Contents available at ScienceDirect

Diabetes Research and Clinical Practice

journal homepage: www.elsevier.com/locate/diabres

Global estimates of incidence of type 1 diabetes in children and adolescents: Results from the International Diabetes Federation Atlas, 10th edition

Graham D. Ogle [a,*], *Steven James* [a,b], *Dana Dabelea* [c], *Catherine Pihoker* [d], *Jannet Svennson* [e,f], *Jayanthi Maniam* [a], *Emma L. Klatman* [a], *Chris C. Patterson* [g]

[a] *Life for a Child, Diabetes NSW, Glebe, New South Wales, Australia*
[b] *School of Nursing, Midwifery and Paramedicine, University of the Sunshine Coast, Petrie, Queensland, Australia*
[c] *Lifecourse Epidemiology of Adiposity and Diabetes Center, University of Colorado Anschutz Medical Campus, Aurora, CO, United States*
[d] *Department of Pediatrics, University of Washington, Seattle, WA, United States*
[e] *Department of Pediatric and Adolescents, Herlev and Gentofte University Hospital, Herlev, Denmark*
[f] *Department of Clinical Medicine, Faculty of Health and Medicine, University of Copenhagen, Copenhagen, Denmark*
[g] *Centre for Public Health, Queen's University Belfast, Belfast, Northern Ireland, United Kingdom*

ARTICLE INFO

Article history:
Received 30 September 2021
Accepted 5 October 2021
Available online xxxx

Keywords:
Adolescents
Atlas
Children
Incidence
Incident
Type 1 diabetes

ABSTRACT

Background: Type 1 diabetes (T1D) incidence in children and adolescents varies widely, and is increasing in many nations. The 10th edition of the International Diabetes Federation Atlas estimated incident cases in 2021 for 215 countries/territories ("countries").

Methods: Studies on T1D incidence for young people aged 0–19 years were sourced and graded using previously described methods. For countries without studies, data were extrapolated from similar nearby countries.

Results: An estimated 108,300 children under 15 years will be diagnosed in 2021, a number rising to 149,500 when the age range extends to under 20 years. The ratio of incidence in 15–19 years compared to those aged 0–14 years was particularly high in some countries in sub-Saharan Africa, North Africa/Middle East, and in Mexico.

Only 97 countries have their own incidence data, with extrapolation required for some very populous nations. Most data published were not recent, with 27 countries (28%) having data in which the last study year was 2015 or afterwards, and 26 (27%) having no data after 1999.

Conclusions: Many countries have recent data but there are large gaps globally. Such data are critical for allocation of resources, teaching, training, and advocacy. All countries are encouraged to collect and publish current data.

© 2021 Elsevier B.V. All rights reserved.

* Corresponding author.
E-mail address: grahamo@diabetesnsw.com.au (G.D. Ogle).

https://doi.org/10.1016/j.diabres.2021.109083
0168-8227/© 2021 Elsevier B.V. All rights reserved.

Please cite this article as: G. D. Ogle, S. James, D. Dabelea et al., Global estimates of incidence of type 1 diabetes in children and adolescents: Results from the International Diabetes Federation Atlas, 10th edition, Diabetes Research and Clinical Practice, https://doi.org/10.1016/j.diabres.2021.109083

1. Introduction

Type 1 diabetes (T1D) is the commonest form of diabetes in children and adolescents, but type 2 diabetes, monogenic diabetes, and other forms also occur (1). T1D is a complex condition to manage. Insulin injections are needed for survival, and good outcomes can only be achieved with multiple daily injections, self-monitoring of blood glucose, comprehensive diabetes education and guidance from skilled health professionals (2).

The International Diabetes Federation (IDF) Atlas is regularly updated to provide evidence to raise awareness of diabetes and inform development of national diabetes plans that are appropriate to unique local contexts. Numbers of new (incident) and existing (prevalent) T1D cases are increasing each year due to rising incidence in many countries/territories (hereafter called "countries") (3), and reductions in mortality (4). This 10th edition of the IDF Atlas estimates that 1,211,900 children and adolescents younger than 20 years have T1D globally.

T1D incidence varies around the world with some regions having much higher incidences than others. Incidence has been increasing in recent decades in nearly all countries studied, although there is now evidence that this increase maybe tailing off or has ceased in some high-income countries (3,5,6). The reasons for this increase are unclear, however various environmental factors have been proposed and are being investigated (3,7).

Complimentary to the 10th edition of the IDF Atlas, this article aims to present current country incidence data, and to identify knowledge gaps.

