International comparison of glycaemic control in people with type 1 diabetes

an update and extension

Title: International comparison of glycaemic control in people with type 1 diabetes: an update and extension

Short title: International comparison of glycaemic control in people with type 1 diabetes

Authors & author affiliations (please note we would like all listed authors to be included even though the webpage limits the number we could enter there)

Scotland

R. Prigge[1], J. A. McKnight[1,2*], S. H. Wild[1*]on behalf of the Scottish Diabetes Research Network Epidemiology Group

1 Usher Institute, University of Edinburgh, Edinburgh, UK,

2 Metabolic Unit and Acute Receiving Unit, Western General Hospital, Edinburgh, UK,

***** Joint senior authors

Australia

A. Haynes[3],T. W. Jones[3,4,5], E. A. Davis[3,4,5]

3 Telethon Kids Institute, The University of Western Australia, Perth, Australia

4 Department of Endocrinology and Diabetes, Perth Children's Hospital, Perth, Australia

5 School of Paediatrics and Child Health, The University of Western Australia, Perth, Australia

Austria

B. Rami-Merhar[6], M. Fritsch[6,7],Christine Prchla[8] on behalf of the German/Austria DPV database

6 Department of Paediatrics and Adolescent Medicine, Medical University of Vienna, Vienna, Austria,

7 Department of Paediatrics and Adolescent Medicine, Medical University of Graz, Graz,

8 Klinik Donaustadt, Department of Paediatrics and Adolescent Medicine, Vienna, Austria

Belgium

A. Lavens[9], K. Doggen[9], S. Chao[9] on behalf of the Belgian Group of Experts IQECAD and IQED

9 Sciensano, Brussels, Belgium

Canada

R. Aronson[10], R. Brown[10]

10 LMC Diabetes & Endocrinology, Toronto, Canada

Denmark

E. H. Ibfelt[11], J. Svensson[12],

11 Steno Diabetes Center Copenhagen, Gentofte, Denmark

12 Department of Paediatrics, Copenhagen University Hospital Herlev, Copenhagen, Denmark

England & Wales

R. Young[13]on behalf of the National Diabetes Audit, J. T. Warner[14], Robinson H[15] on behalf of the National Paediatric Diabetes Audit and the Royal College of Paediatrics and Child Health

13 Diabetes UK, Back Church Lane, London, UK

14 Children's Hospital for Wales, Cardiff, UK

15 Royal College of Paediatrics and Child Health

Finland

T. Laatikainen[16,17, 18], P. Rautiainen[18]

16 Institute of Public Health and Clinical Nutrition, University of Eastern Finland, Kuopio, Finland

17 National Institute for Health and Welfare, Helsinki, Uusimaa, Finland

18 Joint municipal authority for North Karelia social and health services (Siunsote), Joensuu, Finland

France

B. Delemer[19], P. F. Souchon[20], A. M. Diallo[19] on behalf of the CARéDIAB Network

19 Department of Endocrinology, Diabetes and Nutrition, American Memorial Hospital, University Hospital of Reims, France

20 Department of Paediatrics, American Memorial Hospital, University Hospital of Reims, France

Germany

R.W. Holl[21,22],S.M.Schmid[22,23], K. Raile[24] on behalf of the German/Austrian DPV database,

21 Institute of Epidemiology and Medical Biometry, ZIBMT, University of Ulm, Ulm, Germany,

22 German Centre for Diabetes Research (DZD), Munich Neuherberg

23 Institute for Endocrinology and Diabetes, University of Lübeck, Lübeck, Germany

24 Department of Paediatric Endocrinology and Diabetology, Charité, University Medicine Berlin, Berlin, Germany

Greece

S. Tigas[25], A. Bargiota[26], I. Zografou[27]

25 Department of Endocrinology, University of Ioannina,

26 Department of Endocrinology and Metabolic Diseases, University of Thessaly,

27 Second Propaedeutic Department of Internal Medicine, Aristotle University of Thessaloniki, Hippokratio General Hospital, Thessaloniki, Greece

Hong Kong

A. O. Y. Luk[28], J. C. N. Chan[29]

28 The Chinese University of Hong Kong, Hong Kong Institute of Diabetes and Obesity, Department of Medicine & Therapeutics, Shatin, Hong Kong, Peoples Republic China

29 The Chinese University of Hong Kong, Li Ka Shing Inst Hlth Sci, Shatin, Hong Kong, Peoples R China

Ireland

S. F. Dinneen[30,31], C. M. Buckley[32], O. Kgosidialwa[30]

30 Centre for Diabetes, Endocrinology and Metabolism, Galway University Hospital, Galway, Ireland

31 NUI Galway, Galway, Ireland

32 School of Public Health, University College Cork, Ireland

Italy

V. Cherubini[33], R. Gesuita[34] on behalf of the Clinical Registry of the Marche region, Italy

33 Department of Women's and Children's Health, Salesi Hospital, Ancona, Italy

34 Centre of Epidemiology and Biostatistics, Polytechnic University of Marche, Italy

Latvia

I. Strele[35], S. Pildava[36]

35 Department of Public Health and Epidemiology, Riga Stradins University, Riga, Latvia

36 The Centre for Disease Prevention and Control of Latvia, Riga, Latvia

Netherlands

H. Veeze[37], H.-J. Aanstoot[37], D. Mul[37]

37 Diabeter, National Centre for Paediatric and Adolescent Diabetes, Rotterdam, the Netherlands

New Zealand

Craig Jefferies[38]

38 Department of Endocrinology, Starship Children's Health, Auckland, New Zealand

Norway

J. G. Cooper[39], K. Fjeld Løvaas[39]

39 Norwegian Diabetes Register for Adults, Norwegian Organization for Quality Improvement of Laboratory Examinations (Noklus), Haraldsplass Deaconess Hospital, Bergen, Norway

Slovenia

T. Battelino[40,41], K. Dovc[40,41], N. Bratina[40,41]

40 Department of Paediatric Endocrinology, Diabetes and Metabolic Diseases, UMC – University Children's Hospital, University Medical Centre Ljubljana, Ljubljana, Slovenia

41 Faculty of Medicine, University of Ljubljana, Ljubljana, Slovenia

Sweden

K. Eeg-Olofsson[42,43], A.-M. Svensson[43,44], S. Gudbjornsdottir[43,44]on behalf of the National Diabetes Register in Sweden

42 Department of Medicine, Sahlgrenska University Hospital, University of Gothenburg, Gothenburg, Sweden

43 Institute of Medicine, Department of Molecular and Clinical Medicine, University of Gothenburg, Sahlgrenska Academy, Gothenburg, Sweden

44 Centre of Registers in Region VästraGötaland, Göteborg, Sweden

Ukraine

E. Globa[45], N. Zelinska[45]

45 Ukrainian Research Centre of Endocrine Surgery, Endocrine Organs and Tissue Transplantation, MoH of Ukraine, Kyiv, Ukraine

Name and email address of corresponding author:

Sarah H Wild. E-mail: Sarah.Wild@ed.ac.uk

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Novelty statement

What is already known?

- Glycaemic control of type 1 diabetes varies widely within and between countries
- There have been many advances in treatment of diabetes in recent years

What has this study has found?"

- In general glycaemic control has improved over time, particularly among children and adolescents but marked variation in patterns of glycaemic control among people with type 1 diabetes remains

What are the implications of the study?

- Reducing variation between settings requires better understanding of the complex factors affecting management of type 1 diabetes including health care systems and their interaction with patients and families

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Abstract

Aims: To update and extend a previous cross-sectional international comparison of glycaemic control in people with type 1 diabetes.

Methods: Data were obtained for 520,392 children and adults with type 1 diabetes from 17 population and five clinic-based data sources in countries or regions between 2016 and 2020. Median HbA_{1c}(IQR) and proportions of individuals with HbA_{1c}<58mmol/mol (<7.5%), 58 – 74 mmol/mol (7.5 – 8.9%) and ≥ 75 mmol/mol (≥ 9.0%) were compared between populations for individuals aged <15, 15 – 24 and ≥ 25years. Logistic regression was used to estimate the odds ratio (OR) of HbA_{1c}< 58 mmol/mol (< 7.5%) relative to ≥ 58 mmol/mol (≥ 7.5%), stratified and adjusted for sex, age, and data source. Where possible, changes in the proportion of individuals in each HbA_{1c} category compared to previous estimates were calculated.

Results: Median HbA_{1c} varied from 55 to 79 mmol/mol (7.2 to 9.4%) across data sources and age groups so a pooled estimate was deemed inappropriate. OR (95% CI) for HbA_{1c}< 58 mmol/mol (<7.5 %) were 0.91 (0.90 – 0.92) for women compared to men, 1.68 (1.65 – 1.71) for people aged < 15 years and 0.81 (0.79 – 0.82) aged15 – 24 years compared to those aged ≥ 25 years. Differences between populations persisted after adjusting for sex, age, and data source. In general, compared to our previous analysis, the proportion of people with an HbA_{1c}<58 mmol/l (<7.5%) increased and proportions of people with HbA_{1c}≥ 75 mmol/mol (≥ 9.0%) decreased.

Conclusions: Glycaemic control of type 1 diabetes continues to vary substantially between age groups and data sources. While some improvement over time has been observed, glycaemic control remains sub-optimal for most people with Type 1 diabetes.

Key words

Type 1 diabetes. Glycaemic control. HbA_{1c}. Registers of people with diabetes

Introduction

It is widely recognised that lower HbA_{1c} in people with type 1 diabetes reduces the risk of microvascular and macrovascular complications [1]. During the last ten years international guidelines have recommended a target $HbA_{1c}$of 48 – 58 mmol/mol (6.5 – 7.5%) for most people with type 1 diabetes, allowing for clinical judgement to relax these targets for people with severe hypoglycaemia, short life expectancy, severe comorbidity or complications [2-4]. The current International Society of Pediatric and Adolescent Diabetes (ISPAD) and American Diabetes Association (ADA) guidelines recommend HbA_{1c}targets of <53 mmol/mol (<7.0%) for children/adolescents and most non-pregnant adults and a target of <48 mmol/mol (< 6.5%) for other adults, if it can be safely achieved without significant hypoglycaemia [5, 6]. Less stringent goals are recognized to be appropriate for people with a history of severe hypoglycemia, severe co-morbidities or limited life expectancy. The changes in recommended glycaemic targets for people with type 1 diabetes relate in part to evidence of cardiovascular risk reduction from lower targets [7] and also to the availability of new technologies of glucose monitoring, the increasing use of continuous subcutaneous insulin infusion (CSII also known as pump) therapy and their combination.

Type 1 diabetes is a condition which is difficult to manage with current therapies and recommended glycaemic targets are often not achieved. We have previously investigated how well these targets are achieved by analysing HbA_{1c} data from 324,501 people with type 1 diabetes with information derived from population or clinic-based registers from 19 countries or regions [8]. The results revealed substantial variation in glycaemic control among people with type 1 diabetes and room for significant improvement, particularly in young adults. A recent publication describing this pattern among children has also noted significant variation. The HbA_{1c} data in our previous publication were mostly from the years 2010 to 2012. Since then, there has been increasing use of insulin analogues and test strips, improved education and psychological support for patients in some regions and increasing use of the new technologies such as CSII and glucose sensor technology including flash/intermittent glucose monitoring (is-CGM) or continuous/real time glucose monitoring systems (rt-CGM). Our hypothesis is that the sum of these changes will have had a significant impact on HbA_{1c} in the wider population with type 1 diabetes. To our knowledge, this hypothesis has not been tested within and across all age groups across countries/regions.

