter-Leibovici (The Gertner Institute for Epidemiology and Health Policy Research, Israel)*; Amir Kasaeian (Non-Communicable Diseases Research Center, Iran)*; Joanne Katz (Johns Hopkins Bloomberg School of Public Health, USA)*; Prabhdeep Kaur (National Institute of Epidemiology, India)*; Maryam Kavousi (Erasmus Medical Center Rotterdam, Netherlands)*; Sirkka Keinänen-Kiukaanniemi (Oulu University Hospital, Finland)*; Roya Kelishadi (Research Institute for Primordial Prevention of Non-Communicable Disease, Iran)*; Andre P Kengne (South African Medical Research Council, South Africa)*; Mathilde Kersting (Research Institute of Child Nutrition, Germany)*; Yousef Saleh Khader (Jordan University of Science and Technology, Jordan)*; Davood Khalili (Shahid Beheshti University of Medical Sciences, Iran)*; Young-Ho Khang (Seoul National University, Republic of Korea)*; Stefan Kiechl (Medical University Innsbruck, Austria)*; Jeongseon Kim (National Cancer Center, Republic of Korea)*; Patrick Kolsteren (Institute of Tropical Medicine, Belgium)*;

Paul Korrovits (Tartu University Clinics, Estonia)*; Wolfgang Kratzer (University Hospital Ulm, Germany)*; Daan Kromhout (Wageningen University, Netherlands)*; Urho M Kujala (University of Jyväskylä, Finland)*; Krzysztof Kula (Medical University of Łodz, Poland)*; Catherine Kyobutungi (African Population and Health Research Center, Kenya)*; Tiina Laatikainen (National Institute for Health and Welfare, Finland)*; Carl Lachat (Ghent University, Belgium)*; Youcef Laid (INSP, Algeria)*; Tai Hing Lam (University of Hong Kong, China)*; Orlando Landrove (Ministerio de Salud Pública, Cuba)*; Vera Lanska (Institute for Clinical and Experimental Medicine, Czech Republic)*; Georg Lappas (Sahlgrenska Academy, Sweden)*; Avula Laxmaiah (Indian Council of Medical Research, India)*; Catherine Leclercq (Food and Agriculture Organization, Italy)*; Jeannette Lee (National University of Singapore, Singapore)*; Jeonghee Lee (National Cancer Center, Republic of Korea)*; Terho Lehtimäki (Tampere University Hospital, Finland)*; Rampal Lekhraj (Universiti Putra Malaysia, Malaysia)*; Luz M León-Muñoz (Universidad Autónoma de Madrid, Spain)*; Yanping Li (Harvard T H Chan School of Public Health, USA)*; Wei-Yen Lim (National University of Singapore, Singapore)*; M Fernanda Lima-Costa (Oswaldo Cruz Foundation Rene Rachou Research Institute, Brazil)*; Hsien-Ho Lin (National Taiwan University, Taiwan)*; Xu Lin (University of Chinese Academy of Sciences, China)*; Lauren Lissner (University of Gothenburg, Sweden)*; Roberto Lorbeer (University Medicine Greifswald, Germany)*; José Eugenio Lozano (Consejería de Sanidad Junta de Castilla y León, Spain)*; Dalia Luksiene (Lithuanian University of Health Sciences, Lithuania)*; Annamari Lundqvist (National Institute for Health and Welfare, Finland)*; Per Lytsy (University of Uppsala, Sweden)*; Guansheng Ma (Peking University, China)*; George L L Machado-Coelho (Universidade Federal de Ouro Preto, Brazil)*; Suka Machi (The Jikei University School of Medicine, Japan)*; Stefania Maggi (National Research Council, Italy)*; Dianna J Magliano (Baker IDI Heart and Diabetes Institute, Australia)*; Marcia Makdisse (Hospital Israelita Albert Einstein, Brazil)*; Kodavanti Mallikharjuna Rao (Indian Council of Medical Research, India)*; Yannis Manios (Harokopio University, Greece)*; Enzo Manzato (University of Padova, Italy)*; Paula Margozzini (Pontificia Universidad Católica de Chile, Chile)*; Pedro Marques-Vidal (Lausanne University Hospital, Switzerland)*; Reynaldo Martorell (Emory University, USA)*; Shariq R Masoodi (Sher-i-Kashmir Institute of Medical Sciences, India)*; Ellisiv B Mathiesen (UiT The Arctic University of Norway, Norway)*; Tandi E Matsha (Cape Peninsula University of Technology, South Africa)*; Jean Claude N Mbanya (University of Yaoundé 1, Cameroon)*; Shelly R McFarlane (The University of the West Indies, Jamaica)*; Stephen T McGarvey (Brown University, USA)*; Stela McLachlan (University of Edinburgh, UK)*; Breige A McNulty (University College Dublin, Ireland)*; Sounnia Mediene-Benchekor (University of Oran 1, Algeria)*; Aline Meirhaeghe (INSERM, France)*; Ana Maria B Menezes (Universidade Federal de Pelotas, Brazil)*; Shahin Merat (Digestive Disease Research Institute, Iran)*; Indrapal I Meshram (Indian Council of Medical Research, India)*; Jie Mi (Capital Institute of Pediatrics, China)*; Juan Francisco Miquel (Pontificia Universidad Católica de Chile, Chile)*; J Jaime Miranda (Universidad Peruana Cayetano Heredia, Peru)*; Mostafa K Mohamed (Ain Shams University, Egypt)*; Kazem Mohammad (Tehran University of Medical Sciences, Iran)*; Noushin Mohammadifard (Isfahan Cardiovascular Research Center, Iran)*; Viswanathan Mohan (Madras Diabetes Research Foundation, India)*; Muhammad Fadhli Mohd Yusoff (Ministry of Health Malaysia, Malaysia)*; Niels C Møller (University of Southern Denmark, Denmark)*; Dénes Molnár (University of Pécs, Hungary)*; Charles K Mondo (Mulago Hospital, Uganda)*; Alain Morejon (University Medical Science, Cuba)*; Luis A Moreno (Universidad de Zaragoza, Spain)*; Karen Morgan (RCSI Dublin, Ireland)*; George