2. Subjects, materials and methods

The incidence estimates of T1D in children and adolescents (0–14 and 0–19 years of age) were produced by the 10th edition IDF Atlas T1D in Children and Adolescents Special Interest Group, using methodology from the 9th edition of the IDF Atlas as previously described (6), and updated in 2021 with a further search using Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia).

The scientific literature was searched, without language restrictions, for data sources that contained population-based studies on T1D incidence in children and adolescents aged up to 20 years. If more than one study was available for a country, the following criteria were applied to select the most suitable: recent; population-based studies; high (≥90%) ascertainment level; covering a large part of the country; providing age- and sex-specific rates; and including the age ranges 0–14 and 15–19 years. For some countries where two or more studies met these criteria to an equal extent, results were combined by averaging age- and sex-specific rates.

If a country did not have any information available, the incidence rate for ages under 15 years was estimated using data from a similar country, based on geographical proximity, income, and ethnicity. For ages 15–19 years, in the absence of specific country or area data the incidence rate was estimated using the average regional ratio of incidence in the 15–19 years and 0–14 years age groups.

Unless stated, data are presented for ages 0–14 years.

3. Results

3.1. *Atlas estimates*

3.1.1. *Global results*

This study estimates that around 108,300 children and adolescents under 15 years will be diagnosed in 2021, and this number rises to 149,500 when the age range extends to under 20 years (Table 1).

T1D age-standardised incidences are highest in populations of northern European origin, and in several countries in the Middle Eastern and North African Region (Table 2, Fig. 1, and Supplementary Material 1). Table 2 shows the ten countries with the highest published age-standardised incidence of T1D reported in children aged 0–14 years, and estimated number of incident cases of T1D in children aged 0–14 years. India and the United States of America had the highest numbers of estimated incident cases of T1D, followed by various other populous countries.

Similar patterns of age-standardised T1D incidence and estimated incident cases of T1D per year were seen when considering ages 0–19 years (Supplementary Material 1).

Table 1 – Estimated incident cases.

IDF Region	Number of countries with incidence rates available (%)	Incident cases per annum (1000 s)	
		0–14 years	0–19 years
AFR	6/48 (12.5)	7.7	19.7
EUR	44/59 (74.6)	24.7	31.0
MENA	12/21 (57.1)	18.1	25.0
NAC	8/23 (34.8)	18.7	24.4
SACA	12/19 (63.2)	9.5	12.3
SEA	4/7 (57.1)	20.5	25.7
WP	11/38 (29)	0.1	11.6
World	**97/215 (45.1)**	**108.3**	**149.5**

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; and WP = Western Pacific.

Please cite this article as: G. D. Ogle, S. James, D. Dabelea et al., Global estimates of incidence of type 1 diabetes in children and adolescents: Results from the International Diabetes Federation Atlas, 10th edition, Diabetes Research and Clinical Practice, https://doi.org/10.1016/j.diabres.2021.109083

Table 2 – The ten countries/territories with the highest a) published age-standardised incidence of type 1 diabetes reported in children aged 0–14 years; and b) estimated number of incident cases of type 1 diabetes in children aged 0–14 years.

Highest age-standardised incidence				Highest incident cases (2021)			
Rank	Country/territory	IDF Region	Incidence (per 100,000 per annum)	Rank	Country/territory	IDF Region	Incident cases
1	Finland	EUR	52.2	1	India	SEA	19,194
2	Sweden	EUR	44.1	2	United States of America	NAC	15,288
3	Kuwait	MENA	41.7	3	Brazil	SACA	7,117
4	Qatar	MENA	38.1	4	China	WP	4,900
5	Canada	NAC	37.9	5	Algeria	MENA	4,874
6	Algeria	MENA	34.8	6	Russian Federation	EUR	3,345
7	Norway	EUR	33.6	7	Germany	EUR	2,845
8	Saudi Arabia	MENA	31.4	8	United Kingdom	EUR	2,713
9	United Kingdom	EUR	28.1	9	Saudi Arabia	MENA	2,680
10	Ireland	EUR	27.5	10	Canada	NAC	2,274

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

Please cite this article as: G. D. Ogle, S. James, D. Dabelea et al., Global estimates of incidence of type 1 diabetes in children and adolescents: Results from the International Diabetes Federation Atlas, 10th edition, Diabetes Research and Clinical Practice, https://doi.org/10.1016/j.diabres.2021.109083