We therefore set up a further collaboration with colleagues who have access to relevant data to reassess current patterns of glycaemic control in children and adults with type 1 diabetes. Our aim was to update and extend the previous international comparison of glycaemic control in people with type 1 diabetes, and to describe the change in HbA_{1c} profiles in those countries that had contributed to our previous analysis.

Methods

Data source

All collaborators were asked to supply descriptive data and counts of patients within HbA_{1c} categories for the updated analysis of their most recently available data between 2016 and 2020, by sex, age at date of HbA1c measurement, and, where available, diabetes duration and CSII use. In addition, they were asked to provide median HbA_{1c} values for their population over the time period of data included, separately for children aged <15 years, young adults aged 15 – 24 years, and adults aged ≥ 25 years. These age groups were chosen to provide data for children, adolescents/young adults and older adults and to be consistent with our previous study.

We received data from collaborators in 22 different countries. We characterised the datasets as 'national' if they were deemed by the local clinical and data analyst team, to be representative of the population of the country of origin, 'regional' if they were representative of the population within a region, or regions, and 'clinic' if they were from a single or group of clinics that might not represent the breadth of the regional or national population with type 1 diabetes. Details for each data source are given in the supplementary material as Supplementary Text: narrative description of data sources.

Statistical analyses

Descriptive statistics

We performed analyses using R version 3.6.2. Median HbA_{1c} (IQR), sex, CSII use, duration of type 1 diabetes, and the proportions of individuals with no measurement of HbA_{1c} during the study period were compared between data sources in three age groups (< 15 years, 15 – 24 years, ≥ 25 years). In keeping with our previous report, proportions of individuals with HbA_{1c}< 58mmol/mol(< 7.5%), 58 – 74 mmol/mol (7.5 – 8.9%) and ≥ 75mmol/mol (≥ 9.0%) were

compared between data type of source (national or regional population-based vs. clinic-based) in each of the three age groups. Furthermore, we compared the proportion of people in each HbA_{1c} category by age and sex, and we investigated the proportion of people using CSII in each HbA_{1c} category by data source. To incorporate the latest 2020 American Diabetes Association guideline [5], we additionally show the proportions of people meeting the new HbA_{1c} targets of < 53mmol/mol (< 7.0%) and < 48 mmol/mol (< 6.5%) in each of the three age groups by countries and data sources where data were available.

Logistic regression analysis

Logistic regression was used to estimate the odds of HbA_{1c}< 58mmol/mol (< 7.5%) relative to HbA_{1c}≥ 58mmol/mol (≥7.5%) using a complete case analysis (that is exclusion of missing data). The first model was adjusted for sex, age and type of data source. In order to further investigate differences between countries, the second and third model was stratified by type of data source and adjusted for country/region of origin. We used the largest sub-groups as the comparison groups. Data from each source were included in each analysis where information was available for more than 100 people in each age group to reduce variability due to small numbers.

Comparison over time

Using data from the subset of countries that contributed data to this analysis and the same methods and data sources as the previous international comparison [8], we investigated the change in HbA_{1c} profiles by calculating the absolute and relative change in the proportion of individuals with HbA_{1c}< 58 mmol/mol (< 7.5%), 58 – 74 mmol/mol (7.5 – 8.9%) and ≥ 75 mmol/mol (≥ 9.0%). New Zealand and Ukraine contributed data to both analyses but, as different data sources or populations were used or included for the two periods, time comparisons were not performed. For consistency with the previous analysis [8], data from England and Wales were combined for individuals aged 15 – 24 and ≥ 25 years in the time comparison analysis.

Ethics statement

Contributors obtained the appropriate approvals for contributing to this collaboration for their jurisdiction. The nature of the study using anonymised and/or aggregated data in the

form of clinical audit means that individual consent and formal ethical approval is not required.

Results

Study population

Data were obtained from 520,392 children and adults with type 1 diabetes from 17 national or regional population-based registers (Austria, Australia, Belgium, Denmark, England, Finland, Germany, Hong Kong, Italy, Latvia, New Zealand, Norway, Scotland, Slovenia, Sweden, Ukraine, and Wales) and five clinic-based registers (Canada, France, Greece, Ireland, Netherlands). Details of the different data sources including their representativeness and how diagnosis of type 1 diabetes was validated are given in Supplementary Table 1. The time periods for each data source over the 2016 – 2020 period are described in Supplementary Figure 1. Sample sizes ranged from 479 (New Zealand) to 283,414 (England) prior to exclusion of people with missing data and restriction to data from countries where information was available for more than 100 people in each age group (Supplementary Table 2). Data were not available for all groups for all countries, for example when data for children and adults are not collected in the same register.

Descriptive statistics

In total, data were available for 54,158 children aged < 15 years, 83,065 young adults aged 15 – 24 years, and 382,907 adults aged ≥ 25 years (see Table 1 for further detail including type of data source as national, regional or clinic where national or regional data were estimated to cover over 80% of the relevant population). Median HbA_{1c} ranged from 55 to 79 mmol/mol (7.2 to 9.4%) across populations and age groups. The proportion of individuals using CSII varied from 2.2% to 74.8% among children aged < 15 years, 1.0% to 74.6% among young adults aged 15 – 24 years, and 8.1% to 60.8% among adults aged ≥ 25 years. The proportion of individuals who have had diabetes for at least 5 years varied from 32.0% to 75.0%, 62.8% to 83.9%, and 76.3% to 94.8% among the three age groups respectively.

The proportion of individuals with HbA_{1c}≥ 75 mmol/mol (≥ 9.0%) varied between data sources (Figure 1). Proportions with HbA_{1c}≥ 75 mmol/mol (≥ 9.0%) were lower in clinic-based than

population-based data sources among children aged <15 years (10.5% vs. 16.1%), young adults aged 15 – 24 years (28.9% vs. 37.5%), and adults aged ≥ 25 years (19.8% vs. 26.7%). Among all age groups, the proportion with HbA_{1c}≥ 75 mmol/mol (≥ 9.0 %) was slightly lower and the proportion with HbA_{1c}< 58 mmol/mol (<7.5 %) was slightly higher among men than among women (Supplementary Table 3). In the majority of countries, the proportion of individuals using CSII was lowest among those with HbA_{1c}≥ 75 mmol/mol (≥ 9.0%) (Figure 2). For populations with data available for HbA_{1c}< 48 mmol/mol (< 6.5%) the proportions of people in each of the five HbA_{1c} categories in the three age groups by countries and data sources are presented in Supplementary Figure 2.

Comparison of glycaemic outcome between centres and over time

Differences between populations persisted after adjusting for sex, age, and data source (Table 2). Adjusted odds ratios (95% CI) for HbA_{1c}< 58 mmol/mol (< 7.5%) were 1.24 (1.19 – 1.30) for clinic-based data compared to population-based data. In analyses stratified by type of data source, differences between populations persisted after adjusting for sex and age. Among population-based registers, adjusted odds ratios (95% CI) for HbA_{1c} < 58 mmol/mol (< 7.5%) were 0.91 (0.90 – 0.92) for women compared to men, 1.42 (1.39 – 1.46) and 0.77 (0.76 – 0.78) for people aged < 15 years and 15 – 24 years compared to those aged ≥ 25 years, respectively. For data from clinic-based registers, adjusted odds ratios (95% CI) for HbA_{1c} < 58 mmol/mol (< 7.5%) were 0.89 (0.81 – 0.97) for women compared to men, 0.93 (0.76 – 1.14) and 0.52 (0.46 – 0.60) for people aged < 15 years and 15 – 24 years compared to those aged ≥ 25 years, respectively.

In the majority of data sources that have contributed to both our previous and current international comparison, the proportion of people with HbA_{1c}< 58mmol/mol (<7.5 %) increased and the proportion of people with HbA_{1c}≥ 75 mmol/mol (≥9.0 %) decreased over time (Figure 3a, Figure 3b, Figure 3c). Supplementary Tables 4 – 6 describe the absolute and relative change in the proportion of people with HbA_{1c}≥ 75 mmol/mol (≥9.0 %) for the population with available data for each of the three age groups.

Discussion

Our data, describing glycaemic control from over half a million people with type 1 diabetes across 22 different countries, clearly demonstrate the challenge of achieving lower HbA_{1c}

targets to minimise the risk of developing long-term complications. Glycaemic control continues to vary substantially between age groups, countries and type of data source, with large proportions of people with HbA_{1c} ≥ 75 mmol/mol (≥ 9.0 %), particularly among people aged 15 – 24 years. A small proportion of people in each population achieve the tighter glycaemic targets recommended in recent guidelines [5]. We have also shown better glycaemic control in children compared to adults with type 1 diabetes in population-based data. As we did not have access to individual level data, we were not able to establish whether the variations in improvements in glycaemic control over time by age group in this analysis were statistically significant.

Use of new technologies such as CSII, CGM and closed loop, sensor augmented CSII devices are associated with lower HbA_{1c}[9-13] but they were not available to all the populations studied in this report. Previous Scottish studies have shown lower HbA_{1c} in people using CSII in a clinic population [14] and time trends between 2004 and 2016 in declining HbA_{1c} across the whole Scottish population of people with type 1 diabetes, with the most marked improvements in children and adolescents [15].

Data from the National Paediatric Diabetes Audit in England and Wales technologies spotlight audit have demonstrated a 6 mmol/mol lower HbA_{1c} in those using CSII in combination with CGM compared to multiple daily injections alone independent of ethnicity, duration of diabetes or social deprivation [16]. There are several possible explanations for the difference in glycaemic control, including allocation bias arising from the fact that characteristics of people that receive CSII differ from those that do not receive CSII in many settings. In addition, local resource and support for those initiating and continuing CSII is likely to vary within and across populations. The association between use of technology and proportions achieving glycaemic targets may not be consistent within or across different settings.

It is possible that some of the differences between populations and changes over time could be explained by the extent of introduction of new technologies at the time of the data extraction. However we did not observe any association between proportions of each population using CSII and median HbA1c (using data reported in table 1). We did not collect data on use of CSII and CGM for our previous analysis or on CGM for this analysis and have therefore not been able to explore their role in temporal changes. The fact that data included in this comparison were extracted between 2016 and 2020 (although most data were for

2018-2019, see Supplementary Figure 1) and use of technologies differs between countries limits direct comparisons. Other important contributing factors to differences between populations that we were unable to consider include socioeconomic deprivation, educational attainment, diet, eating habits, ethnicity, physical activity, diabetes education, social and psychological support and health systems including insurance coverage in some countries.

Despite noting that many people do not achieve recommended glycaemic targets, we have found an improvement in glycaemic control among people with type 1 diabetes in most countries over time, though to a greater extent in some than others, but particularly amongst those aged <15 years. This is encouraging and is likely to be due to a combination of the factors described above.

This analysis has several possible limitations, including selection bias. We have described our data sources in detail. The data from clinics are more likely to be affected by selection bias than those from population-based datasets but missing data may introduce bias in population-based datasets. It seems probable that data are more likely to be missing from people with poor engagement with services who are less likely to have good control, as illustrated by data from north-east Scotland [17]. Although we have described data sources using the name of the country of origin, it is important to recognise that some of these datasets may not be representative of the wider community of people with diabetes in that country if regional differences exist or clinic based populations are a selected sub-group of the population of interest. We did not collect data on duration of diabetes that would have been needed to sub-divide data for the oldest age-group that includes both people with type 1 diabetes since childhood and people who developed type 1 diabetes as adults.

