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IDF Diabetes Atlas: Global, regional and country-level diabetes prevalence estimates for 2021 and projections for 2045

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A R T I C L E I N F O

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A B S T R A C T

Aims: To provide global, regional, and country-level estimates of diabetes prevalence and health expenditures for 2021 and projections for 2045.
Methods: A total of 219 data sources meeting pre-established quality criteria reporting research conducted between 2005 and 2020 and representing 215 countries and territories were identified. For countries without data meeting quality criteria, estimates were extrapolated from countries with similar economies, ethnicity, geography and language. Logistic

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regression was used to generate smoothed age-specific diabetes prevalence estimates. Diabetes-related health expenditures were estimated using an attributable fraction method. The 2021 diabetes prevalence estimates were applied to population estimates for 2045 to project future prevalence.

Results: The global diabetes prevalence in 20–79 year olds in 2021 was estimated to be 10.5% (536.6 million people), rising to 12.2% (783.2 million) in 2045. Diabetes prevalence was similar in men and women and was highest in those aged 75–79 years. Prevalence (in 2021) was estimated to be higher in urban (12.1%) than rural (8.3%) areas, and in high-income (11.1%) compared to low-income countries (5.5%). The greatest relative increase in the prevalence of diabetes between 2021 and 2045 is expected to occur in middle-income countries (21.1%) compared to high- (12.2%) and low-income (11.9%) countries. Global diabetes-related health expenditures were estimated at 966 billion USD in 2021, and are projected to reach 1,054 billion USD by 2045.

Conclusions: Just over half a billion people are living with diabetes worldwide which means that over 10.5% of the world's adult population now have this condition.

1. Introduction

Diabetes has emerged as one of the most serious and common chronic diseases of our times, causing life threatening, disabling and costly complications, and reducing life expectancy. [1] The global prevalence of diabetes had reached pandemic proportions with the 9th edition of the IDF reporting a prevalence of 9% (463 million adults) in 2019. The rising prevalence of diabetes has been attributed principally to the ageing of populations. However, decreasing mortality among those with diabetes due to improving medical care as well as increases in diabetes incidence in some countries resulting from increasing prevalence of diabetes risk factors, especially obesity, are also important drivers of higher prevalence. [2–3]

The aim of the 10th edition of the IDF Diabetes Atlas is to provide updated estimates and projections of diabetes prevalence as well as health expenditure due to diabetes at national, regional, and global levels.

2. Methods

The IDF Diabetes Atlas methods have been previously described in detail. [4] This study complies with the Guidelines for Accurate and Transparent Health Estimates Reporting (GATHER) recommendations (see Supplementary material for checklist). [5] The following sections provide a brief summary, and includes any changes introduced by the 10th edition.

For the 10th edition of the IDF Diabetes Atlas, the list of countries and territories was re-evaluated based on the UN list of countries [6] (United Nation, Department of Economic and Social Affairs Population Dynamics), with a total of 215 countries and territories being included in the 10th edition of the IDF Diabetes Atlas.

2.1. Literature review

For the 10th edition of the IDF Diabetes Atlas, a literature search of resources providing diabetes estimates in adults older than 20 years was carried out in Medline via Pubmed from 1st January 2019 until 31st December 2020. The search was limited to 2019–2020 publications. Any new data retrieved were included along with data from the previous IDF Diabetes Atlas editions. The search terms used were (((MH "Diabetes Mellitus, Type 2+") OR (MH "Diabetes Mellitus+") OR (MH "Noncommunicable Diseases") OR AB diabet* OR TI diabet* OR AB type 2 diabetes OR TI type 2 diabetes OR AB type 2 diabetes mellitus OR TI type 2 diabetes mellitus OR AB type 2 dm OR TI type 2 dm OR AB t2dm OR TI t2dm OR AB type ii diabet* OR TI type ii diabet* OR AB type-ii diabet* OR TI type-ii diabet*) AND ((MH "Prevalence") OR (MH "Cross-Sectional Studies") OR AB prevalence OR TI prevalence OR AB prevalen* OR TI prevalen* OR AB epidemiology OR TI epidemiology OR AB statistics OR TI statistics OR AB screen* OR TI screen* OR AB cross-sectional OR TI cross-sectional OR AB cross sectional OR TI cross sectional)) NOT (AB animal OR TI animal OR AB rat OR TI rat OR AB rats OR TI rats OR AB mice OR TI mice OR AB mouse OR TI mouse OR AB trial OR TI trial OR AB case-control OR TI case-control OR AB case control OR TI case control OR AB case series OR TI case series OR TI case report OR AB genetic OR TI genetic OR AB editorial OR TI editorial OR AB covid-19 OR TI covid-19 OR AB coronavirus OR TI coronavirus OR TI hospital).

A grey literature search was also conducted focusing on identifying data from national diabetes registries, national health surveys and population-based administrative datasets which capture diabetes prevalence. The available national World Health Organization (WHO) STEPwise approach to Surveillance (STEPS) studies were reviewed and the IDF Regional offices in Africa (AFR), Europe (EUR), Middle East and North Africa (MENA), North America and Caribbean (NAC), South and Central America (SACA), South-East Asia (SEA), and the Western Pacific (WP) were also contacted regarding the availability of new sources of diabetes prevalence data.