Moschonis (Harokopio University, Greece)*; Malgorzata Mossakowska (International Institute of Molecular and Cell Biology, Poland)*; Aya Mostafa (Ain Shams University, Egypt)*; Jorge Mota (University of Porto, Portugal)*; Jorge Motta (Gorgas Memorial Institute of Public Health, Panama)*; Thet Thet Mu (Department of Public Health, Myanmar)*; Maria Lorenza Muiesan (University of Brescia, Italy)*; Martina Müller-Nurasyid (Helmholtz Zentrum München, Germany)*; Jaakko Mursu (University of Eastern Finland, Finland)*; Gabriele Nagel (Ulm University, Germany)*; Jana Námešná (Regional Authority of Public Health, Banska Bystrica, Slovakia)*; Ei Ei K Nang (National University of Singapore, Singapore)*; Vinay B Nangia (Suraj Eye Institute, India)*; Eva Maria Navarrete-Muñoz (CIBER en Epidemiología y Salud Pública, Spain)*; Ndeye Coumba Ndiaye (INSERM, France)*; Ilona Nenko (Jagiellonian University Medical College, Poland)*; Flavio Nervi (Pontificia Universidad Católica de Chile, Chile)*; Nguyen D Nguyen (University of Pharmacy and Medicine of Ho Chi Minh City, Vietnam)*; Quang Ngoc Nguyen (Hanoi Medical University, Vietnam)*; Ramfis E Nieto-Martínez (Universidad Centro-Occidental Lisandro Alvarado, Venezuela)*; Guang Ning (Shanghai Jiao-Tong University School of Medicine, China)*; Toshiharu Ninomiya (Kyushu University, Japan)*; Marianna Noale (National Research Council, Italy)*; Davide Noto (University of Palermo, Italy)*; Mohannad Al Nsour (Eastern Mediterranean Public Health Network, Jordan)*; Angélica M Ochoa-Avilés (Universidad de Cuenca, Ecuador)*; Kyungwon Oh (Korea Centers for Disease Control and Prevention, Republic of Korea)*; Altan Onat (Istanbul University, Turkey)*; Pedro Ordunez (Pan American Health Organization, USA)*; Clive Osmond (MRC Lifecourse Epidemiology Unit, UK)*; Johanna A Otero (Fundación Oftalmológica de Santander, Colombia)*; Ellis Owusu-Dabo (Kwame Nkrumah University of Science and Technology, Ghana)*; Elena Pahomova (University of Latvia, Latvia)*; Luigi Palmieri (Istituto Superiore di Sanità, Italy)*; Songhomitra Panda-Jonas (Ruprecht-Karls-University of Heidelberg, Germany)*; Francesco Panza (University of Bari, Italy)*; Mahboubeh Parsaeian (Non-Communicable Diseases Research Center, Iran)*; Sergio Viana Peixoto (Oswaldo Cruz Foundation Rene Rachou Research Institute, Brazil)*; Catherine Pelletier (Public Health Agency of Canada, Canada)*; Markku Peltonen (National Institute for Health and Welfare, Finland)*; Annette Peters (Helmholtz Zentrum München, Germany)*; Niloofar Peykari (Non-Communicable Diseases Research Center, Iran)*; Son Thai Pham (Vietnam National Heart Institute, Vietnam)*; Aida Pilav (Federal Ministry of Health, Bosnia and Herzegovina)*; Freda Pitakaka (University of New South Wales, Australia)*; Aleksandra Piwonska (The Cardinal Wyszynski Institute of Cardiology, Poland)*; Jerzy Piwonski (The Cardinal Wyszynski Institute of Cardiology, Poland)*; Pedro Plans-Rubió (Public Health Agency of Catalonia, Spain)*; Miquel Porta (Institut Hospital del Mar d'Investigacions Mèdiques, Spain)*; Marileen L P Portegies (Erasmus Medical Center Rotterdam, Netherlands)*; Hossein Poustchi (Tehran University of Medical Sciences, Iran)*; Rajendra Pradeepa (Madras Diabetes Research Foundation, India)*; Jacqueline F Price (University of Edinburgh, UK)*; Margus Punab (Tartu University Clinics, Estonia)*; Radwan F Qasrawi (Al-Quds University, Palestine)*; Mostafa Qorbani (Alborz University of Medical Sciences, Iran)*; Ricardas Radisauskas (Lithuanian University of Health Sciences, Lithuania)*; Mahmudur Rahman (Institute of Epidemiology Disease Control and Research, Bangladesh)*; Olli Raitakari (University of Turku, Finland)*; Sudha Ramachandra Rao (National Institute of Epidemiology, India)*; Ambady Ramachandran (India Diabetes Research Foundation, India)*; Jacqueline Ramke (University of New South Wales, Australia)*; Rafel Ramos (Institut Universitari d'Investigació en Atenció Primària Jordi Gol, Spain)*; Sanjay Rampal (University of Malaya, Malaysia)*; Wolfgang Rathmann (German Diabetes Center, Germany)*; Josep Redon (University of Valencia, Spain)*; Paul Ferdinand M Reganit (University of the Philippines, Philippines)*; Fernando Rigo (Health Center San Agustín, Spain)*; Sian M Robinson (University of Southampton, UK)*; Cynthia Robitaille (Public Health Agency of Canada, Canada)*; Fernando Rodríguez-Artalejo (Universidad Autónoma de Madrid, Spain)*; María del Cristo Rodriguez-Perez (Canarian Health Service, Spain)*; Laura A Rodríguez-Villamizar (Universidad Industrial de Santander, Colombia)*; Rosalba Rojas-Martinez (Instituto Nacional de Salud Pública, Mexico)*; Kimmo Ronkainen (University of Eastern Finland, Finland)*; Annika Rosengren (University of Gothenburg, Sweden)*; Adolfo Rubinstein (Institute for Clinical Effectiveness and Health Policy, Argentina)*; Ornelas Rui (University of Madeira, Portugal)*; Blanca Sandra Ruiz-Betancourt (Instituto Mexicano del Seguro Social, Mexico)*; Andrea RV Russo Horimoto (Heart Institute, Brazil)*; Marcin Rutkowski (Medical University of Gdansk, Poland)*; Charumathi Sabanayagam (Singapore Eye Research Institute,