Some variability in HbA_{1c} values might be caused by different laboratory methods in our populations, even if all national standards for good laboratory practice were met. In addition, it was not possible to compare incidence of hypoglycaemic episodes, use of different types of CSII, glucose sensors or any sensor-augmented systems.

We have demonstrated differences in glycaemic control in different populations and age groups and shown that differences persist between populations over time. Further research is required to better understand whether apparent differences between health systems may relate to such influences as societal factors, structure and delivery of clinical care and resource

allocation. Their better understanding could help inform development of cost-effective interventions to improve outcomes. Our data reinforce existing knowledge that adolescence and early adulthood is a particularly challenging time for managing type 1 diabetes and that there is considerable scope for improving glycaemic control in this age group in most populations. The consistent pattern of improvement in those <15 years is the greatest encouragement, and it will be informative to see if it continues as this group becomes older. In general, data that are available for children are more representative than for adults and subsequent analysis of better quality data would be helpful to address the limitations of this work.

It is possible that wider use of newer technologies including sensors and closed loop systems could contribute to further improvements in glycaemic control, particularly among populations where they are not yet available. However, use of technology is only one factor in glycaemic control and maximising the effectiveness of conventional approaches to management of type 1 diabetes, including education, encouraging acceptance of the condition and frequent glucose measurement, remain important. These latter aspects are obviously particularly relevant in low resource settings although all health services need to adapt to changes in the available technology.

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Tables

Table 1: Characteristics of populations of people with type 1 diabetes by country for each of the three age groups presented in decreasing population size for national, regional and clinic based data sources. Data included were extracted between 2016 and 2020 (see Supplementary Figure 1 for details.)

Country or region	Data source	N	Male (%)*	Median HbA_{1c} mmol/mol (IQR)	HbA_{1c} % (IQR)	Missing HbA_{1c} (%)*	Diabetes duration ≥ 5 years (%)*	CSII use (%)*
< 15 years								
England	national	18,514	51.4	60 (54; 68)	7.7 (7.0; 8.3)	6.1	---	38.8
Germany	national	17,463	52.1	58 (51; 67)	7.5 (6.8; 8.3)	1.3	---	59.3
Ukraine	national	6,618	51.4	67 (56; 83)	8.3 (7.3; 9.7)	13.3	32.0	2.2
Belgium	national	2,242	51.9	56 (50; 63)	7.3 (6.7; 7.9)	1.0	36.6	24.6
Scotland	national	1,960	51.7	62 (56; 69)	7.8 (7.3; 8.5)	2.2	35.6	46.4
Denmark	national	1,869	52.6	57 (50; 64)	7.4 (6.7; 8.0)	15.5	28.5	71.3
Austria	national	1,444	54.4	57 (50; 64)	7.4 (6.8; 8.1)	0.6	---	63.8
Wales	national	1,045	48.3	60 (52; 68)	7.7 (7.0; 8.4)	5.6	---	37.8
Latvia	national	396	46.5	76 (62; 95)	9.1 (7.8; 10.8)	12.1	36.4	---
Slovenia	national	382	48.4	58 (53; 65)	7.5 (7.0; 8.1)	0.0	36.6	74.8
Hong Kong	national	228	38.2	65 (56; 75)	8.1 (7.3; 9.0)	8.3	39.5	---
Australia	regional	627	51.7	60 (52; 66)	7.6 (6.9; 8.2)	3.5	38.0	48.0
New Zealand	regional	324	47.2	67 (57; 81)	8.3 (7.4; 9.6)	8.8	42.8	22.5
Italy	regional	192	55.7	55 (51; 65)	7.2 (6.8; 8.1)	0.0	36.5	37.0
Finland	regional	131	64.1	62 (56; 68)	7.8 (7.3; 8.4)	2.3	---	---
France	regional	40	55.0	64 (58; 69)	8.0 (7.5; 8.5)	0.0	75.0	2.6
Netherlands	clinic	583	50.6	57 (52; 65)	7.4 (6.9; 8.1)	2.2	43.1	66.0
Ireland	clinic	74	43.2	68 (58; 78)	8.4 (7.5; 9.2)	12.2	38.9	31.1
Greece	clinic	26	46.2	55 (51; 60)	7.2 (6.8; 7.6)	3.8	50.0	15.4
15 – 24 years								
England	national	43,115	53.5	72 (60; 88)	8.7 (7.6; 10.2)	18.7	69.1	11.2
Germany	national	10,823	54.1	62 (53; 74)	7.8 (7.0; 8.9)	1.8	---	42.4
Wales	national	5,995	53.4	73 (61; 88)	8.8 (7.7; 10.2)	20.6	69.1	11.2
Sweden†	national	5,175	55.9	58 (50; 70)	7.5 (6.7; 8.6)	2.4	82.1	40.6
Belgium	national	4,692	53.3	60 (52; 69)	7.6 (6.9; 8.5)	2.2	71.5	12.8
Scotland	national	4,237	52.1	71 (60; 86)	8.6 (7.6; 10.0)	9.0	77.0	24.0
Ukraine‡	national	2,665	52.5	72 (61; 88)	8.7 (7.7; 10.2)	10.0	62.8	1.0
Norway†	national	1,632	56.1	66 (55; 77)	8.2 (7.2; 9.2)	2.1	78.8	52.9
Latvia	national	529	54.6	79 (64; 99)	9.4 (8.0; 11.2)	21.9	74.5	---
Hong Kong	national	410	46.1	64 (54; 77)	8.0 (7.0; 9.2)	16.3	70.7	---
Slovenia	national	355	54.9	61 (53; 70)	7.7 (7.0; 8.6)	0.8	76.9	74.6
Australia§	regional	484	50.2	64 (55; 78)	8.0 (7.2; 9.3)	1.9	73.6	48.1
Italy	regional	324	50.6	60 (53; 69)	7.6 (7.0; 8.5)	1.2	76.5	26.5

Finland	regional	177	53.1	68 (59; 76)	8.3 (7.5; 9.1)	4.5	---	---
New Zealand	regional	155	57.4	72 (58; 88)	8.7 (7.5; 10.1)	6.6	69.0	23.2
Netherlands	clinic	1,392	46.8	63 (55; 75)	7.9 (7.2; 9.0)	2.9	83.1	60.6
Canada	clinic	419	51.1	67 (56; 79)	8.3 (7.2; 9.3)	17.7	83.9	41.3
Ireland	clinic	222	49.5	71 (62; 80)	8.6 (7.8; 9.5)	24.3	76.9	17.6
France	clinic	142	47.2	64 (53; 75)	8.0 (7.0; 9.0)	0.0	83.1	33.1
Greece	clinic	122	53.3	56 (50; 66)	7.3 (6.7; 8.2)	5.7	76.2	21.3
≥ 25 years								
England	national	221,545	56.3	66 (57; 78)	8.2 (7.4; 9.3)	10.2	85.7	8.1
Sweden	national	43,510	55.7	58 (51; 67)	7.5 (6.8; 8.3)	1.5	93.4	22.6
Belgium	national	30,398	55.0	58 (52; 67)	7.5 (6.9; 8.3)	2.3	90.5	12.1
Wales	national	27,160	53.8	68 (58; 80)	8.4 (7.5; 9.5)	13.8	84.3	10.2
Scotland	national	25,844	56.7	67 (58; 79)	8.3 (7.5; 9.4)	12.2	93.0	11.5
Norway	national	12,136	55.1	61 (52; 70)	7.7 (7.0; 8.5)	2.4	90.5	30.9
Germany	national	8,644	51.9	58 (50; 68)	7.4 (6.7; 8.4)	7.2	---	12.4
Latvia	national	1,958	53.6	67 (57; 80)	8.3 (7.4; 9.5)	31.7	94.8	---
Hong Kong	national	1,597	49.1	60 (51; 72)	7.6 (6.8; 8.7)	21.1	76.3	---
Italy	regional	2,468	55.5	61 (53; 69)	7.7 (7.0; 8.5)	1.1	90.5	18.5
Finland	regional	1,130	58.5	64 (56; 74)	8.1 (7.3; 8.9)	7.5	---	---
Canada	clinic	3,454	54.5	62 (54; 70)	7.8 (7.0; 8.6)	8.7	90.7	36.2
Ireland	clinic	1,341	53.5	66 (56; 76)	8.2 (7.3; 9.1)	45.4	91.2	11.4
Netherlands	clinic	720	49.4	56 (50; 65)	7.3 (6.7; 8.1)	5.8	93.2	60.8
France	clinic	644	51.1	64 (53; 75)	8.0 (7.0; 9.0)	0.0	91.2	59.9
Greece	clinic	358	45.0	58 (52; 68)	7.5 (6.9; 8.4)	2.0	89.5	19.3

[*] Patients with missing information were not included in the denominator.
[†]Data are for individuals aged 18 – 24 years.
[‡]Data are for individuals aged 15 – 18 years.
[§]Data are for individuals aged 15 – 21 years.

Table 2: Odds ratios (95 % CI) for HbA_{1c}<58 mmol/mol for sex, age, data source, and country. Data included were extracted between 2016 and 2020 (see Supplementary Figure 1 for details.)

	Overall		Data source			
			Population-based		Clinic-based	
Variable	**OR (95 % CI)**	**p**	**OR (95 % CI)**	**p**	**OR (95 % CI)**	**p**
Sex						
Female	0.91 (0.90; 0.92)	<0.001	0.91 (0.90; 0.92)	<0.001	0.89 (0.81; 0.97)	0.011
Male	ref.	—	ref.	—	ref.	—
Age groups						
< 15 years	1.68 (1.65; 1.71)	<0.001	1.42 (1.39; 1.46)	<0.001	0.93 (0.76; 1.14)	0.469
15 – 24 years	0.81 (0.79; 0.82)	<0.001	0.77 (0.76; 0.78)	<0.001	0.52 (0.46; 0.60)	<0.001
≥ 25 years	ref.	—	ref.	—	ref.	—
Data source						
Clinic	1.24 (1.19; 1.30)	<0.001	—	—	—	—
Population	ref.	—	—	—	—	—
Country (population based)						
Australia	—	—	1.57 (1.38; 1.77)	<0.001	—	—
Austria	—	—	2.21 (1.98; 2.46)	<0.001	—	—
Belgium	—	—	2.09 (2.05; 2.14)	<0.001	—	—
Denmark	—	—	2.29 (2.07; 2.54)	<0.001	—	—
Finland	—	—	0.94 (0.84; 1.06)	0.340	—	—
Germany	—	—	2.08 (2.03; 2.13)	<0.001	—	—
Hong Kong	—	—	1.74 (1.58; 1.91)	<0.001	—	—
Italy	—	—	1.77 (1.64; 1.90)	<0.001	—	—
Latvia	—	—	0.71 (0.64; 0.79)	<0.001	—	—

New Zealand	—	—	0.55 (0.44; 0.68)	<0.001	—	—
Norway	—	—	1.65 (1.59; 1.71)	<0.001	—	—
Scotland	—	—	0.80 (0.78; 0.83)	<0.001	—	—
Slovenia	—	—	1.91 (1.65; 2.21)	<0.001	—	—
Sweden	—	—	2.30 (2.25; 2.34)	<0.001	—	—
Wales	—	—	1.00 (0.98; 1.03)	0.768	—	—
England	—	—	ref.	—	—	—
Country (clinic based)						
France	—	—	—	—	1.01 (0.85; 1.18)	0.946
Greece	—	—	—	—	1.88 (1.55; 2.29)	<0.001
Ireland	—	—	—	—	0.48 (0.41; 0.57)	<0.001
Netherlands	—	—	—	—	1.75 (1.53; 2.01)	<0.001
Canada	—	—	—	—	ref.	—

Figure legends

Figure 1: Proportions of individuals in each HbA_{1c} category in each of the three age groups by country and type of data source

* Data in age group 15 – 24 years are for individuals aged 15 – 21 years.