2.2. Data source review and data extraction

Medline searches were screened in Covidence. [7] The title and abstract of each data source was initially reviewed by two independent reviewers for relevance, and then the full text was reviewed. Conflicts were resolved by discussion with a third reviewer. The decision for including or excluding the data sources for use in the estimation was based on pre-defined criteria, listed in Table 1.

The complete set of data sources for the estimation of diabetes prevalence included new studies retrieved from the 2020 literature search or the grey literature, as well as eligible data sources from the previous IDF Diabetes Atlas editions. To ensure that our modelling of diabetes prevalence estimates reflects the most recent data sources, studies conducted prior to 2005 were excluded except in circumstances were there was no other credible in-country data and extrapolation from nearby countries provided implausible results. WHO STEPS studies based on capillary blood glucose where the glucose threshold applied was not specified or was incorrect according to Lin et al. were also excluded. [8]

2.3. *Data source characteristics and selection*

To evaluate the quality of the individual datasets, each source was scored, as previously described, by the Analytical Hierarchy Process (AHP), an approach commonly used in operations research. [4,9] This quantifies the relative quality of a variety of different aspects of study methods. [4,10] Briefly, to create the scoring algorithm, expert members of the IDF Diabetes Atlas Committee completed preference charts on the relative importance of five study characteristics – diagnostic criteria, sample size, sample representation, date of data collection, and type of publication (peer-reviewed publication, national health survey, national registry reports, other official report or publication by a health regulatory body, WHO STEPS study report, or a unpublished study). The relative value of the different categories was ranked by the committee. Using these values, each data source was assigned a score, with higher scores indicating better quality. The 10th edition of the IDF Diabetes Atlas used the same weights as developed and used in the 9th edition. As such a minimum score of 0.29 was required for the data source to be included in the model. For countries with more than one available study, the highest scoring study was selected together with other studies within an increment of 0.1 of the highest score.

2.4. *Estimation of diabetes prevalence*

Prevalence data were extracted in age, sex and urbanization strata from the selected studies. For each country, logistic regression was used to generate smoothed age- and sex-specific prevalence estimates for 5-year age groups for adults aged 20–79 years. The regression included age (as midpoint of each age-group) and the quadratic transformation of age in the model. This was performed in separate analyses for each sub-group (sex and urban/rural area).

When more than one study had been selected, prevalence was calculated as the weighted average of the different studies, the weights being those used in the AHP scoring process. In the case where there were several serial cross-sectional surveys conducted in the same manner (e.g., replicated at a regular time interval), only data from the most recent survey were used even if all studies met the required AHP threshold. Urban to rural diabetes prevalence ratios were similarly averaged when more than one study was available for use. Where primary data were not stratified by urban and rural status, an urban/rural ratio was applied. The ratio was derived from aggregated available data on urbanisation from countries within the same IDF Region based on the UN Population Division Urbanisation Prospects. [11] For high-income countries, the urban to rural diabetes prevalence ratio was assumed to be 1.0.

When reported prevalence was based only on self-report, this value was adjusted by the proportion of undiagnosed diabetes in that country to represent total prevalence of diabetes using the following formulae [12]

$$\textit{Prevalence of total diabetes} = \left(\textit{Prevalence of self report diabetes} / \left(\frac{100 - \textit{the proportion of undiagnosed diabetes}}{100}\right)\right) \times 100$$

The prevalence of undiagnosed diabetes was estimated using the methodology of previous editions [4,9] based on studies which presented both self-report and laboratory data and which met the pre-specified quality criteria.

The strata-specific prevalence estimates were then applied to the age, sex and urbanisation strata of each national population, as obtained from the UN, to produce the number of people with diabetes and overall prevalence for 2021 for each country. In the 10th edition of the IDF Diabetes Atlas, as in the previous editions, two different prevalence estimates were produced for each country and region: one age-standardised to the country's 2021 population and another age-standardised to the UN world population referred to as "comparative diabetes prevalence". [11] As the UN does not provide age- and sex-stratified population data for countries and territories with populations smaller than 90,000, for these areas, regional level age- and sex-specific population data were used.

2.5. *Extrapolation of diabetes estimates for countries without data or with only low-quality in-country data*

For countries without data from studies conducted in 2005 or later, or with only low-quality in-country data, prevalence was estimated by extrapolation from studies in countries of similar geographical location, IDF Region, World Bank income classification (low-, middle-, and high-income) [13], ethnicity and language. [14–15]

2.6. *Estimation of global and regional diabetes prevalence for 2021*

The number of people with diabetes in each of the seven IDF Regions and each World Bank income classification was then calculated by aggregating the number of people with diabetes from each country within the respective IDF Region and World Bank income classification, separately for diabetes prevalence and for comparative diabetes prevalence and dividing by the region/group total population 20–79 years of age. Global estimates were similarly calculated by summing the total number of people with diabetes from each country and dividing by the total estimated UN world population 20–79 years of age for 2021.

Table 1 – Inclusion and exclusion criteria for IDF Diabetes Atlas data sources.