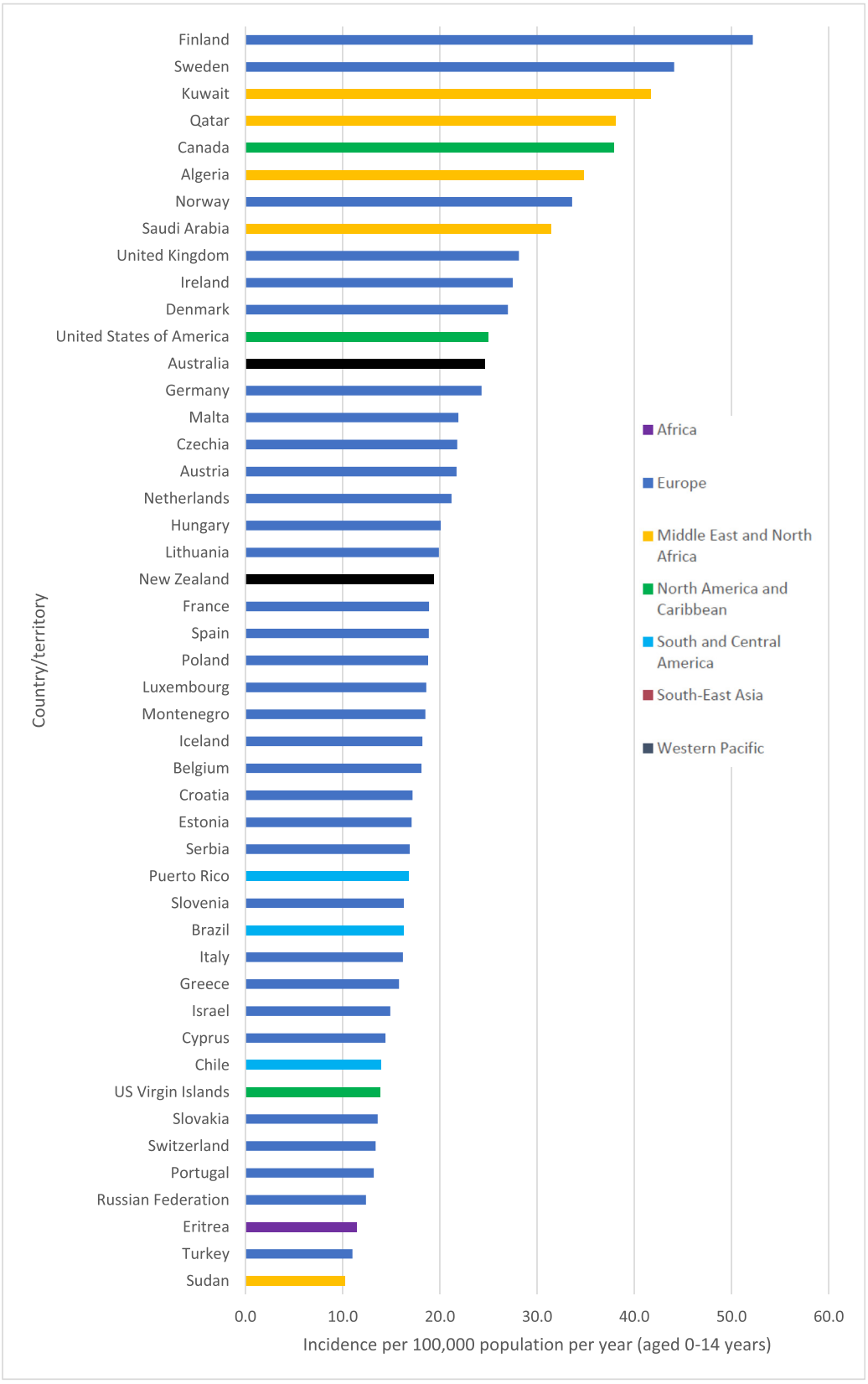

Fig. 1 – Published age-standardised incidence of type 1 diabetes reported in children aged 0–14 years.

Please cite this article as: G. D. Ogle, S. James, D. Dabelea et al., Global estimates of incidence of type 1 diabetes in children and adolescents: Results from the International Diabetes Federation Atlas, 10th edition, Diabetes Research and Clinical Practice, https://doi.org/10.1016/j.diabres.2021.109083