†Data in age group 15 – 24 years are for individuals aged 18 – 24 years.

‡Data in age group 15 – 24 years are for individuals aged 15 – 18 years.

Figure 2: Proportions of individuals using CSII by HbA_{1c} category and country and type of data source in each of the three age groups

* Data in age group 15 – 24 years are for individuals aged 15 – 21 years.

†Data in age group 15 – 24 years are for individuals aged 18 – 24 years.

Figure 3: Analysis of change between 2010-2012 and 2016-2020 time periods in the proportions of individuals in each HbA_{1c} category in each of the three age groups for countries that had contributed to both the previous and current international comparison: (a) <15years old, (b) 15 – 24 years old, (c) ≥ 25 years old

* Data in age group 15 – 24 years are for individuals aged 15 – 21 years.

†Data in age group 15 – 24 years are for individuals aged 18 – 24 years.

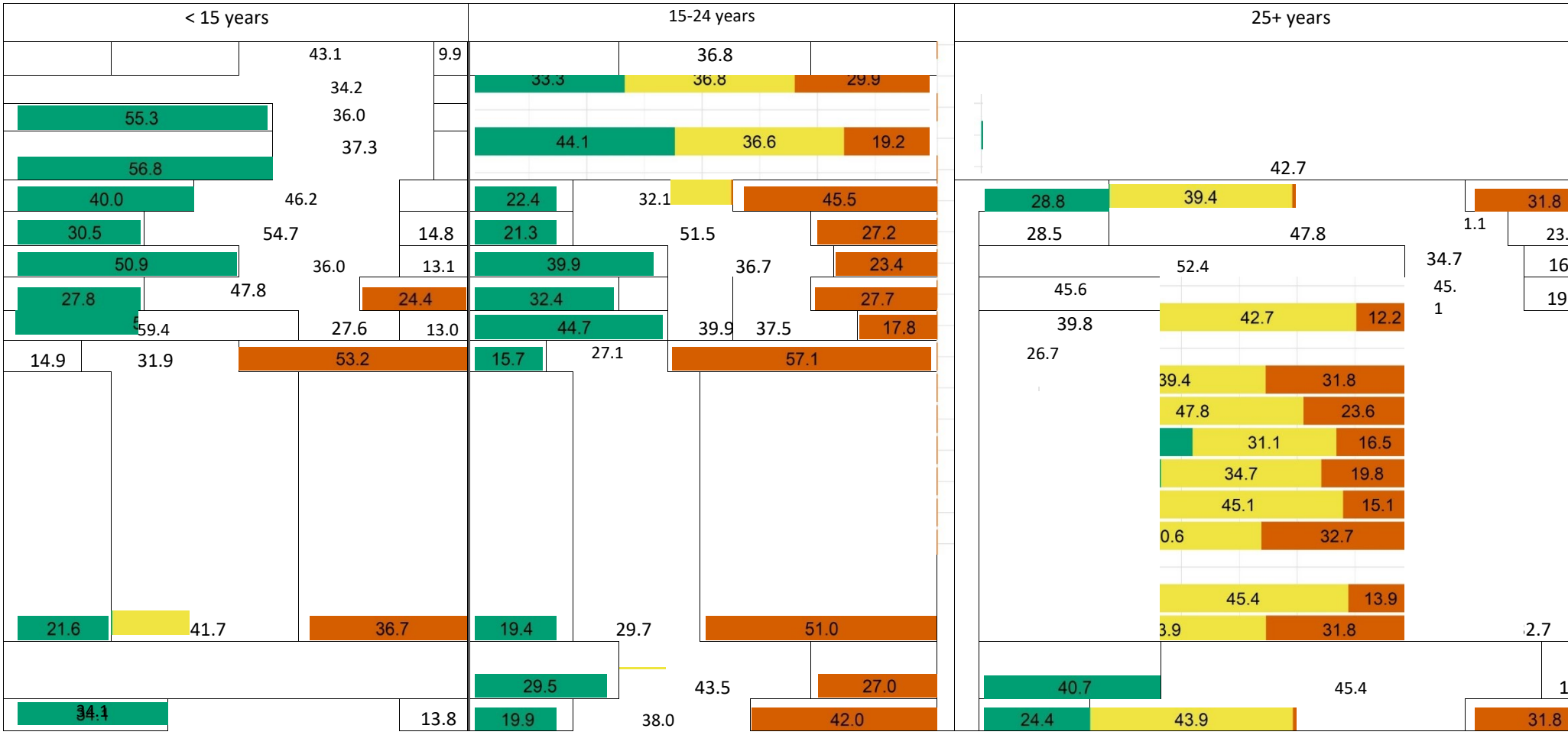
Figure 3 (a) <15years old