Inclusion criteria	Exclusion criteria
1. Data on diabetes prevalence and/or number of people with diabetes* 2. Population-based (national or regional) 3. Adults (20–79 years) 4. Surveys, registries and ‘whole of population’ insurance-based data	1. Diabetes in specific populations (e.g., nurses, taxi drivers) 2. Diabetes in specific diseases (e.g., in people with cardiovascular disease, kidney disease) 3. Diabetes in specific age groups (e.g. 65 + years) 4. Hospital- or clinic- or general practice-based studies 5. Studies reporting only in children and adolescents 6. Studies reporting only Type 1 diabetes 7. Family studies, birth cohorts 8. Studies where the sample size was < 200

* Studies were required to have diabetes data available for at least three age groups. If age-stratified data were not reported, authors were contacted to provide data, otherwise the study was excluded.

2.7. Estimation of future diabetes prevalence

Each age/sex/urbanization specific stratum prevalence was applied to the UN 2045 estimated population to produce national estimates of the prevalence and number of people with diabetes in 2045. [11] Initially, this was done using population estimates for each individual country as the standard population, and then, to obtain the "comparative diabetes prevalence" using the 2045 world population as the standard population. The latter standardisation of estimates only accounted for age.

All modelling was conducted with the statistical package R version 3.6.2 [16] and Microsoft Excel.

2.8. Estimation of uncertainty intervals

There were minor modifications in the method of estimating the confidence intervals [4] for the prevalence estimates in the 10th edition of the IDF Diabetes Atlas as described below. It should be noted that confidence intervals in the traditional sense cannot be calculated in the IDF model. Instead, we estimated uncertainty intervals.

2.8.1. Simulation to estimate uncertainty in raw data

For each underlying study, five hundred estimates of prevalence were randomly sampled from within a normal distribution constructed from within the lower and upper bounds of the corresponding confidence intervals of every prevalence estimate presented in the study. These samples were then used in the IDF estimation procedure as conducted for the original raw data. [4] From these modelled estimates, the minimum and the maximum were calculated, representing the uncertainty intervals in the raw age- specific data from each study.

2.8.2. Uncertainty due to study selection

We employed a jack-knife procedure to understand the sensitivity of the global diabetes prevalence estimates to the study selection process. [17] To do this, one study was randomly removed from the overall global list each time and the global prevalence was calculated from the remaining studies. This procedure was repeated as many times as there were studies in the analysis. We then used the maximum and minimum values obtained as the bounds of the uncertainty interval.

Finally, the confidence intervals from the uncertainty due to study selection and uncertainty in raw data were combined to create the widest possible overall uncertainty interval by defining its lower and upper bounds as the minimum and maximum values of the study selection and raw data intervals. For example, if the interval from uncertainty due to study selection was (a, b) and from uncertainty in raw data was (c, d), where $a < c$ and $d > b$, the widest possible intervals when combining the two intervals would be (a, d) and this was considered as the overall uncertainty interval. A detailed description of these methods has been published previously. [4]

2.9. Estimation of health expenditure

Direct cost estimates were calculated using an attributable fraction method, which relies on ratios of health expenditures for people with diabetes compared to those without diabetes, stratified by age, sex, rural versus urban area, diagnosed and undiagnosed diabetes and income per Region. These attributable fractions were then combined with UN population estimates for 2021 and population projections for 2045, [11] and WHO global health expenditures per capita (for 2018); with the distribution by age and sex being imputed based on mortality rates. [18] The WHO definition of health expenditure includes health expenditures from both public and private sources. [18]

3. Results

3.1. Study sources

The 2019–2020 literature review identified 13,570 articles of which 153 met the pre-defined inclusion criteria (Fig. 1) and proceeded to data extraction. After contacting authors or organisations from 94 studies to obtain detailed age- and sex-stratified data and further details about methods, a total of 106 new studies met our inclusion criteria and were added into the IDF Diabetes Atlas database. The grey literature search (including data from the IDF Regional offices and WHO STEPwise approach to Surveillance (STEPS) studies led to the identification of an additional 53 new eligible data sources. The analytic hierarchy process was then applied to the data sources retrieved from literature search, grey literature, WHO STEPS studies and existing studies in the databases. From this process, a total of 219 data sources from 144 countries were selected for inclusion. Among these, 81 represented new sources identified from 67 countries. The data sources used in the 10th edition of the Atlas comprise a total of 41 WHO STEP studies, 16 diabetes registries, 109

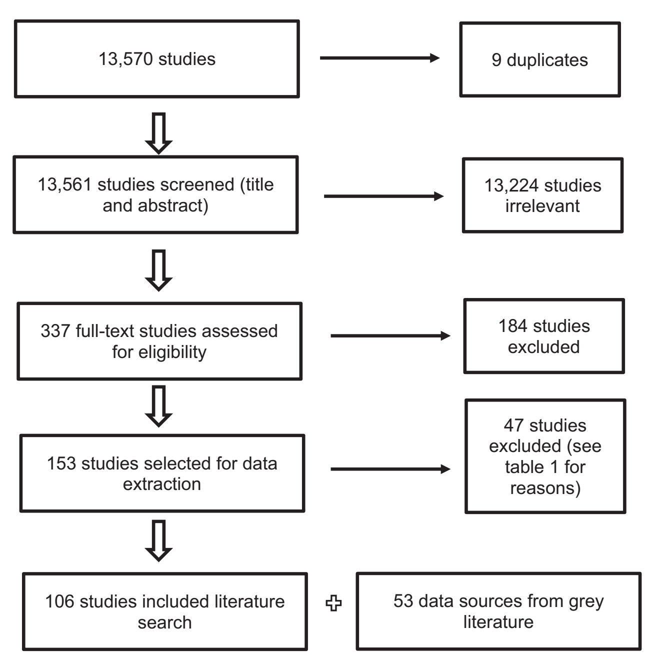

Fig. 1 – Results of 2019–2020 literature search for articles describing diabetes prevalence in adults.