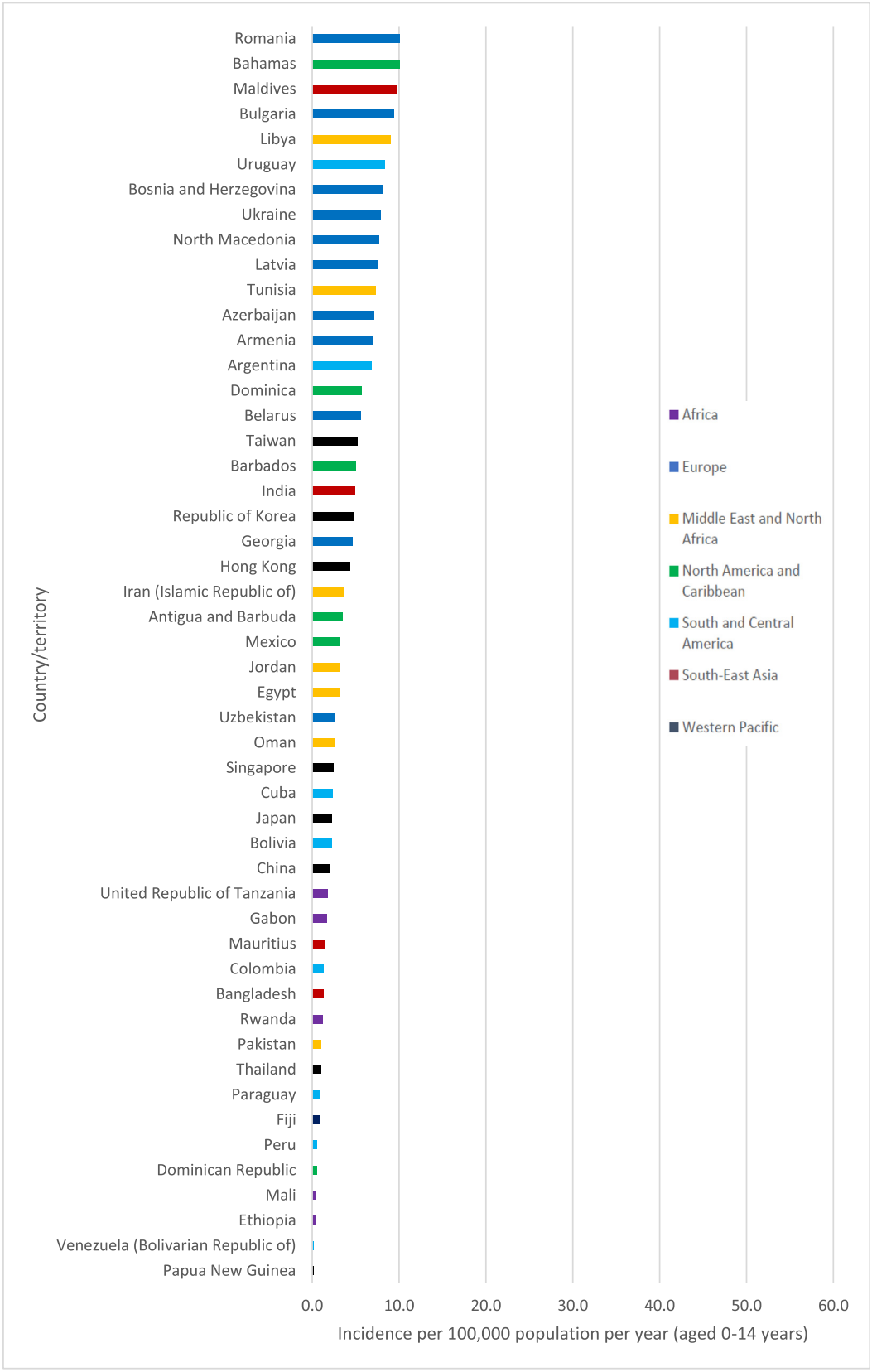

Fig 1. *(continued)*

Please cite this article as: G. D. Ogle, S. James, D. Dabelea et al., Global estimates of incidence of type 1 diabetes in children and adolescents: Results from the International Diabetes Federation Atlas, 10th edition, Diabetes Research and Clinical Practice, https://doi.org/10.1016/j.diabres.2021.109083