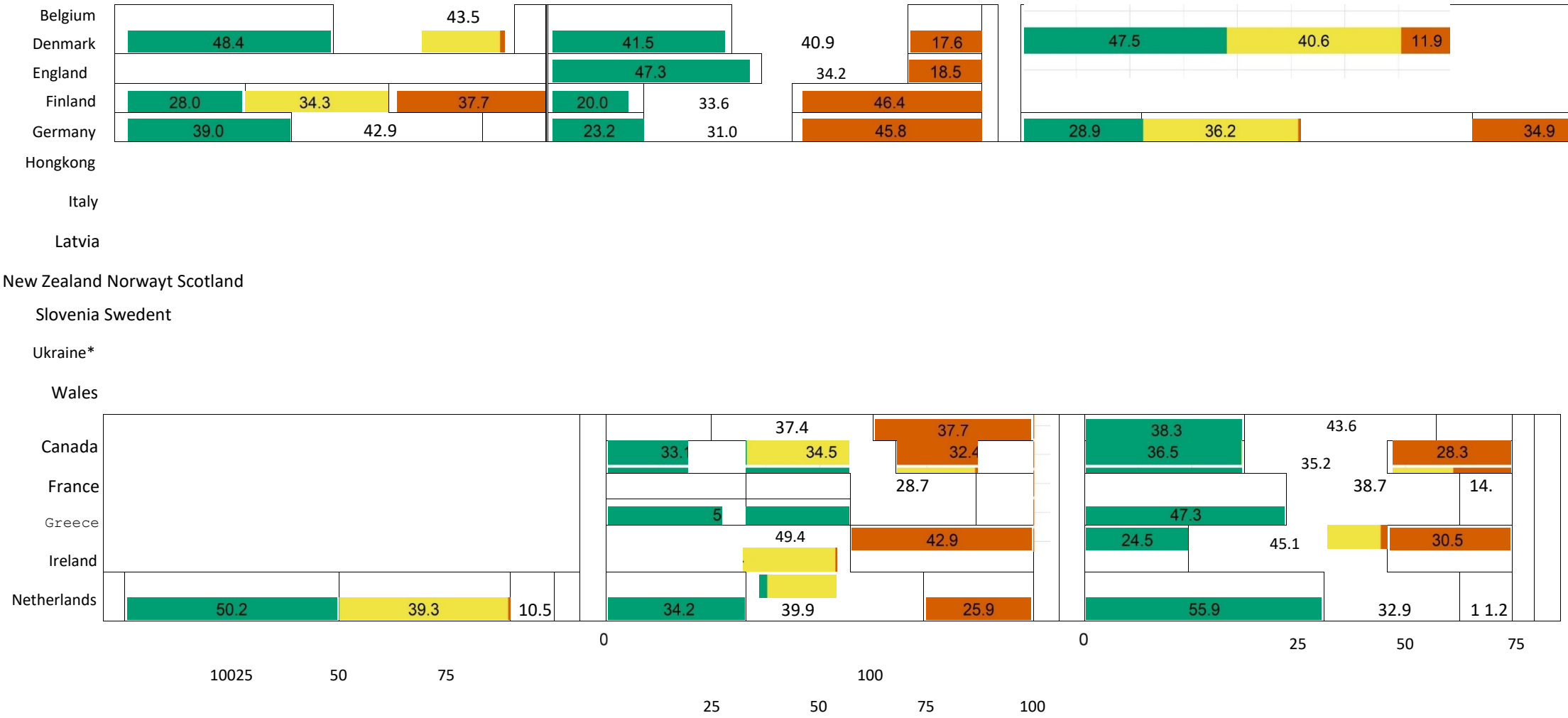
Figure 3b) 15 – 24 years old

Figure 3 c) ≥ 25 years old

Australia*

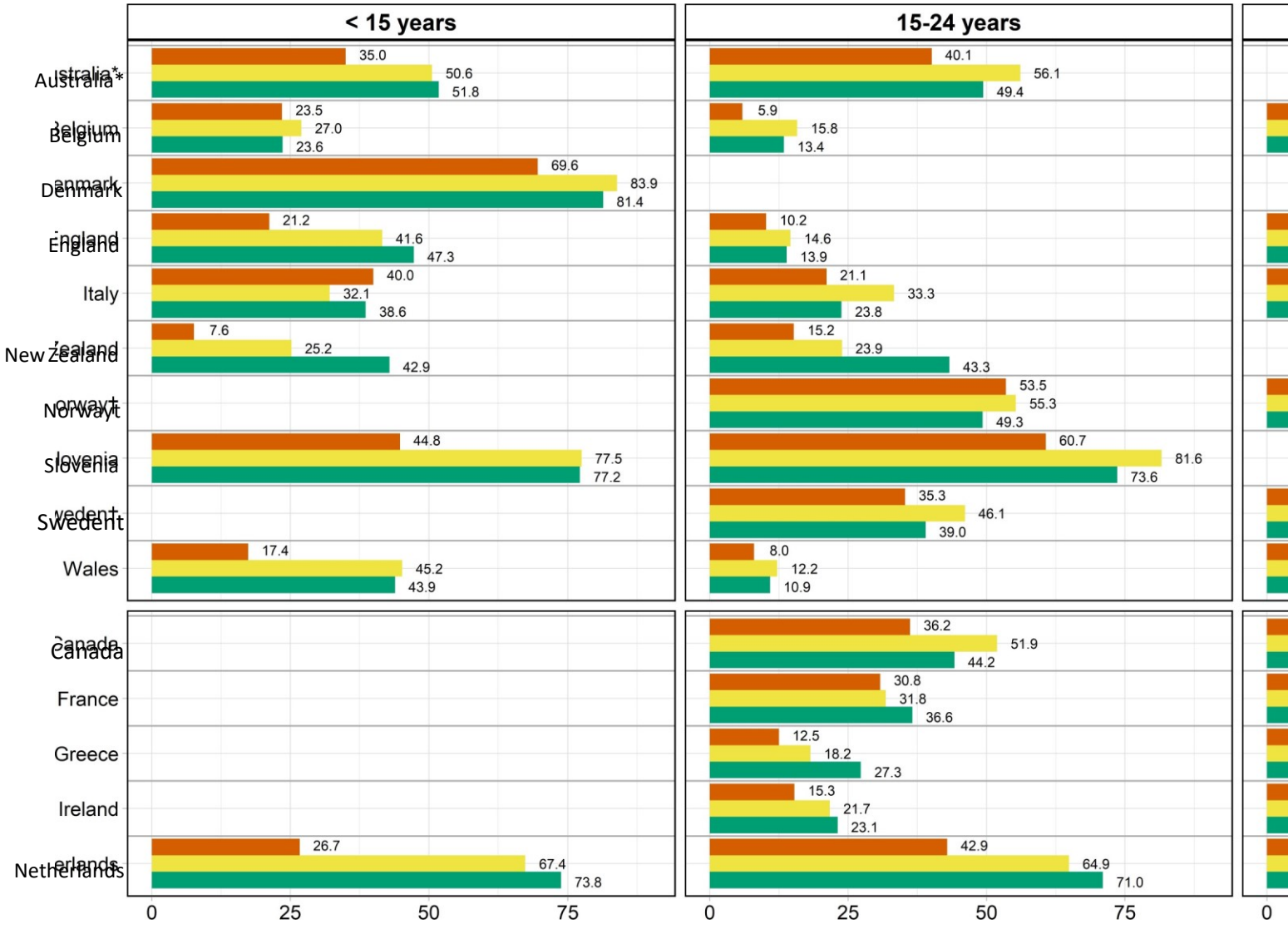
Austria




Belgium
Denmark
England
Finland
Germany
Hongkong
Italy
Latvia
New Zealand Norwayt Scotland
Slovenia Swedent
Ukraine*
Wales
Canada
France
Greece
Ireland
Netherlands
48.4
43.5
41.5
40.9
17.6
47.5
40.6
11.9
47.3
34.2
18.5
28.0
34.3
37.7
20.0
33.6
46.4
39.0
42.9
23.2
31.0
45.8
28.9
36.2
34.9
37.4
37.7
38.3
43.6
33.1
34.5
32.4
36.5
28.3
35.2
28.7
38.7
14.
5
47.3
49.4
42.9
24.5
45.1
30.5
50.2
39.3
10.5
34.2
39.9
25.9
55.9
32.9
1 1.2
0
0
25
50
75
10025
50
75
100
25
50
75
100

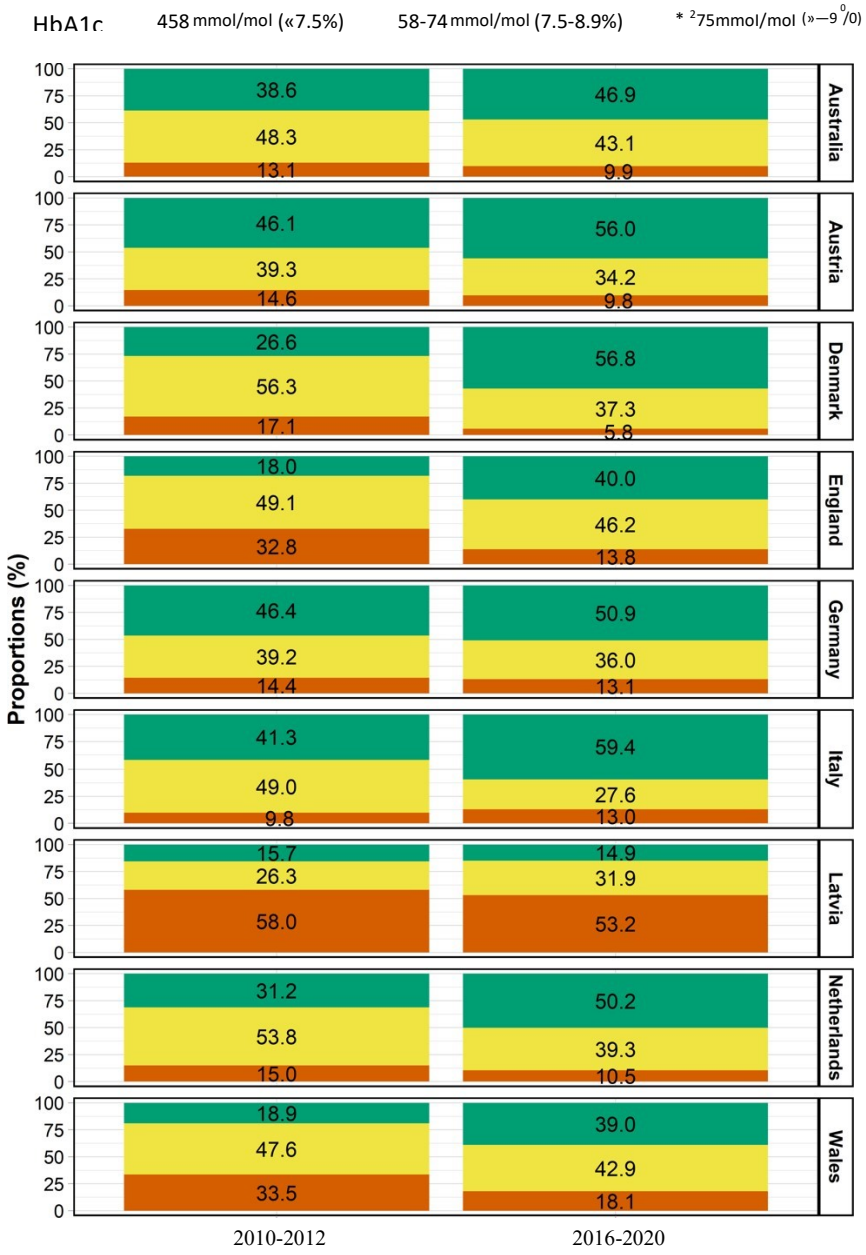
Proportions (^{0}/0)

HbA1c categories	<58 mmol/mol (<7.5%)	58-74 mmol/mol (7.5-8.9%)	>=75mmol/mol (>=9%)



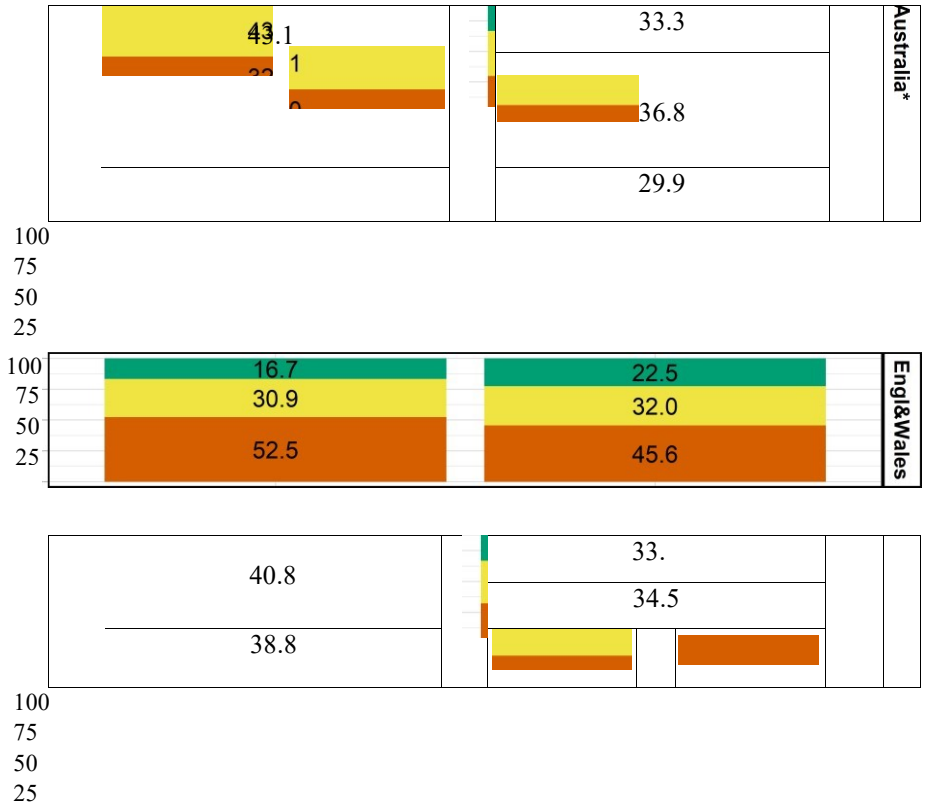
Proportions of individuals using CSII (^{0}/0)

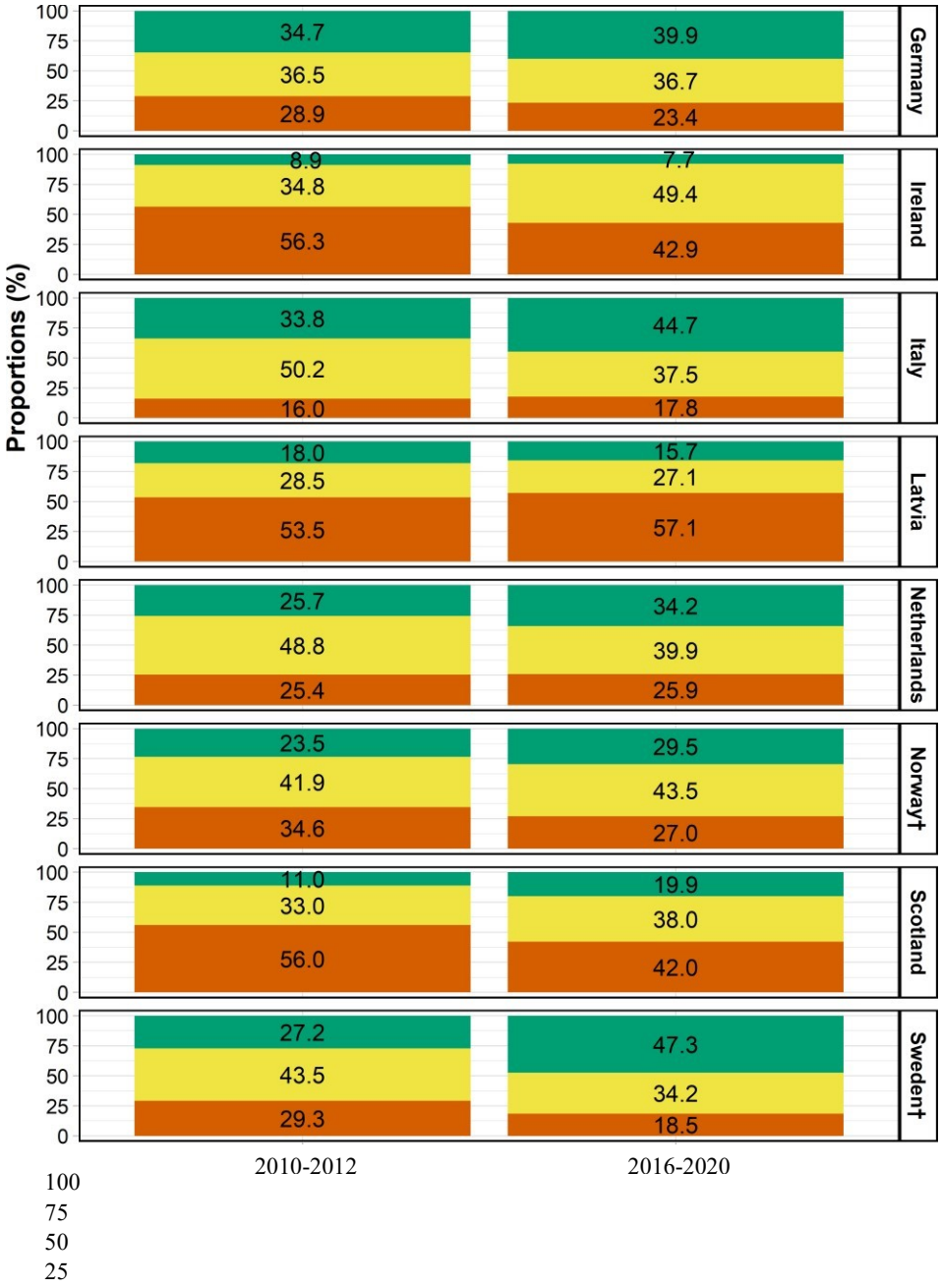
HbA1 c categories <58 mmol/mol (<7.5%) 58-74 mmol/mol (7.5-8.9%) >=75mmol/mol