peer- reviewed studies, 51 national health surveys (35 of which had been published) and 2 non-peer reviewed government reports. The majority 205 (93.6 %) of the data sources were nationally representative. Among the data sources used, 49 (22.4%), 91 (41.6%), 12(5.5%), 2(0.9%) and 1 (0.5%) used oral glucose tolerance test (OGTT), fasting blood/plasma glucose, HbA1c, random blood glucose and glycosuria to diagnose diabetes. An exception was made for one study which used glycosuria only in a country with no other data source. A further 16 (7%) were diagnosed by a physician or a clinical diagnosis. A total of 48 (21.9%) sources captured diabetes using self-report only. The list of sources used can be found at www.diabetesatlas.org.

The number of original data sources from each IDF Region varied. The SEA Region had the most countries (85.7%, 18 out of 21 countries) with at least one in-country data source while the AFR Region the least (41.7%, 20 out of 48 countries). Data sources were available in-country from 73.7% (28 out of 38 countries), 84.2% (16 out of 19 countries), 66.1% (39 out of 59 countries), 73.9% (17 out of 23 countries) of countries from the WP, SACA, EUR and NAC Regions, respectively. Since studies that were conducted prior to 2005 were excluded in this analysis, the 10th Edition used a smaller number of data sources compared to the previous edition.

3.2. Estimates of numbers of people with diabetes and diabetes prevalence

In 2021, we estimate that there were 536.6 million people with diabetes (uncertainty interval: 424.2–612.3 million) among adults ages 20–79 in in 215 countries and territories. For 2045, we project that 783.2 million (uncertainty interval: 605.2–898.6 million) people will have diabetes (Table 2). Detailed estimates for each country are available online at www.diabetesatlas.org, and in Supplementary Table 1.

The global diabetes prevalence in adults aged 20–79 years standardised to the 2021 UN world population was estimated at 10.5% (uncertainty interval: 8.3%–12.0%), 10.8% in men and 10.2% in women (Fig. 2). Prevalence increases with age with the highest prevalence of diabetes (24.0%) observed in those aged 75–79 years of age (Fig. 2). Prevalence was greater in men than in women in those aged 25 to 69 years of age. Table 2 shows the prevalence of diabetes in low-, middle- and high-income countries when standardised to the national population of each country, and to the world population in 2021 and 2045. In both years, comparative prevalence was highest in the middle-income countries and the lowest in the low-income countries. A high proportion of people with diabetes (80.6%, 432.7 million) live in low- and middle-income countries. The greatest relative increase in prevalence from 2021 to 2045 is expected to take place in middle-income countries, followed by high- and low-income countries (21.1% vs 12.2% vs 11.9%), respectively. The increase in the number of adults with diabetes in middle-income countries from 2021 until 2045 will exceed 200 million. The AFR region will see the greatest relative increase in numbers of people with diabetes (Table 3).

In 2021, the estimated numbers of people with diabetes living in urban and rural areas were 360.0 million and 176.6 million, with prevalence estimated at 12.1% and 8.3%, respec-

Table 2 – Estimates of number of adults (20–79 years) with diabetes and diabetes prevalence for the world and by per World Bank income classification for 2021 and 2045 together with uncertainty intervals, expressed in parentheses.

World Bank income classification	2021 Number of people with diabetes (millions)	2021 Diabetes prevalence[i] (%)	2021 Comparative diabetes prevalence[ii] (%)	2045 Number of people with diabetes (millions)	2045 Diabetes prevalence[i] (%)	2045 Comparative diabetes prevalence[ii] (%)
World	536.6 (424.2–612.3)	10.5 (8.3–12.0)	9.8 (7.7–11.2)	783.2 (605.2–898.6)	12.2 (9.5–14.0)	11.2 (8.6–12.9)
High-income countries	103.9 (87.6–116.9)	11.1 (9.3–12.5)	8.4 (7.1–9.6)	117.7 (98.4–132.4)	12.4 (10.4–14.0)	10.3 (8.8–11.7)
Middle-income countries	414.0 (321.6–470.8)	10.8 (8.4–12.3)	10.5 (8.0–11.9)	623.3 (473.0–709.3)	13.1 (9.9–14.9)	12.0 (9.0–13.6)
Low-income countries	18.7 (15.0–24.6)	5.5 (4.4–7.2)	6.7 (5.5–9.0)	42.2 (33.8–56.9)	6.1 (4.9–8.3)	7.0 (5.8–9.7)

[i] Prevalence standardised to national populations for the respective year, aged 20–79 years.
[ii] Prevalence standardised to the world population for the respective year, aged 20–79 years.