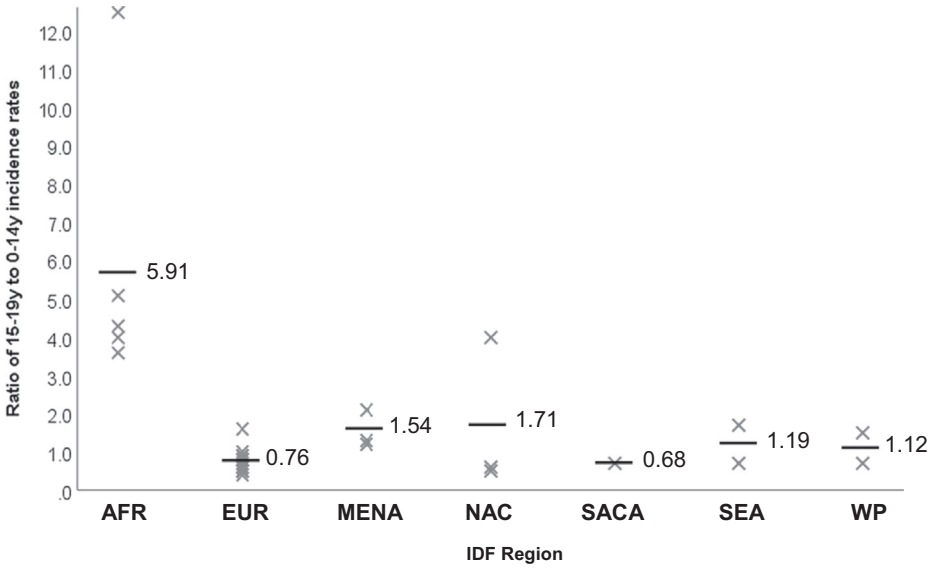

Fig. 2 – Ratio estimates for type 1 diabetes 0–14-year rates to 15–19-year rates. *IAFR = Africa; EUR = Europe; MENA = Middle East and North Africa, NAC = North America and Caribbean; SACA = South and Central America; SEA = South-East Asia; and WP = Western Pacific.*

3.1.2. *Age ratio calculations for 15–19-year age group*

All included studies had data for 0–14 years. However, only 26 countries also had data for 15–19 years (Supplementary Material 2).

The mean ratio of incidence 15–19 years compared to incidence 0–14 years was calculated by IDF Region (Fig. 2). The Africa Region ratio (5.91) was over three times higher than any other region.

3.1.3. *Income level*

The World Bank categorises all countries into four income groups (8). Within high-income countries, highest incidences were seen in Northern European and some Middle Eastern countries, with much lower rates in Japan and Singapore (Supplementary Material 1). For upper-middle income countries, rates were again highest in European countries as well as Brazil, and lower in China and some other non-European population countries. For lower-middle income countries, the highest rates were seen in Northern African countries and the Ukraine. For low-Income countries, incidence was highest in Eritrea.

3.2. *Gaps in knowledge*

3.2.1. *Data extrapolation*

Only 97 of the 215 countries covered by the Atlas have their own incidence data (Table 1, Fig. 1, and Supplementary Material 1). Table 3 lists countries used for extrapolation and the countries without incidence data to which rates were extrapolated.

3.2.2. *Period of data*

Much published data were not recent, with only 27 of the 97 countries (28%) including data from years as recent as 2015. Thirty-seven countries (38%) had data with the most recent year between 2010 and 2014, 7 (7%) with most recent years between 2000 and 2009, and 26 (27%) with most recent year between 1990 and 1999. The median most recent year of data was 2012. Fig. 3 shows the geographical variation around period of most recent data, indicating the limited data from the African Region.

4. Discussion

This article presents most recent country T1D incidence data for children and adolescents and identifies various gaps.

In the two years since the IDF Atlas 9th Edition in 2019 (9), estimated numbers of new T1D cases 0–14 years have increased from 98,200 to 108,300 and for 0–19 years from 128,900 to 149,500. Increases were most pronounced in the African, Middle East and North Africa Regions. For the African Region, this is due to new data from Gabon (10) and Eritrea (11), as well as updated data from Tanzania (12) that were higher than previous estimates and also extrapolated to various other countries in sub-Saharan Africa without any data. For the Middle East and North Africa Region, new data from Algeria increased estimates.

These data continue to show great differences globally, with incidence in the highest country (Finland) over fifty times higher than various countries in South Asia, Africa, South and Central America and the Western Pacific. It must be noted that some countries had studies that are quite dated, and also there is also the strong possibility of underestimation of incidence rates because of death through missed diagnosis in some countries (2,4,10,13). However, both Finland and Japan have recent data and well-resourced health systems but still have a 24-fold difference in rates 0–14 years (52.2 versus 2.2 per 100,000 per year).

Only 97 of the 215 countries covered by the Atlas have their own incidence data. Countries without any data include some very populous nations such as Nigeria, Indonesia, Philippines, Vietnam, and South Africa. In these cases, data are extrapo-

Table 3 – Data extrapolation.