HbA1c
458 mmol/mol («7.5%)
58-74 mmol/mol (7.5-8.9%)
* ²75mmol/mol (»—9 0/0)
Proportions (%)
Australia
38.6
48.3
13.1
46.9
43.1
9.9
Austria
46.1
39.3
14.6
56.0
34.2
9.8
Denmark
26.6
56.3
17.1
56.8
37.3
5.8
England
18.0
49.1
32.8
40.0
46.2
13.8
Germany
46.4
39.2
14.4
50.9
36.0
13.1
Italy
41.3
49.0
9.8
59.4
27.6
13.0
Latvia
15.7
26.3
58.0
14.9
31.9
53.2
Netherlands
31.2
53.8
15.0
50.2
39.3
10.5
Wales
18.9
47.6
33.5
39.0
42.9
18.1
2010-2012
2016-2020

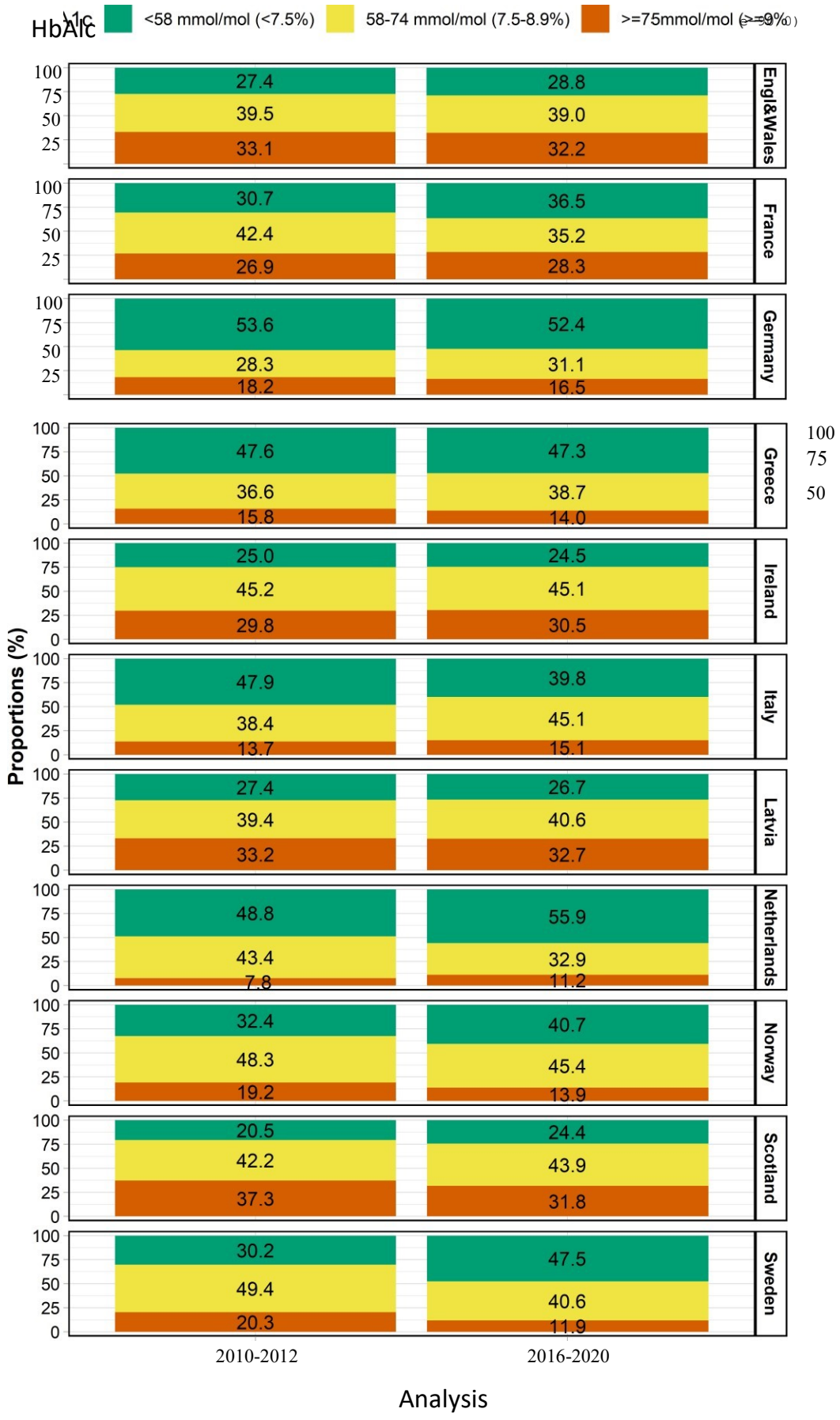
Analysis

HbA1c 458 mmol/mol («7.5%) 58-74 mmol/mol (7.5-8.9%) »-75mmol/mol (»-9 0/0)




Proportions (%)
100
75
50
25
0
Germany
34.7
36.5
28.9
39.9
36.7
23.4
Ireland
8.9
34.8
56.3
7.7
49.4
42.9
Italy
33.8
50.2
16.0
44.7
37.5
17.8
Latvia
18.0
28.5
53.5
15.7
27.1
57.1
Netherlands
25.7
48.8
25.4
34.2
39.9
25.9
Norway†
23.5
41.9
34.6
29.5
43.5
27.0
Scotland
11.0
33.0
56.0
19.9
38.0
42.0
Sweden†
27.2
43.5
29.3
47.3
34.2
18.5
2010-2012
2016-2020

Analysis


HbA1c
<58 mmol/mol (<7.5%)
58-74 mmol/mol (7.5-8.9%)
>=75mmol/mol (>=9%)
Engl&Wales
27.4
39.5
33.1
28.8
39.0
32.2
France
30.7
42.4
26.9
36.5
35.2
28.3
Germany
53.6
28.3
18.2
52.4
31.1
16.5
Greece
47.6
36.6
15.8
47.3
38.7
14.0
Ireland
25.0
45.2
29.8
24.5
45.1
30.5
Italy
47.9
38.4
13.7
39.8
45.1
15.1
Latvia
27.4
39.4
33.2
26.7
40.6
32.7
Netherlands
48.8
43.4
7.8
55.9
32.9
11.2
Norway
32.4
48.3
19.2
40.7
45.4
13.9
Scotland
20.5
42.2
37.3
24.4
43.9
31.8
Sweden
30.2
49.4
20.3
47.5
40.6
11.9
Proportions (%)
100
75
50
25
0
2010-2012
2016-2020
Analysis

Supplementary material for International comparison of glycaemic control in people with type 1 diabetes: an update and extension

Narrative description of data sources

Australia: Data are derived from the Western Australian Children's Diabetes Database (WACDD) – a population based prospective clinical diabetes database that was established in 1987 at the only tertiary paediatric hospital in Western Australia.

Austria: Sixteen Austrian centres participated in the analysis. The diabetes centres are all hospital-based outpatient settings and use the German DPV system (described below). More than 80% of the Austrian paediatric diabetes patients are included in the DPV, but above the age of 18 years only few adult centres are using DPV, primarily for pump users. Due to the missing adult data only the age group < 15 years was included in this analysis.

Belgium: All specialized diabetes centres are obliged to contribute to the quality improvement projects "Initiative for Quality improvement and Epidemiology in Diabetes (IQED)" and "Initiative for Quality Improvement and Epidemiology in Children and Adolescents with Diabetes (IQECAD)". More details of those projects can be found here: https://www.sciensano.be/en/projects/initiative-quality-improvement-and-epidemiology-diabetes andhttps://www.sciensano.be/en/projects/initiative-quality-improvement-and-epidemiology-children-and-adolescents-diabetes. For this project, data from both of these projects were combined.

Data are collected through a combination of semi-automatic extraction of data from electronic patient files and manual completion of the registrations in a software installed locally in all centres. Data are collected from all children and adolescents with diabetes. Due to the excessive number of adult diabetic patients, IQED data are collected from a representative sample. Centres are asked to complete a questionnaire for 10% of their patients with diabetes, with a minimum of 50 patients with diabetes for the small centres. In addition to the minimum of 50 patients, centres are asked– after the fulfilling of the min 50 patients – to have data registered from minimum 25 patients with type 1 diabetes. Those 'additional' patients with type 1 diabetes are indicated in the questionnaire to

calculate the distribution of diabetes type in a centre. Separately, an additional questionnaire is used to ascertain the total number of patients with diabetes and diabetes distribution in each centre.

All of this information is used to weigh the data towards representative national numbers. The weighted data were used in this project.

Canada: Patients who attend LMC Healthcare clinics in the provinces of Ontario, Quebec and Alberta who provide consent for their health records to be used for research purposes.

Denmark: DanDiabKids was initiated in 1996 as a national register. Data are collected as a tool for quality assessment in diabetes care in children and adolescents and national results are published in yearly reports. The register is web-based, and 19 centres annually report clinical data obtained during outpatient visits and send one HbA_{1c} sample for central assessment. Included data are from yearly status visits. Reporting to the register is mandatory and the ascertainment rate is >95 %. For this project, the center was not permitted to include data with <3 individuals per data cell. Therefore, in the analyses, an approximation was used for data combinations resulting in small cells.

England & Wales: People registered with diabetes in GP practices in England and Wales and people under the care of specialist diabetes services. For children and young people receiving care from paediatric services, the data was submitted by individual participating centres.

The National Diabetes Audit (NDA) and the National Paediatric Diabetes Audit (NPDA) are commissioned by the Healthcare Quality Improvement Partnership as part of the National Clinical Audit and Patient Outcomes Programme following advice to the English and Welsh Departments of Health from the National Advisory Group on Clinical Audit and Enquiries (http://www.hscic.gov.uk/nda and http://www.rcpch.ac.uk/child-health/standards-care/clinicalaudit-and-quality-improvement/national-paediatric-diabetesaudi).

The NDA is managed by the Health and Social Care Information Centre in partnership with Diabetes UK and Public Health England. Data are collected annually from the Electronic Records of General Practices and specialist services including type of diabetes, age, sex, year of onset and latest HbA_{1c}.

The NPDA is managed by the Royal College of Paediatrics and Child Health (RCPCH), which collects data annually from 175 (2018/19) paediatric diabetes centres delivering care for children and young people with diabetes in England and Wales. The NPDA is commissioned by the Healthcare Quality Improvement Partnership (HQIP) which is led by a consortium of the Academy of Medical Royal Colleges, the Royal College of Nursing and National Voices. The programme is funded by NHS England and NHS Wales. NPDA was not permitted to include data with <5 individuals per data cell. Thus, an approximation for these combinations was used in this analysis.

Finland: Data are derived from the electronic health records (EHRs) of joint municipal authority for North Karelia social and health care (Siunsote) covering both the public primary and secondary level health services in North Karelia region. Joint EHR in the region has been established in 2010 and thus information on onset of disease is not complete. Data does not include information on analyses performed in the private sector.

France: Data are collected from a regional network database called CARéDIAB Champagne Ardenne, réseau, Diabètewhich collects almost all of the young type 1 diabetic patients of our region and hospital baseddata (CHU de Reims) for adults with type 1 diabetes. Champagne Ardenne is the region centred by the city of Reims where the university hospital is located.