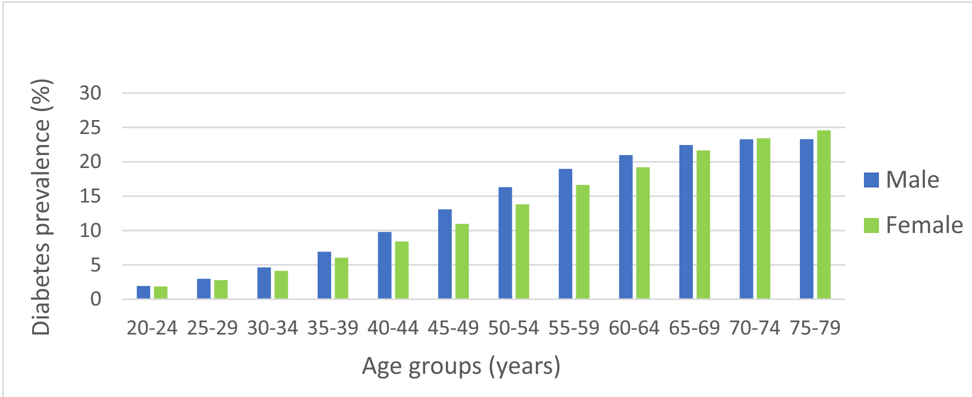

Fig. 2 – Diabetes prevalence by age and sex in 2021: *IDF Diabetes Atlas*.

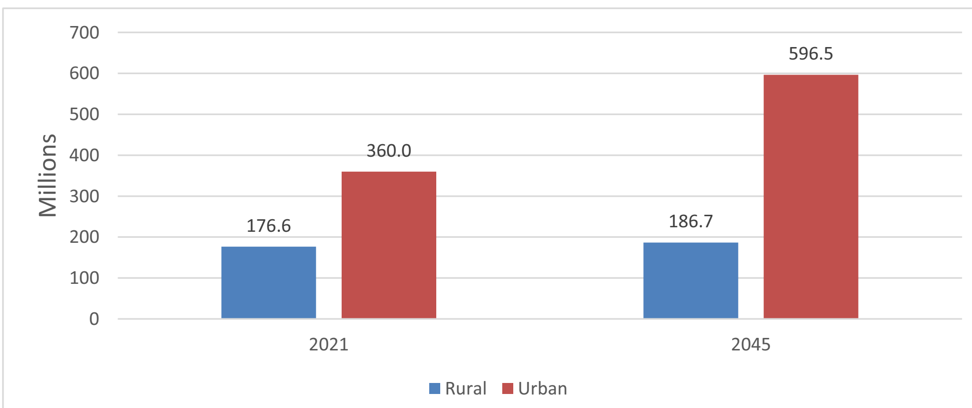

Fig. 3 – Number of people with diabetes in adults (20–79 years) living in urban and rural areas in 2021 and 2045.

tively. The number of people with diabetes living in urban areas is expected to increase to 596.5 million in 2045 (Fig. 3), as a result of global urbanisation, with predicted urban prevalence of diabetes increasing to 13.9%, due to population ageing.

The highest comparative prevalence of diabetes was in the MENA Region (18.1%) while the lowest world comparative prevalence was in the AFR Region (5.3%). The largest number of people with diabetes (206 million) was found in the WP Region. The regions which are forecasted to experience the largest relative growth in the number of people with diabetes are AFR and MENA and the regions with the smallest relative growth in the number of people with diabetes are the EUR, NAC, and WP Regions (Table 3).

Table 4 shows the ten countries with the highest estimated comparative prevalence for the years 2021 and 2045. The country with the highest prevalence at 31% is Pakistan which is projected to have a prevalence of over 34% in 2045, remaining in top position in 2045. All of the top ten countries have prevalence estimates exceeding 20%.

The top 10 countries in terms of number of people who have diabetes in the years 2021 and 2045 are shown in Table 5. China has the most people with diabetes with estimates of over 140 million in 2021, reaching over 174 million by 2045. China and India, the two countries with the greatest numbers of people with diabetes also have the largest populations.

3.3. *Health expenditure*

In 2021, the total estimated global healthcare expenditure for people aged 20–79 years was 966 billion USD, with the NAC Region accounting for 42.9% of the total amount spent worldwide on diabetes (415 billion USD) and the SEA Region just 1.0%, despite it having almost double the number of individuals living with diabetes of NAC. WP and EUR were estimated to currently spend 241 and 189 billion USD annually accounting for 25.0% and 19.6% of the total expenditures, respectively. Collectively, the remaining IDF Regions were responsible for 12.5% of the total global healthcare expenditure for diabetes (Fig. 4). Global spending was greatest for men 60–69 years (132.5 billion USD), being 27.5% higher than for women of the same age. Expenditure was also 19% higher for middle-aged men (50–59 years) compared to women of the same age. Healthcare expenditure per person was highest in the NAC Region (8,209 USD), and lowest in the SEA Region (112 USD) (Fig. 5). Predicted expenditure for adults for 2045 was

Table 3 – Estimated number of people with diabetes and prevalence of diabetes in adults (20–79 years) in IDF Regions in 2021 and 2045, ranked by 2021 comparative diabetes prevalence together with uncertainty intervals, expressed in parentheses.