Source country/territory	Country/territory data extrapolated to
African Region	
Eritrea	Djibouti and Somalia
Gabon	Benin, Cameroon, Cape Verde, Congo, Côte d'Ivoire, Equatorial Guinea, Ghana, Mauritania, Nigeria, Sao Tome and Principe and Senegal
Mali	Burkina Faso, Central African Republic, Chad, Gambia, Guinea, Guinea-Bissau, Liberia, Niger, Sierra Leone and Togo
Mauritius	Comoros, Mayotte and Seychelles
United Republic of Tanzania	Angola, Eswatini, Kenya, Lesotho, Madagascar, Malawi, Mozambique, Namibia, South Africa, Uganda, Zambia and Zimbabwe
Rwanda	Botswana, Burundi, Democratic Republic of the Congo
Sudan	South Sudan
European Region	
China	Kazakhstan and Kyrgyzstan
Denmark	Faroe Islands and Greenland
France	Monaco
Italy	Holy See and San Marino
North Macedonia	Albania
Romania	Moldova
Spain	Andorra
Switzerland	Liechtenstein
Turkey	Turkmenistan
United Kingdom	Channel Islands and Isle of Man
Uzbekistan	Tajikistan
Middle Eastern and Northern African Region	
Algeria	Morocco
Jordan	Iraq, Lebanon, State of Palestine and Syria
Oman	Bahrain, United Arab Emirates and Yemen
Uzbekistan	Afghanistan
North American and Caribbean Region	
Barbados	Grenada, St Kitts and Nevis, St Lucia, St Vincent and the Grenadines, and Trinidad, and Tobago
Cuba	Cayman Islands and Jamaica
Dominican Republic	Haiti
Gabon	Bermuda
Mexico	Belize
US Virgin Islands	British Virgin Islands
Venezuela	Aruba, Curaçao, Guyana and Suriname
South and Central American Region	
Colombia	Costa Rica, Ecuador and Panama
Mexico	El Salvador, Guatemala, Honduras and Nicaragua
South-East Asian Region	
India	Bhutan, Nepal and Sri Lanka
Western Pacific Region	
China	Mongolia
Fiji	American Samoa, French Polynesia, Kiribati, New Caledonia, Northern Mariana Islands, Samoa, Tonga, Tuvalu and Vanuatu
Hong Kong, China	Macao
Thailand	Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Timor L'Este and Vietnam
Papua New Guinea	Guam, Marshall Islands, Micronesia (Federated States of), Nauru, Palau, and the Solomon Islands
Republic of Korea	Democratic People's Republic of Korea

Please cite this article as: G. D. Ogle, S. James, D. Dabelea et al., Global estimates of incidence of type 1 diabetes in children and adolescents: Results from the International Diabetes Federation Atlas, 10th edition, Diabetes Research and Clinical Practice, https://doi.org/10.1016/j.diabres.2021.109083