Singapore)*; Harshpal S Sachdev (Sitaram Bhartia Institute of Science and Research, India)*; Olfa Saidi (University Tunis El Manar, Tunisia)*; Sibel Sakarya (Marmara University, Turkey)*; Benoit Salanave (French Institute for Health Surveillance, France)*; Jukka T Salonen (University of Helsinki, Finland)*; Massimo Salvetti (University of Brescia, Italy)*; Jose Sánchez-Abanto (National Institute of Health, Peru)*; Diana Santos (University of Lisbon, Portugal)*; Renata Nunes dos Santos (University of São Paulo Clinics Hospital, Brazil)*; Rute Santos (University of Porto, Portugal)*; Jouko L Saramies (South Karelia Social and Health Care District, Finland)*; Luis B Sardinha (University of Lisbon, Portugal)*; Nizal Sarrafzadegan (Isfahan Cardiovascular Research Center, Iran)*; Kai-Uwe Saum (German Cancer Research Center, Germany)*; Marcia Scazufca (University of São Paulo Clinics Hospital, Brazil)*; Herman Schargrodsky (Hospital Italiano de Buenos Aires, Argentina)*; Christa Scheidt-Nave (Robert Koch Institute, Germany)*; Aye Aye Sein (Ministry of Health, Myanmar)*; Sanjb K Sharma (B P Koirala Institute of Health Sciences, Nepal)*; Jonathan E Shaw (Baker IDI Heart and Diabetes Institute, Australia)*; Kenji Shibuya (The University of Tokyo, Japan)*; Youchan Shin (Singapore Eye Research Institute, Singapore)*; Rahman Shiri (Finnish Institute of Occupational Health, Finland)*; Rosalynn Siantar (Singapore Eye Research Institute, Singapore)*; Abla M Sibai (American University of Beirut, Lebanon)*; Mary Simon (India Diabetes Research Foundation, India)*; Judith Simons (St Vincent's Hospital, Australia)*; Leon A Simons (University of New South Wales, Australia)*; Michael Sjostrom (Karolinska Institutet, Sweden)*; Jolanta Slowikowska-Hilczer (Medical University of Łodz, Poland)*; Przemyslaw Slusarczyk (International Institute of Molecular and Cell Biology, Poland)*; Liam Smeeth (London School of Hygiene & Tropical Medicine, UK)*; Marieke B Snijder (Academic Medical Center of University of Amsterdam, Netherlands)*; Hung-Kwan So (The Chinese University of Hong Kong, China)*; Eugène Sobngwi (University of Yaoundé 1, Cameroon)*; Stefan Söderberg (Umeå University, Sweden)*; Vincenzo Solfrizzi (University of Bari, Italy)*; Emily Sonestedt (Lund University, Sweden)*; Aicha Soumare (University of Bordeaux, France)*; Jan A Staessen (University of Leuven, Belgium)*; Maria G Stathopoulou (INSERM, France)*; Jostein Steene-Johannessen (Norwegian School of Sport Sciences, Norway)*; Peter Stehle (Bonn University, Germany)*; Aryeh D Stein (Emory University, USA)*; Jochanan Stessman (Hadassah University Medical Center, Israel)*; Doris Stöckl (Helmholtz Zentrum München, Germany)*; Jakub Stokwiszewski (National Institute of Hygiene, Poland)*; Karien Stronks (University of Amsterdam, Netherlands)*; Maria Wany Strufaldi (Federal University of São Paulo, Brazil)*; Chien-An Sun (Fu Jen Catholic University, Taiwan)*; Johan Sundström (Uppsala University, Sweden)*; Yn-Tz Sung (The Chinese University of Hong Kong, China)*; Paibul Suriyawongpaisal (Mahidol University, Thailand)*; Rody G Sy (University of the Philippines, Philippines)*; E Shyong Tai (National University of Singapore, Singapore)*; Abdonas Tamosiunas (Lithuanian University of Health Sciences, Lithuania)*; Line Tang (Research Centre for Prevention and Health, Denmark)*; Mohammed Tarawneh (Ministry of Health, Jordan)*; Carolina B Tarqui-Mamani (National Institute of Health, Peru)*; Anne Taylor (The University of Adelaide, Australia)*; Holger Theobald (Karolinska Institutet, Sweden)*; Lutgarde Thijs (University of Leuven, Belgium)*; Betina H Thuesen (Research Centre for Prevention and Health, Denmark)*; Hanna K Tolonen (National Institute for Health and Welfare, Finland)*; Janne S Tolstrup (University of Southern Denmark, Denmark)*; Murat Topbas (Karadeniz Technical University, Turkey)*; Maties Torrent (IB-SALUT Area de Salut de Menorca, Spain)*; Pierre Traissac (Institut de Recherche pour