		2021			2045		
Rank	IDF Region	Number of people with diabetes (millions)	Diabetes prevalence[i] (%)	Comparative diabetes prevalence[ii] (%)	Number of people with diabetes (millions)	Diabetes prevalence[i] (%)	Comparative diabetes prevalence[ii] (%)
	World	536.6 (424.2–612.3)	10.5 (8.3–12.0)	9.8 (7.7–11.2)	783.2 (605.2–898.6)	12.2 (9.5–14.0)	11.2 (8.6–12.9)
1	MENA	72.7 (38.2–81.8)	16.2 (8.5–18.3)	18.1 (9.5–20.3)	135.7 (71.2–153.5)	19.3 (10.1–21.9)	20.4 (10.7–23.1)
2	NAC	50.5 (44.5–57.1)	14.0 (12.3–15.8)	11.9 (10.0–13.6)	62.8 (55.5–71.4)	15.2 (13.4–17.3)	14.2 (12.1–16.2)
3	SEA	90.2 (76.8–99.9)	8.7 (7.4–9.7)	10.0 (8.6–11.1)	151.5 (130.9–167.1)	11.3 (9.8–12.5)	11.3 (9.7–12.4)
4	WP	205.6 (174.7–233.2)	11.9 (10.1–13.5)	9.9 (8.4–11.3)	260.2 (220.0–297.3)	14.4 (12.1–16.4)	11.5 (9.8–13.1)
5	SACA	32.5 (27.5–40.4)	9.5 (8.1–11.9)	8.2 (6.9–10.2)	48.9 (41.1–61.3)	11.9 (10.0–14.9)	9.8 (8.3–12.3)
6	EUR	61.4 (47.5–69.9)	9.2 (7.1–10.4)	7.0 (5.5–8.1)	69.2 (51.8–78.3)	10.4 (7.7–11.7)	8.7 (6.6–9.9)
7	AFR	23.6 (15.0–29.8)	4.5 (2.8–5.7)	5.3 (3.6–6.7)	54.9 (34.8–69.7)	5.2 (3.3–6.6)	5.6 (3.8–7.2)

Abbreviations: IDF: International Diabetes Federation; AFR: Africa; EUR: Europe; MENA: Middle East and North Africa; NAC: North America and Caribbean; SACA: South and Central America; SEA: South-East Asia; WP: Western Pacific.

*Based on 2021 comparative diabetes prevalence

[i] Prevalence was standardised to national populations for the respective year, aged 20–79 years

[ii] Prevalence was standardised to world population, for the respective year, aged 20–79 years

Table 4 – Top 10 countries or territories when ranked by age-adjusted comparative diabetes prevalence in adults (20–79 years) in 2021 and 2045.

2021			2045		
Rank	Country	Comparative diabetes prevalence[i] (%)	Rank	Country	Comparative diabetes prevalence[i] (%)
1	Pakistan	30.8	1	Pakistan	33.6
2	French Polynesia	25.2	2	Kuwait	29.8
3	Kuwait	24.9	3	French Polynesia	28.2
4	New Caledonia[ii]	23.4	4	Mauritius	26.6
5	Northern Mariana Islands[i]	23.4	5	New Caledonia[ii]	26.2
6	Nauru[ii]	23.4	6	Northern Mariana Islands[ii]	26.2
7	Marshall Islands	23.0	7	Nauru[ii]	26.2
8	Mauritius	22.6	8	Marshall Islands	26.0
9	Kiribati	22.1	9	Kiribati	24.1
10	Egypt	20.9	10	Egypt	23.4

[i] Prevalence is standardised to world population (aged 20–79) for the respective year.
[ii] Countries without in-country data sources. Estimates are extrapolated.

Table 5 – Top 10 countries or territories when ranked by the number of adults (20–79 years) with diabetes in 2021 and 2045.

2021			2045		
Rank	Country	Number of people with diabetes (millions)	Rank	Country	Number of people with diabetes (millions)
1	China	140.9	1	China	174.4
2	India	74.2	2	India	124.9
3	Pakistan	33.0	3	Pakistan	62.2
4	USA	32.2	4	USA	36.3
5	Indonesia	19.5	5	Indonesia	28.6
6	Brazil	15.7	6	Brazil	23.2
7	Mexico	14.1	7	Bangladesh	22.3
8	Bangladesh	13.1	8	Mexico	21.2
9	Japan	11.0	9	Egypt	20.0
10	Egypt	10.9	10	Turkey	13.4

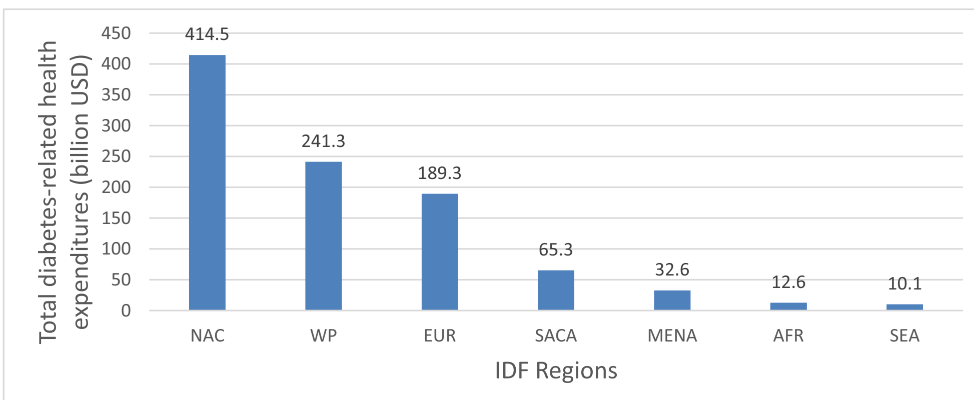

Fig. 4 – Total diabetes-related health expenditures (billion USD) in adults with diabetes (20–79 years) in 2021 by IDF Region IDF: International Diabetes Federation; AFR: Africa; EUR: Europe; MENA: Middle East and North Africa; NAC: North America and Caribbean; SACA: South and Central America; SEA: South-East Asia; WP: Western Pacific.