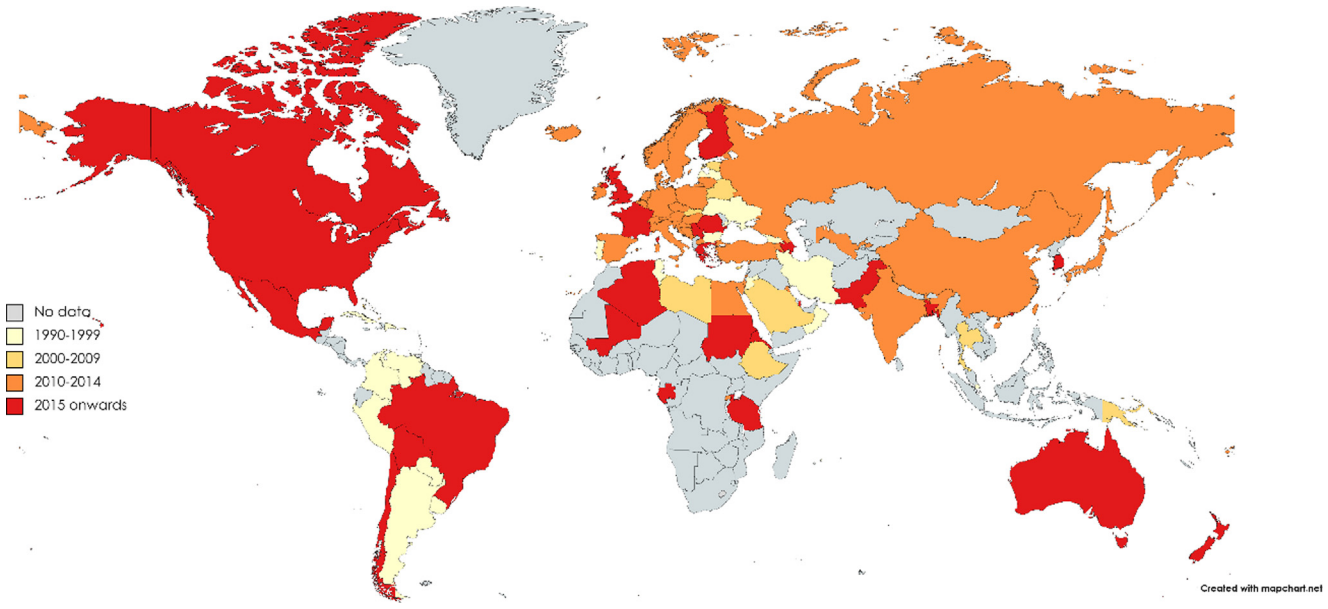

Fig. 3 – Period of most recent data.

lated from a nearby country with similar characteristics, but there are various reasons why such data may not be very accurate. Gaps are greatest in sub-Saharan Africa and parts of Asia, South and Central America, and the Caribbean. Only six of the 48 countries in the Africa Region have data. This sparsity of data results in wide extrapolations of incidence data across the continent. Given that this region has great genetic diversity, these extrapolations may be inaccurate (14).

Most data published were also not recent; only 27 countries (28%) having data in which the last study year was as recent as 2015, with 26 (27%) having most recent data between 1990 and 1999. Given the global rise in incidence over the last few decades, incidence figures are likely to be markedly under-estimated. For instance, a 3% annual rise over 20 years will increase incidence by 81%.

Incidence data are also much more limited for the 15–19 year than for the 10–14-year age groups, with only 26 countries having 15–19-year data. This is particularly important as the peak age of onset of T1D varies substantially. In Finland, T1D incidence peaks in the 5–9 years age group (15) and in most other non-European origin populations in the 10–14 years group (3,16). T1D onset has become earlier over the last few decades in these populations (9). However, peak age of T1D onset in most sub-Saharan African studies is later, in the late teens or even later (4,11,13,17). Possible reasons for this include different phenotypes of T1D, a greater likelihood of deaths with missed diagnosis in younger children, and a temporal delay in the environmental changes that have resulted in earlier age of onset in European-origin populations. A higher ratio of onset at 15–19 years is also seen in Iran (Islamic Republic of), Sudan, Libya, and Mexico, raising the ratio for their respective Regions.

Given the very wide range of measured T1D incidence and the fact that incidence has been increasing over time in most countries (3,5), it is essential that countries ascertain their current rates of new and existing cases of T1D for children and adolescents. Knowledge of the number of new and existing cases is critical so that sufficient health resources can be allocated. These numbers inform health professional training and advocacy efforts.

The authors and the IDF, Life for a Child, and the International Society for Pediatric and Adolescent Diabetes (ISPAD) are very willing to advise and foster new incidence studies in countries that either have no data or no recent data. The IDF Guide for Diabetes Epidemiological Studies, released in 2021 and available on the IDF website (18), provides useful and practical information on how to plan, conduct, and report such studies.

In summary, compared with the 9th edition of the IDF Atlas in 2019, estimated numbers of new cases of T1D have increased, particularly in the Africa, Middle East and North Africa Regions. However, less than half of the countries and territories covered by the Atlas have their own incidence data, with many studies having dated data. Data limitations can only be resolved with more, and more recent data. Efforts should be made by all countries to ascertain their current rates of new and existing cases of T1D for children and adolescents. Such information will guide allocation of health resources as well as health professional training and advocacy efforts.

5. Authors' contributions

All authors (excluding SJ) co-designed the study, collected, and analysed the data. SJ wrote the first draft of the manuscript, and all authors contributed to the manuscript.

Funding

GDO, JM and ELK were partly funded by a grant from The Leona M and Harry B Helmsley Charitable Trust.

Please cite this article as: G. D. Ogle, S. James, D. Dabelea et al., Global estimates of incidence of type 1 diabetes in children and adolescents: Results from the International Diabetes Federation Atlas, 10th edition, Diabetes Research and Clinical Practice, https://doi.org/10.1016/j.diabres.2021.109083

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.

Acknowledgements

We thank Suvi Karuranga (International Diabetes Federation, Brussels, Belgium) for her ongoing support, and Mapchart.net, whose software were used to create Fig. 3; work licensed under a Creative Commons Attribution-ShareAlike 4.0 International License.

REFERENCES

[1] Mayer-Davis E, Kahkoska A, Jefferies C, Dabelea D, Balde N, Gong C, et al. ISPAD clinical practice consensus guidelines 2018: Definition, epidemiology, and classification of diabetes in children and adolescents. Pediatr Diabetes. 2018;19:7-19 PMID: 30226024 10.1111/pedi.12773.