le Développement, France)*; Oanh T H Trinh (University of Pharmacy and Medicine of Ho Chi Minh City, Vietnam)*; Marshall K Tulloch-Reid (The University of the West Indies, Jamaica)*; Tomi-Pekka Tuomainen (University of Eastern Finland, Finland)*; Maria L Turley (Ministry of Health, New Zealand)*; Christophe Tzourio (University of Bordeaux, France)*; Peter Ueda (Harvard T H Chan School of Public Health, USA)*; Flora A M Ukoli (Meharry Medical College, USA)*; Hanno Ulmer (Medical University of Innsbruck, Austria)*; Hannu M T Uusitalo (Tampere University Hospital, Finland)*; Gonzalo Valdivia (Pontificia Universidad Católica de Chile, Chile)*; Damaskini Valvi (Harvard T H Chan School of Public Health, USA)*; Lenie van Rossem (University Medical Center Utrecht, Netherlands)*; Irene GM van Valkengoed (Academic Medical Center of University of Amsterdam, Netherlands)*; Dirk Vanderschueren (Katholieke Universiteit Leuven, Belgium)*; Diego Vanuzzo (Centro di Prevenzione Cardiovascolare Udine, Italy)*; Tomas Vega (Consejería de Sanidad Junta de Castilla y León, Spain)*; Gustavo Velasquez-Melendez (Universidade Federal de Minas Gerais, Brazil)*; Giovanni Veronesi (University of Insubria, Italy)*; W M Monique Verschuren (National Institute for Public Health and the Environment, Netherlands)*; Roosmarijn Verstraeten (Institute of Tropical Medicine, Belgium)*; Lucie Viet (National Institute for Public Health and the Environment, Netherlands)*; Jesus Vioque (Universidad Miguel Hernandez, Spain)*; Jyrki K Virtanen (University of Eastern Finland, Finland)*; Sophie Visvikis-Siest (INSERM, France)*; Bharathi Viswanathan (Ministry of Health, Seychelles)*; Peter Vollenweider (Lausanne University Hospital, Switzerland)*; Sari Voutilainen (University of Eastern Finland, Finland)*; Martine Vrijheid (Centre for Research in Environmental Epidemiology, Spain)*; Alisha N Wade (University of the Witwatersrand, South Africa)*; Aline Wagner (University of Strasbourg, France)*; Janette Walton (University College Cork, Ireland)*; Wan Nazaimoon Wan Mohamud (Institute for Medical Research, Malaysia)*; Feng Wang (Peking University Sixth Hospital, China)*; Ming-Dong Wang (Public Health Agency of Canada, Canada)*; Qian Wang (Xinjiang Medical University, China)*; Ya Xing Wang (Beijing Tongren Hospital, China)*; S Goya Wannamethee (University College London, UK)*; Deepa Weerasekera (Ministry of Health, New Zealand)*; Peter H Whincup (St George's, University of London, UK)*; Kurt Widhalm (Medical University of Vienna, Austria)*; Andrzej Wiecek (Medical University of Silesia, Poland)*; Alet H Wijga (National Institute for Public Health and the Environment, Netherlands)*; Rainford J Wilks (The University of the West Indies, Jamaica)*; Johann Willeit (Medical University Innsbruck, Austria)*; Tom Wilsgaard (UiT The Arctic University of Norway, Norway)*; Bogdan Wojtyniak (National Institute of Hygiene, Poland)*; Tien Yin Wong (Duke-NUS Graduate Medical School, Singapore)*; Jean Woo (The Chinese University of Hong Kong, China)*; Mark Woodward (University of Sydney, Australia; University of Oxford, UK)*; Frederick C Wu (University of Manchester, UK)*; Shou Ling Wu (Kailuan General Hospital, China)*; Haiquan Xu (Institute of Food and Nutrition Development of Ministry of Agriculture, China)*; Weili Yan (Fudan University, China)*; Xiaoguang Yang (Chinese Center for Disease Control and Prevention, China)*; Xingwang Ye (University of Chinese Academy of Sciences, China)*; Akihiro Yoshihara (Niigata University, Japan)*; Novie O Younger-Coleman (The University of the West Indies, Jamaica)*; Sabina Zambon (University of Padova, Italy)*; Abdul Hamid Zargar (Center for Diabetes and Endocrine Care, India)*; Tomasz Zdrojewski (Medical University of Gdansk, Poland)*; Wenhua Zhao (Chinese Center for Disease Control and Prevention, China)*; Yingfeng Zheng (Singapore Eye Research Institute, Singapore)*; Julio Zuñiga Cisneros (Gorgas Memorial Institute of Public Health, Panama)*.