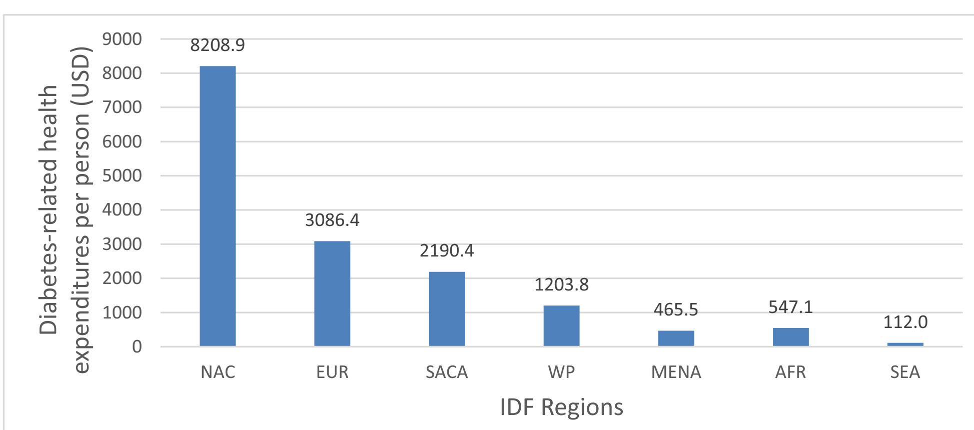

Fig. 5 – Diabetes-related health expenditures (USD) per person with diabetes (20–79 years) in 2021 by IDF Region IDF: International Diabetes Federation; AFR: Africa; EUR: Europe; MENA: Middle East and North Africa; NAC: North America and Caribbean; SACA: South and Central America; SEA: South-East Asia; WP: Western Pacific.

USD 1,054 billion, representing an increase of 9.1% compared to that in 2021 (Supplementary Table 2).

4. Discussion

The 10th edition IDF Diabetes Atlas estimates that in 2021 there are 537 million people living with diabetes worldwide. Overall, the global prevalence of diabetes is now estimated to be over 10%. Among income groups, the highest prevalence was observed in middle-income countries. Compared to the previous 9th IDF Diabetes Atlas edition, we report an overall 12.9% increase in diabetes prevalence, with prevalence increasing in many world regions

Future projections suggest that by 2045 the absolute number of people with diabetes will have increased by 46%, with the greatest absolute growth in terms of number of persons with diabetes between 2021 and 2045 occurring in middle-income countries. This is consistent with the fact that this group, which includes both India and China as well as most countries of the world with greater than 100 million population, has the largest fraction of the world´s population, with growth in number of cases of diabetes between 2021 and 2045 driven by greater median age and increasing urbanisation. Among the IDF Regions, the AFR and MENA Regions are projected to experience the largest relative increases in the number of people with diabetes, while the EUR, SACA and NAC Regions will see the greatest relative increases in comparative prevalence from 2021 to 2045.

The IDF Diabetes Atlas presents estimates of both prevalence and number of people with diabetes. Unsurprisingly, countries with large populations such as China, India, Pakistan, and the USA contribute the most to the total number of people with diabetes. However, despite the WP having a larger total population, the greatest absolute growth in the number of people with diabetes over time is expected to take place in the SEA and MENA Regions. This reflects the variation in forecasted population changes in these regions in terms of greater mean age, overall population size and increasing proportions of people living in cities. [19]

The increasing burden of diabetes worldwide is, not surprisingly, accompanied by greater health expenditures for the care of this disease, which we estimate will exceed one trillion USD by 2045. The NAC Region accounts for the highest proportion of health expenditures for diabetes, while the smallest proportion of expenditures occurs in the SEA Region. Global diabetes-related health expenditures in several age categories for men exceed those for women. How much of this difference represents a greater need for health care in men or a healthcare disparity is not known but represents an area where additional research would be informative. The discordance between the large projected increase in diabetes cases and the only slight increase in projected diabetes-related health expenditures occurs because most of the increase in diabetes cases is in low- and middle-income countries in which expenditures related to diabetes are much lower.