Germany: The DPV is a computer-based longitudinal documentation system for diabetes patients with all types of diabetes and in all age groups since more than 30 years. The electronic health hrecord is documented and stored locally in each participating treatment centre. Twice a year, anonymized data are transmitted to the central administrative unit in Ulm, Germany, where they are aggregated into a cumulative database. Potentially incorrect data are reported back to the participating centres for correction or confirmation. The resulting data pool is used for quality management (benchmarking reports twice yearly) and patient-centred analyses (for a list of publications, see http://www.d-p-v.eu). By March 2020, 450 specialized German diabetes centres had participated in the analysis, 199 treatment centres for adult diabetes patients and 251 paediatric centres. The German DPV registry is funded by the German Centre for Diabetes Research (DZD grant 82DZD14A02), the German Robert-Koch-Institute and the German Diabetes Association.

Greece: Data were obtained for people with type 1 diabetes attending the diabetes clinics at two major regional referral centres (University hospital of Ioannina and University hospital of Larisa) in central Greece and one referral hospital in Thessaloniki in Northern Greece.

Hong Kong: Identified from the electronic medical record system of the Hong Kong Hospital Authority, a statutory body governing all public hospitals/ clinics.

Republic of Ireland: Data are from Galway and Roscommon University Hospitals.The hospitals provide diabetes care to a catchment area ofapproximately 250,000 individuals. Data were extracted from a clinicalinformation system, DIAMOND (Hicom, Brookwood, UK),used to capture all outpatient clinical encounters involvingpatients with diabetes. There is no formalprotocol for validation of the diagnosis of Type 1 diabetes. All new patients would have been formally reviewed by aconsultant endocrinologist at their first visit. During thisvisit, the classification of the patient's diabetes would bediscussed and recorded.

Italy: Data from regional electronic clinical registry. Data on mean values of HbA_{1c} were extracted for the 12- month period prior to 30 August 2011 from eight local registries (whole regions: Valle D'Aosta, Liguria, Marche, Abruzzo, Calabria, Toscana; provinces: Bari-Foggia, Messina). The registry for type 1 diabetes in Italy (RIDI) is a coordinating centre of registries that prospectively collectsdata on newly diagnosed patients under 15 years of age.Local population-based registries operate at the region or province level. Electronic clinical records are stored locally. The register is estimated to be 99 % complete for children and 93% complete for adults.

Latvia: Latvian data come from the population-based Diabetes Register, which is the part of the Register of Patients with Particular Diseases. The current owner of this system is the Centre for Disease Prevention and Control of Latvia. The Diabetes Register was set up in 1997. Information about diabetes patients, at an individual level, is provided by family doctors or endocrinologists; it must be updated at least once per year. Although the completeness of the register has not been formally evaluated and, therefore, no results published, since 2009, in order to ensure completeness, the register data are regularly compared with electronic records of the dispensed reimbursed medications (insulin prescriptions are 100% reimbursed) and, consequently, prescribing physicians are contacted if no matches are found between register and dispensing data. Mean $HbA_{1c}$from 1 January 2016 to 31 December 2017 was estimated. The case definition of type 1 diabetes was based on clinical diagnosis (as stated in the register) plus age at diagnosis < 30 years and insulin therapy.

Netherlands: People with diagnosed type 1 diabetes who receive treatment at the Diabeter clinics (dedicated clinics for people with T1D).Data were provided by Diabeter, a national centre with a focus on paediatric and adolescent diabetes. Diabeter has three locations in the Netherlands, which serve as primary referral centres for all children and adolescents (aged 0– 18 years) with newly diagnosed type 1 diabetes in an area with 1 600 000 inhabitants. Twenty per cent of the patients submitted in this dataset have received diabetes care at Diabeter since the onset of their type 1 diabetes. In addition, Diabeter is a secondary referral centre for type 1 diabetes. Eighty per cent of the patients submitted in this dataset were diagnosed in another clinic before they were referred to Diabeter. All adult patients were diagnosed at other clinics.Type 1 diabetes was diagnosed based on clinical featuresplus the presence of autoantibodies. Patients withoutautoantibodies, with clinical characteristics such as low insulin dose or with characteristics to suggest other diagnoses (e.g. monogenetic diabetes, type 2) are not included.

New Zealand: Data from the Auckland region held in the paediatric diabetes database. All children were captured from a comprehensive database that gathers data on all children with type 1 diabetes in the Auckland super-city region. This information was cross-referenced with hospital admission data

and subsequent clinical follow up, leading to a case ascertainment >95% for children with type 1 diabetes. All care for children is in the Starship children's hospital covering the entire city region in one service. Type 1 diabetes was diagnosed based on clinical features. All patients had elevated blood glucose at presentation: either a random measurement of >11.1 mmol/l and presence of classical symptoms, or fasting blood glucose >7.1 mmol/l. In addition, all patients met at least one of the following criteria: a) diabetic ketoacidosis; b) presence of at least two type 1 diabetes antibodies (to glutamic acid decarboxylase, islet antigen 2, islet cell, or insulin autoantibodies); or c) ongoing requirement for insulin therapy.

Norway: People with diagnosed type 1 diabetes who receive treatment at a hospital clinic.Data were extracted for the 12-month period prior to December 2018 from the National Diabetes Register for Adults, which includes data from 45 of 51 hospitals where the majority of adults with type 1 diabetes receive care so the data are deemed to be national. The estimated coverage of the register for this period is 55%.

Scotland: Most people with diagnosed diabetes in Scotland who receive treatment at a hospital or GP clinics. Population-based data were obtained from the 2011 extract of the Scottish Care Information – Diabetes Collaboration dataset. This register, now containing data for ~ 99 % of individuals with diagnosed diabetes in Scotland, has been in place since 2001 and is populated by daily downloads from primary and secondary databases [18].

Slovenia: All individuals with childhood type 1 diabetes (onset < 18 years)

Sweden: Population-based data were obtained from the Swedish National Diabetes Register (NDR).The National Diabetes Register has been an integrated part of Swedish diabetes care for more than 20 years and has engaged the participation of both hospitals and primary care clinics nationwide. Patient's data are either reported continuously via medical electronic records, through local extraction software, or registered directly online to the NDR. The register is both a repository of clinical variables and an educational tool for improving local quality assessment efforts.All individuals have provided consent before reported to the registry.In Sweden,almost all patients with type 1 diabetes receive theirtreatment at hospital outpatient clinics.

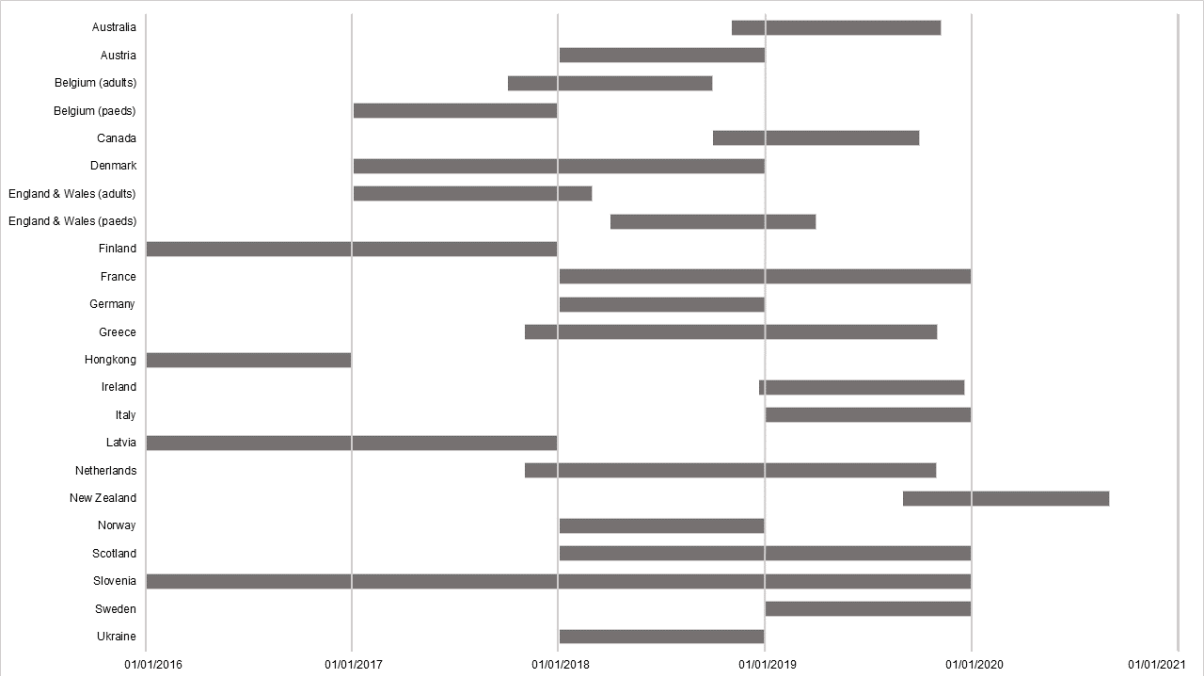
Ukraine: Population-based data were obtained from the Ukrainian Paediatric National Diabetes Register (NDR). It was created in 2004 and contains information about the child's age, sex, date of diagnosis of diabetes, the type and dose of insulin, the presence of acute and chronic complications, HbA_{1c}level, the use of CSII etc.

Supplementary table 1: Description of data sources in each country or region

Country	Sample representativeness	HbA1c definition	Sample size (age)	HbA_{1c} method alignment	Validation of type 1 diabetes diagnosis
Australia (Western)	> 99 % completeness for <15 year olds, likely to be much lower for ≥ 18 year old patients	Mean value	1,111 (1 – 21 years)	IFCC	Diagnosis is made according to current diagnostic definitions and criteria (ADA/ISPAD) and based on combination of clinical signs and symptoms, biochemical investigations (blood glucose, C-peptide), islet autoantibody (IA, IAA-2, GAD) and HLA testing. Those found to be antibody negative are tested for MODY
Austria	The registry covers > 80 % of paediatric type-1 patients (defined < 18 years of age), the coverage in adults is lower. Since data of adults are incomplete only the age group <15 years was included.	Mean value	2,979 (all ages)	IFCC	Diagnosis is made by certified paediatric or adult diabetologists. In suspicious cases (for example CF-Diabetes on insulin classified as type-1 diabetes), the registry reports this back to the treatment centre for correction
Belgium	In Belgium, all people have access to national health insurance. People with type 1 diabetes are required to register to a specialized diabetes centre where they have access to a multidisciplinary diabetes team and extensive coverage of insulin and diabetes self-management tools. As a result, the completeness in IQED and IQECAD is expected to be very high.	Most recent	37,332 (all ages)	IFCC	Clinical diagnosis by an endocrinologist, subsequent registration validation based on previous registrations of that patient, age of diagnosis and time-interval before start of insulin treatment
Canada	Estimated 6.1% population coverage, estimated 90% of all patients who attend the aforementioned LMC Healthcare clinics	Mean value	3,873 (15 – 93 years)	IFCC	Clinical diagnosis by an endocrinologist, based on clinical history and lab values
Denmark	Estimated 95 % completeness. Completeness is checked against the Danish National Patient register holding ICD-codes of all in- and out- patients' hospital visits in Denmark.	Mean value	1,920 (<15 years)	IFCC	Children included for quality of care monitoring. Registered at the treating hospital with follow-up data each year around the child's birthday
England & Wales (adults)	98.2% completeness of GP practices in England, 99.8% complete of GP practices in Wales, 101 participating specialist diabetes services	Mean value	263,450 (≥ 15 years)	IFCC	During the automatic NDA 2017-18 data extraction from GP primary care systems, read v2 and CTv3 codes were used to extract a person's diabetes diagnosis (updated to SNOMED codes for 2018-19 and beyond). The codes used are selected/amended by primary care coding specialists, working alongside NDA clinical leads. The mapping of codes to a diabetes diagnosis is reviewed within the team and with clinicians annually