Declaration of interests

ME reports a charitable grant from Youth Health Programme of AstraZeneca, outside the submitted work. JAR reports personal fees from Tres Montes Lucchetti and grants from Danone Mexico, outside the submitted work. All other members of the Pooled Analysis and Writing Group declare no competing interests.

Acknowledgments

The study was funded by the Wellcome Trust. We thank Christina Banks, Dheeya Rizmie, and Yasaman Vali for assistance with data extraction. We thank WHO country and regional offices and the World Heart Federation for support in data identification and access.

References

1 Global Burden of Metabolic Risk Factors for Chronic Diseases Collaboration. Cardiovascular disease, chronic kidney disease, and diabetes mortality burden of cardiometabolic risk factors from 1980 to 2010: a comparative risk assessment. *Lancet Diabetes Endocrinol* 2014; **2:** 634–47.

2 Seuring T, Archangelidi O, Suhrcke M. The economic costs of type 2 diabetes: a global systematic review. *Pharmacoeconomics* 2015; **33:** 811–31.

3 WHO. Global action plan for the prevention and control of noncommunicable diseases 2013–2020. 2013. http://apps.who.int/iris/bitstream/10665/94384/1/9789241506236_eng.pdf?ua=1 (accessed Aug 14, 2015).

4 Danaei G, Finucane MM, Lu Y, et al. National, regional, and global trends in fasting plasma glucose and diabetes prevalence since 1980: systematic analysis of health examination surveys and epidemiological studies with 370 country-years and 2·7 million participants. *Lancet* 2011; **378:** 31–40.

5 Guariguata L, Whiting DR, Hambleton I, Beagley J, Linnenkamp U, Shaw JE. Global estimates of diabetes prevalence for 2013 and projections for 2035. *Diabetes Res Clin Pract* 2014; **103:** 137–49.