4.1. *Limitations*

The IDF estimates of diabetes prevalence are not without limitations. With each new IDF Diabetes Atlas edition, our methods are reviewed and improvements are made where possible. For our projections, we only consider demographic changes in age, sex and urbanisation, ignoring potential effects on diabetes incidence due to changes in the prevalence of risk factors such as obesity as well as the potential for greater longevity of those with diabetes over time. It is important to point out, however, that our analyses do capture part of these changes, to the extent that they result from urbanization, which we do consider in our analyses. [20] However, if changes in incidence or survival go beyond those predicted by urbanisation, our projections may underestimate future diabetes prevalence and number of people affected. Incidentally, recent evidence suggests that diabetes incidence is levelling off or decreasing in several high-income countries. [21]

The ascertainment of diabetes in many of the studies used in the IDF Diabetes Atlas is based on an epidemiological definition. When based on glucose testing, this definition requires abnormal glycemia by only one test at one moment, compared to a clinical diagnosis of diabetes, which requires confirmation by a repeat test in the absence of symptoms of hyperglycaemia. While several studies did include more than one test for diabetes, their criteria for ascertainment rarely required two abnormal results. Thus, to the extent that our findings are based on laboratory determinations, the prevalence reported will likely overestimate the prevalence of clinically-defined diabetes. [22]

Vast amounts of diabetes-specific data in the form of large administrative ‘whole of population’ datasets and clinical data, such as medication reimbursement data and national health insurance data, are currently available worldwide. In this 10th IDF Diabetes Atlas edition, we included contemporary data from many such sources. Key advantages of such data are that the ‘whole population’ nature of the sample likely reduces selection bias and ascertainment based on a clinical definition. One key limitation of registries and administrative data however is that only diagnosed diabetes is captured. Thus, estimates from these sources are adjusted by the estimated proportion of undiagnosed diabetes in that country to predict the total prevalence of diabetes, introducing another source of uncertainty. Further, achieving good capture rates in diabetes registries or administrative data can take several years due to delays in the recording of diabetes due to less than annual medical visits or delay in the recognition and recording of the presence of diabetes.

The raw data used in our analyses are subject to considerable heterogeneity in terms of calendar year, diagnostic methods, precision and design of the underlying studies. We have attempted to address this by using strict selection criteria and the analytic hierarchy process to choose for inclusion only higher quality research. Further, the data from each study were smoothed using regression modelling in order to generate the most plausible age-specific estimates. These methods, however, do not eliminate all potential biases. Therefore, it is important to consider such differences in underlying study methodology when making comparisons between countries. An important change in the methods since the last edition is the exclusion of all studies published before 2005. Since older studies generally tend to report lower prevalence, the exclusion of these studies may have contributed to the 12.9% rise in global prevalence when compared to the prevalence estimate from the 9th edition of Atlas.

As with earlier IDF Diabetes Atlas editions, our aim was to produce what we believe is the best estimate of diabetes prevalence for all countries and territories with a population of at least 50,000 persons. Therefore, when a country lacked internal data on diabetes prevalence, this was estimated by extrapolation of the prevalence from a country with similar economy, language and demographic features. We acknowledge that these extrapolations may represent sources of error.

An additional limitation is that our estimates are not separated by diabetes type. However, the overwhelming majority of people with diabetes in 2021 have type 2 diabetes and the increases to 2045 are projected to be similarly predominantly of type 2 diabetes. This mainly reflects differences in the pathophysiology of type 1 and 2 diabetes, with the former occurring due to an incompletely understood combination of genetic and environmental factors leading to an autoimmune process which is less sensitive to environmental change, whereas type 2 diabetes is due to the combined effects of excess body weight, sedentary behaviour, dietary changes, and other factors that have become more prevalent worldwide as the environment has changed. The incidence of type 1 diabetes peaks in childhood, while the incidence of type 2 diabetes in adults is an order of magnitude higher and peaks in middle and older ages. [23] Therefore, in this report that focuses on adults, the prevalence trends mainly reflect type 2 diabetes.

Finally, health expenditure projections in our analyses are conservative because we assumed that age-specific risk factors did not change, and that per-patient treatment costs remained constant despite increasing wealth and development in low- and middle-income countries, where an increasing proportion of those with diabetes will reside in the future. Future research is warranted to examine results through varying analytic assumptions for projecting health expenditures.

5. Conclusion

The 10th edition of the IDF Diabetes Atlas suggests that in 2021 more than 1 in 10 adults now have diabetes globally and that the number of people with diabetes will continue to expand rapidly in the future. As our projections only consider demographic changes in populations relating to ageing and urbanisation, and not changes in risk factor prevalence or in survival, it is likely that our projected increases over time are conservative. Prevalence is predicted to increase the most among middle-income countries where populations will grow and age considerably and major urbanisation will continue to occur. While our ability to generate health data which can be used for disease monitoring has increased, there still remain considerable knowledge gaps from many countries worldwide due to absent or poor-quality data. Nonetheless, our sobering estimations herald a continually expanding diabetes epidemic that will increasingly impact the health of all populations across the globe. With ageing and urbanisation being inevitable drivers of the epidemic, and better diabetes treatment paradoxically increasing prevalence through decreased mortality, a strong need exists for the implementation of effective intervention strategies and policies that aim to stall the increase in the number of people developing diabetes and its complications.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Erratum

Erratum to "IDF Diabetes Atlas: Global, regional and country-level diabetes prevalence estimates for 2021 and projections for 2045" [Diabetes Res. Clin. Pract. 183 (2022) 109119]

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The publisher regrets the associated supplementary material was missing from the above-mentioned published article.

The supplementary is now available online.

The publisher would like to apologise for any inconvenience caused.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.diabres.2023.110945.

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