[2] Ogle G, von Oettingen J, Middlehurst A, Hanas R, Orchard T. Levels of type 1 diabetes care in children and adolescents for countries at varying resource levels. Pediatr Diabetes. 2019;20 (1):93-8 PMID: 30471084 10.1111/pedi.12801.

[3] Tuomilehto J, Ogle G, Lund-Blix N, Stene L. Update on worldwide trends in occurrence of childhood type 1 diabetes in 2020. Pediatric endocrinology reviews : PER. 2020;17:198-209 PMID: 32208564 10.17458/per.vol17.2020.tol. epidemiologychildtype1diabetes.

[4] Sandy J, Besançon S, Sidibé A, Minkailou M, Togo A, Ogle G. Rapid increases in observed incidence and prevalence of type 1 diabetes in children and youth in Mali, 2007-2016. Pediatr Diabetes. 2021:1-7 10.1111/pedi.13191.

[5] Patterson C, Harjutsalo V, Rosenbauer J, Neu A, Cinek O, Skrivarhaug T, et al. Trends and cyclical variation in the incidence of childhood type 1 diabetes in 26 European centres in the 25 year period 1989-2013: A multicentre prospective registration study. Diabetologia. 2019;62(3):408-17 PMID: 30483858 10.1007/s00125-018-4763-3.

[6] Patterson C, Karuranga S, Salpea P, Saeedi P, Dahlquist G, Soltesz G, et al. Worldwide estimates of incidence, prevalence and mortality of type 1 diabetes in children and adolescents: Results from the International Diabetes Federation Diabetes Atlas, 9th edition. Diab Res Clin Pract. 2019;157:107842.

[7] Katsarou A, Gudbjörnsdottir S, Rawshani A, Dabelea D, Bonifacio E, Anderson BJ, et al. Type 1 diabetes mellitus. Nat Rev Dis Primers 2017;3(1). https://doi.org/10.1038/nrdp.2017.16.

[8] World Bank. World Bank country and lending groups. Available at: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups, accessed 28th June 2021.

[9] International Diabetes Federation. IDF diabetes atlas. 9th edition. International Diabetes Federation: Brussels. 2019.

[10] Pambou Damiens A, Ganga –Zandzou PS, Tsoucka Ibounde E, Kayemba-Kay's S, Baye E, Biloghe P, et al. Type 1 diabetes mellitus in Gabon: A study of epidemiological aspects. Int J Pediatr Adolesc Med 2019;6(3):87–91. https://doi.org/10.1016/j.ijpam.2019.02.007.

[11] Mebrahtu G, Maniam J, James S, Ogle G. High incidence of type 1 diabetes in adolescents and young adults in Eritrea. Diabet Med. 2021;38:e14544 10.1111/dme.

[12] Jasem D, Majaliwa E, Ramiaya K, Najem S, Swai A, Ludvigsson J. Incidence, prevalence and clinical manifestations at onset of juvenile diabetes in Tanzania. Diabetes Res Clin Pract. 2019;156:107817 10.1016/j.diabres.2019.

[13] Marshall S, Edidin DA, VC, Becker D, Bunker C, Gishoma C, Gishoma F, et al. Prevalence and incidence of clinically recognized cases of Type 1 diabetes in children and adolescents in Rwanda, Africa. Diabet Med. 2015;32(9):1186-92.

[14] Tishkoff S, Reed F, Friedlaender F, Ehret C, Ranciaro A, Froment A, et al. The genetic structure and history of Africans and African Americans. Science. 2009;324 (5930):1035–44 10.126/science.1172257.

[15] Harjutsalo H, Sund R, Knip M, Per-Henrik Groop P-H. Incidence of type 1 diabetes in Finland. JAMA 2013;310 (4):427–8.

[16] Diaz-Valencia P, Bougnères P, Valleron A-J. Global epidemiology of type 1 diabetes in young adults and adults: a systematic review. BMC Public Health 2015;15(255):1–15.

[17] Alemu S, Dessie A, Seid E, Bard E, Lee P, Trimble E, et al. Insulin-requiring diabetes in rural Ethiopia: should we reopen the case for malnutrition-related diabetes? Diabetologia. 2009;52(9):1842-5.

[18] International Diabetes Federation. International Diabetes Federation's guide for diabetes epidemiologcial studies. Available at: https://www.idf.org/our-activities/epidemiology-research/idf-guide-for-diabetes-epidemiology-studies.html, accessed 24th September 2021. 2021.