6 International Diabetes Federation. IDF Diabetes Atlas, 6th edn. Brussels: International Diabetes Federation, 2013.

7 Guariguata L, Whiting D, Weil C, Unwin N. The International Diabetes Federation Diabetes Atlas methodology for estimating global and national prevalence of diabetes in adults. *Diabetes Res Clin Pract* 2011; **94:** 322–32.

8 NCD Risk Factor Collaboration. Effects of diabetes definition on global surveillance of diabetes prevalence and diagnosis: a pooled analysis of 96 population-based studies with 331 288 participants. *Lancet Diabetes Endocrinol* 2015; **3:** 624–37.

9 Beagley J, Guariguata L, Weil C, Motala AA. Global estimates of undiagnosed diabetes in adults. *Diabetes Res Clin Pract* 2014; **103:** 150–60.

10 Zhang X, Geiss LS, Cheng YJ, Beckles GL, Gregg EW, Kahn HS. The missed patient with diabetes: how access to health care affects the detection of diabetes. *Diabetes Care* 2008; **31:** 1748–53.

11 Gakidou E, Mallinger L, Abbott-Klafter J, et al. Management of diabetes and associated cardiovascular risk factors in seven countries: a comparison of data from national health examination surveys. *Bull World Health Organ* 2011; **89:** 172–83.

12 Finucane MM, Paciorek CJ, Danaei G, Ezzati M. Bayesian estimation of population-level trends in measures of health status. *Stat Sci* 2014; **29:** 18–25.

13 Danaei G, Finucane MM, Lin JK, et al. National, regional, and global trends in systolic blood pressure since 1980: systematic analysis of health examination surveys and epidemiological studies with 786 country-years and 5·4 million participants. *Lancet* 2011; **377:** 568–77.

14 Stevens GA, Bennett JE, Hennocq Q, et al. Trends and mortality effects of vitamin A deficiency in children in 138 low-income and middle-income countries between 1991 and 2013: a pooled analysis of population-based surveys. *Lancet Glob Health* 2015; **3:** e528–36.

15 Singh GM, Danaei G, Pelizzari PM, et al. The age associations of blood pressure, cholesterol, and glucose: analysis of health examination surveys from international populations. *Circulation* 2012; **125:** 2204–11.

16 NCD Risk Factor Collaboration (NCD-RisC). Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19·2 million participants. *Lancet* 2016; **387:** 1377–96.

17 Ezzati M, Riboli E. Behavioral and dietary risk factors for noncommunicable diseases. *N Engl J Med* 2013; **369:** 954–64.

18 Wandell PE, Carlsson AC. Gender differences and time trends in incidence and prevalence of type 2 diabetes in Sweden--a model explaining the diabetes epidemic worldwide today? *Diabetes Res Clin Pract* 2014; **106:** e90–92.

19 Gale EA, Gillespie KM. Diabetes and gender. *Diabetologia* 2001; **44:** 3–15.

20 Hwang CK, Han PV, Zabetian A, Ali MK, Narayan KM. Rural diabetes prevalence quintuples over twenty-five years in low- and middle-income countries: a systematic review and meta-analysis. *Diabetes Res Clin Pract* 2012; **96:** 271–85.

21 A mass survey of diabetes mellitus in a population of 300,000 in 14 provinces and municipalities in China (author's transl). *Zhonghua Nei Ke Za Zhi* 1981; **20:** 678–83 (in Chinese).

22 Eliasson M, Lindahl B, Lundberg V, Stegmayr B. No increase in the prevalence of known diabetes between 1986 and 1999 in subjects 25–64 years of age in northern Sweden. *Diabet Med* 2002; **19:** 874–80.

23 Icks A, Moebus S, Feuersenger A, Haastert B, Jockel KH, Giani G. Diabetes prevalence and association with social status--widening of a social gradient? German national health surveys 1990–1992 and 1998. *Diabetes Res Clin Pract* 2007; **78:** 293–97.

24 Teuscher AU, Diem P, Thomas W, Janett J, Teuscher A. Incidence of insulin-dependent diabetes mellitus in Switzerland (1972–1993) in 19-year-old men. *Schweiz Med Wochenschr* 1995; **125:** 1041–45 (in German).

25 Menke A, Casagrande S, Geiss L, Cowie CC. Prevalence of and trends in diabetes among adults in the United States, 1988–2012. *JAMA* 2015; **314:** 1021–29.

26 Imkampe AK, Gulliford MC. Increasing socio-economic inequality in type 2 diabetes prevalence--repeated cross-sectional surveys in England 1994–2006. *Eur J Public Health* 2011; **21:** 484–90.

27 Hamer M, Kengne AP, Batty GD, Cooke D, Stamatakis E. Temporal trends in diabetes prevalence and key diabetes risk factors in Scotland, 2003–2008. *Diabet Med* 2011; **28:** 595–98.

28 Charvat H, Goto A, Goto M, et al. Impact of population aging on trends in diabetes prevalence: A meta-regression analysis of 160,000 Japanese adults. *J Diabetes Investig* 2015; **6:** 533–42.

29 Li MZ, Su L, Liang BY, et al. Trends in prevalence, awareness, treatment, and control of diabetes mellitus in mainland China from 1979 to 2012. *Int J Endocrinol* 2013; **2013:** 753150.

30 Zuo H, Shi Z, Hussain A. Prevalence, trends and risk factors for the diabetes epidemic in China: a systematic review and meta-analysis. *Diabetes Res Clin Pract* 2014; **104:** 63–72.

31 Jayawardena R, Ranasinghe P, Byrne NM, Soares MJ, Katulanda P, Hills AP. Prevalence and trends of the diabetes epidemic in South Asia: a systematic review and meta-analysis. *BMC Public Health* 2012; **12:** 380.

32 Misra P, Upadhyay RP, Misra A, Anand K. A review of the epidemiology of diabetes in rural India. *Diabetes Res Clin Pract* 2011; **92:** 303–11.

33 Mohan V, Deepa M, Deepa R, et al. Secular trends in the prevalence of diabetes and impaired glucose tolerance in urban South India—the Chennai Urban Rural Epidemiology Study (CURES-17). *Diabetologia* 2006; **49:** 1175–78.

34 Ramachandran A, Snehalatha C, Shetty AS, Nanditha A. Trends in prevalence of diabetes in Asian countries. *World J Diabetes* 2012; **3:** 110–17.

35 Esteghamati A, Etemad K, Koohpayehzadeh J, et al. Trends in the prevalence of diabetes and impaired fasting glucose in association with obesity in Iran: 2005–2011. *Diabetes Res Clin Pract* 2014; **103:** 319–27.

36 Satman I, Omer B, Tutuncu Y, et al. Twelve-year trends in the prevalence and risk factors of diabetes and prediabetes in Turkish adults. *Eur J Epidemiol* 2013; **28:** 169–80.

37 Alharbi NS, Almutari R, Jones S, Al-Daghri N, Khunti K, de Lusignan S. Trends in the prevalence of type 2 diabetes mellitus and obesity in the Arabian Gulf States: systematic review and meta-analysis. *Diabetes Res Clin Pract* 2014; **106:** e30–33.

38 Hales CN, Barker DJ. Type 2 (non-insulin-dependent) diabetes mellitus: the thrifty phenotype hypothesis. *Diabetologia* 1992; **35:** 595–601.

39 Chambers JC, Zhang W, Zabaneh D, et al. Common genetic variation near melatonin receptor MTNR1B contributes to raised plasma glucose and increased risk of type 2 diabetes among Indian Asians and European Caucasians. *Diabetes* 2009; **58:** 2703–08.

40 Ramachandran A, Ma RC, Snehalatha C. Diabetes in Asia. *Lancet* 2010; **375:** 408–18.

41 Bhargava SK, Sachdev HS, Fall CH, et al. Relation of serial changes in childhood body-mass index to impaired glucose tolerance in young adulthood. *N Engl J Med* 2004; **350:** 865–75.

42 Chan JC, Malik V, Jia W, et al. Diabetes in Asia: epidemiology, risk factors, and pathophysiology. *JAMA* 2009; **301:** 2129–40.

43 Colagiuri R, Colagiuri S, Yach D, Pramming S. The answer to diabetes prevention: science, surgery, service delivery, or social policy? *Am J Public Health* 2006; **96:** 1562–69.

44 Knowler WC, Barrett-Connor E, Fowler SE, et al. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med* 2002; **346:** 393–403.

45 Farzadfar F, Murray CJ, Gakidou E, et al. Effectiveness of diabetes and hypertension management by rural primary health-care workers (Behvarz workers) in Iran: a nationally representative observational study. *Lancet* 2012; **379:** 47–54.

46 Ley SH, Hamdy O, Mohan V, Hu FB. Prevention and management of type 2 diabetes: dietary components and nutritional strategies. *Lancet* 2014; **383:** 1999–2007.

47 Sutheran HL, Reynolds T. Technical and clinical accuracy of three blood glucose meters: clinical impact assessment using error grid analysis and insulin sliding scales. *J Clin Pathol* 2016; published online Feb 5. DOI: 10.1136/jclinpath-2015-203339.

48 Pfutzner A, Mitri M, Musholt PB, et al. Clinical assessment of the accuracy of blood glucose measurement devices. *Curr Med Res Opin* 2012; **28:** 525–31.

49 Diaz-Valencia PA, Bougneres P, Valleron AJ. Global epidemiology of type 1 diabetes in young adults and adults: a systematic review. *BMC Public Health* 2015; **15:** 255.

50 Tuomilehto J. The emerging global epidemic of type 1 diabetes. *Curr Diab Rep* 2013; **13:** 795–804.

51 American Diabetes Association. Diagnosis and classification of diabetes mellitus. *Diabetes Care* 2004; **27** (suppl 1)**:** S5–10.

52 Centers for Disease Control and Prevention. National diabetes statistics report: estimates of diabetes and its burden in the United States, 2014. Atlanta, GA: US Department of Health and Human Services, 2014.

53 Global Burden of Disease Study Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 301 acute and chronic diseases and injuries in 188 countries, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2015; **386:** 743–800.

54 Pan SC, Ku CC, Kao D, Ezzati M, Fang CT, Lin HH. Effect of diabetes on tuberculosis control in 13 countries with high tuberculosis: a modelling study. *Lancet Diabetes Endocrinol* 2015; **3:** 323–30.

55 Holman RR, Paul SK, Bethel MA, Matthews DR, Neil HA. 10-year follow-up of intensive glucose control in type 2 diabetes. *N Engl J Med* 2008; **359:** 1577–89.

56 The ADVANCE Collaborative Group. Intensive blood glucose control and vascular outcomes in patients with type 2 diabetes. *N Engl J Med* 2008; **358:** 2560–72.

57 The Look AHEAD Research Group. Effect of a long-term behavioural weight loss intervention on nephropathy in overweight or obese adults with type 2 diabetes: a secondary analysis of the Look AHEAD randomised clinical trial. *Lancet Diabetes Endocrinol* 2014; **2:** 801–09.

58 Holman RR, Sourij H, Califf RM. Cardiovascular outcome trials of glucose-lowering drugs or strategies in type 2 diabetes. *Lancet* 2014; **383:** 2008–17.

59 Skyler JS, Bergenstal R, Bonow RO, et al. Intensive glycemic control and the prevention of cardiovascular events: implications of the ACCORD, ADVANCE, and VA diabetes trials: a position statement of the American Diabetes Association and a scientific statement of the American College of Cardiology Foundation and the American Heart Association. *Circulation* 2009; **119:** 351–57.

60 Cefalu WT. Glycemic targets and cardiovascular disease. *N Engl J Med* 2008; **358:** 2633–35.

61 Gaede P, Vedel P, Larsen N, Jensen GV, Parving HH, Pedersen O. Multifactorial intervention and cardiovascular disease in patients with type 2 diabetes. *N Engl J Med* 2003; **348:** 383–93.

62 Fox CS, Golden SH, Anderson C, et al. Update on prevention of cardiovascular disease in adults with type 2 diabetes mellitus in light of recent evidence: a scientific statement from the American Heart Association and the American Diabetes Association. *Circulation* 2015; **132:** 691–718.

63 Ali MK, Bullard KM, Saaddine JB, Cowie CC, Imperatore G, Gregg EW. Achievement of goals in U.S. diabetes care, 1999–2010. *N Engl J Med* 2013; **368:** 1613–24.

64 Gregg EW, Albright AL. The public health response to diabetes--two steps forward, one step back. *JAMA* 2009; **301:** 1596–98.

65 Gregg EW, Li Y, Wang J, et al. Changes in diabetes-related complications in the United States, 1990–2010. *N Engl J Med* 2014; **370:** 1514–23.

66 Tuomilehto J, Lindstrom J, Eriksson JG, et al. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *N Engl J Med* 2001; **344:** 1343–50.

67 Ramachandran A, Snehalatha C, Mary S, et al. The Indian Diabetes Prevention Programme shows that lifestyle modification and metformin prevent type 2 diabetes in Asian Indian subjects with impaired glucose tolerance (IDPP-1). *Diabetologia* 2006; **49:** 289–97.

68 Saaristo T, Moilanen L, Korpi-Hyovalti E, et al. Lifestyle intervention for prevention of type 2 diabetes in primary health care: one-year follow-up of the Finnish National Diabetes Prevention Program (FIN-D2D). *Diabetes Care* 2010; **33:** 2146–51.

69 DePue JD, Dunsiger S, Seiden AD, et al. Nurse-community health worker team improves diabetes care in American Samoa: results of a randomized controlled trial. *Diabetes Care* 2013; **36:** 1947–53.

70 Narayan KM, Echouffo-Tcheugui JB, Mohan V, Ali MK. Analysis & commentary: global prevention and control of type 2 diabetes will require paradigm shifts in policies within and among countries. *Health Aff (Millwood)* 2012; **31:** 84–92.