Country	Sample representativeness	HbA1c definition	Sample size (age)	HbA_{1c} method alignment	Validation of type 1 diabetes diagnosis
England & Wales (children)	100% of 175 paediatric centres providing clinical care to children and young people with type 1 diabetes submitted data to the NPDA in England and Wales. From incidence and prevalence data it is estimated that the capture rate is >95 % of all children and young people with diabetes in the two nations	Median value	19,557 (<15 years)	IFCC	A summary of data submitted is generated upon submission of data into the NPDA data capture system, including the total number of children and young people with T1D being managed within the service. Before annual data analysis commences, unit clinical leads complete a sign off form which asks them to confirm that they have reviewed the summary generated, and that it is complete and accurate
Finland	Practically all type 1 diabetes patients should be represented in the sample	Mean of last measurements in year 2016 and 2017	1,438 (all ages)	IFCC	Validated by a physician
France	Representation of children estimated at 80 % (< 15 years) and 40 % (≥ 15 years)	Mean value	826 (all ages)	No	Clinical history and biological analysis (antibodies) performed by endocrinologists, paediatricians and family doctors
Germany	> 90 % of paediatric type-1 patients (defined < 18 years of age), <30% in adults	Mean value	36,930 (all ages)	IFCC	Diagnosis is made by certified paediatric or adult diabetologists. In suspicious cases (for example CF-Diabetes on insulin classified as type-1 diabetes, the registry reports this back to the treatment centre for correction
Greece	~2% completeness at population level, ~15.6% completeness for central Greece	Mean value	508 (all ages)	IFCC	The diagnosis is based on clinical history, age at diagnosis, islet autoantibody screen and C-peptide measurement (when appropriate) and treatment patterns
Hong Kong	Providing about 90% of total health services in Hong Kong	Mean value	2,235 (all ages)	IFCC	Using an algorithm based on ICD-9 codes, insulin use and other treatment patterns
Ireland	Galway and Roscommon region, clinic database data; providing 60% of paediatric patient data and at least 75% of adult patient data	Mean value	1,637 (all ages)	IFCC	Using an algorithm based on clinical record, age at diagnosis and treatment patterns
Italy	Estimated more than 99 % completeness for the region	Mean value	2,984 (all ages)	IFCC	Based on clinical record, lab results, treatment

Country	Sample representativeness	HbA1c definition	Sample size (age)	HbA_{1c} method alignment	Validation of type 1 diabetes diagnosis
Latvia	Although not formally evaluated, the completeness of registered type 1 diabetes patients should be close to 100%. Since 2009, the records between the Diabetes Register and the database of reimbursed dispensed prescriptions are regularly compared and, in the case of no matches, prescribing physicians are contacted. The representativeness of HbA_{1c} tests themselves is unknown: these are selected test results that were specifically reported to the Register by physicians; this reporting must be done once per year	Mean value	2,883 (all ages)	IFCC	Diagnosis of type 1 diabetes is made by endocrinologists. In children, the diagnosis must be confirmed in Children Clinical University Hospital. There are some built-in algorithms in the Register system, e.g., type 1 diabetes patient must be on insulin therapy. In the past, some family doctors used to change the diagnosis of type 2 diabetes to type 1 after the initiation of insulin therapy. Nowadays, the system requires a justified reason for the change of diagnosis. In order to minimize misclassification, only patients diagnosed before age 30 were included in this analysis. In summary: clinical diagnosis, age at diagnosis less than 30 years and insulin therapy
Netherlands	Estimated 2.5% completeness	Mean value	2,695 (all ages)	IFCC	Using an algorithm based on clinical picture, antibody profile (if data present), age at diagnosis and treatment patterns
New Zealand	Estimated >95% of children aged < 15years providing in Auckland super city region, covering 1/3 of national population of New Zealand.	Mean value	479 (<18 years)	IFCC	Type 1 diabetes diagnosis based on algorithm using presence of hyperglycaemia, clinical record, presence of pre-type 1 diabetes antibody status or DKA, age at diagnosis and treatment patterns.
Norway	Estimated 55% completeness	Mean value	13,768 (≥ 18 years)	IFCC	Type 1 diabetes diagnosis based on clinical record ICD-10 code. The clinician making the diagnosis will have access to age at diagnosis and in many cases C-peptide and antibody status
Scotland	Estimated 99.5% completeness	Mean value	32,578 (all ages)	IFCC	Using an algorithm based on clinical record, age at diagnosis and treatment patterns. Patients with definite type 1 diabetes were included, patients with possible type 1 diabetes were excluded
Slovenia	Estimated 99.5% completeness	Mean value	5,496 (< 25 years)	IFCC	Using an algorithm based on clinical record, age at diagnosis and treatment patterns
Sweden	Estimated 94% completeness	Most recent (LOCF)	48,685 (≥ 18 years)	IFCC	Type 1 diabetes based on clinical record ICD10 code by clinician at special clinics
Ukraine	Estimated 97.1% completeness	Mean value	9,283 (0 – 18 years)	IFCC	Using an algorithm based on clinical record, age at diagnosis and treatment patterns



Supplementary figure 1: Overview of time period of data included, separately for each country or region

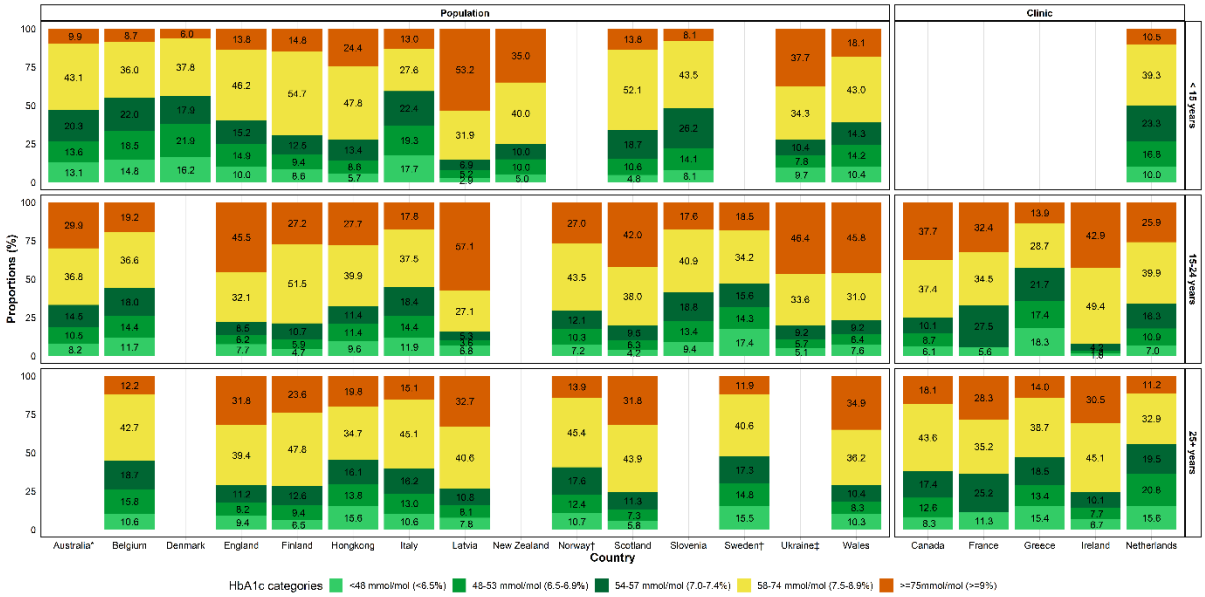
	Table 1	Figure 1	Figure 2	Table 2	Figure 3
Exclusions	Missing age: n = 262	Missing age or HbA_{1c} or n<100 in age groups: n = 47,767	Missing age, HbA_{1c} or pump use or n<100 in age groups: n = 100,831	Missing age, sex or HbA_{1c} or n<100 in age groups: n = 56,106	Did not participate in previous comparison, missing age or HbA_{1c} or n<100 in age groups: n = 102,308
Number of people included	520,130	472,625	419,561	464,286	418,084
Country			**% of original sample included**		
Australia	100.0	97.2	96.7	97.2	97.2
Austria	100.0	99.4	0.0	99.4	99.4
Belgium	100.0	97.8	95.6	97.4	0.0
Canada	100.0	90.4	90.4	90.4	0.0
Denmark	100.0	84.5	84.5	84.5	84.5
England	99.9	88.7	88.7	88.7	88.7
Finland	100.0	93.3	0.0	93.3	0.0
France	100.0	95.2	61.5	95.2	95.2
Germany	100.0	97.0	0.0	97.0	97.0
Greece	99.6	91.7	91.7	91.7	69.1
Hongkong	100.0	81.1	0.0	81.1	0.0
Ireland	100.0	55.0	55.0	55.0	55.0
Italy	100.0	98.9	98.9	98.9	98.9
Latvia	100.0	72.8	0.0	72.8	72.8
Netherlands	100.0	96.4	96.4	96.4	96.4
New Zealand	100.0	100.0	100.0	100.0	0.0
Norway	100.0	97.7	95.8	97.7	97.7
Scotland	100.0	88.8	88.8	88.8	82.9
Slovenia	100.0	99.6	96.5	99.6	0.0
Sweden	100.0	98.4	96.3	98.4	98.4
Ukraine	100.0	87.7	0.0	0.0	0.0
Wales	99.9	85.2	85.2	85.2	85.2

Supplementary table 2: Overview of sample size and numbers included as well as proportions of each country population included in each of the analyses

Supplementary table 3:Number (%) of people in different HbA_{1c} categories by age and sex

HbA_{1c}	Age group						Total	
	< 15 years		15 – 24 years		≥ 25 years			
	Female	Male	Female	Male	Female	Male	Female	Male
< 58 mmol/mol (< 7.5 %)	9,822 (44.6)	10,926 (46.7)	9,027 (27.5)	11,160 (30.2)	50,434 (32.4)	66,304 (34.3)	69,284 (32.9)	88,390 (34.8)
58 – 74 mmol/mol (7.5 – 8.9 %)	9,113 (41.4)	9,510 (40.6)	11,448 (34.8)	12,391 (33.5)	62,994 (40.5)	76,605 (39.6)	83,555 (39.7)	98,506 (38.8)
≥ 75mmol/mol (≥ 9 %)	3,088 (14.0)	2,978 (12.7)	12,409 (37.7)	13,414 (36.3)	42,284 (27.2)	50,532 (26.1)	57,781 (27.4)	66,924 (26.4)

Supplementary figure 2: Proportions of individuals with HbA_{1c}<48 mmol/mol (<6.5%), 48 – 53mmol/mol (6.5 – 6.9 %), 54 – 57mmol/mol (7.0 – 7.4%), 58 – 74 mmol/mol (7.5 – 8.9 %) and ≥ 75 mmol/mol (≥ 9.0 %) in each of the three age groups by data source



* Data in age group 15 – 24 years are for individuals aged 15 – 21 years.

†Data in age group 15 – 24 years are for individuals aged 18 – 24 years.

‡Data in age group 15 – 24 years are for individuals aged 15 – 18 years.

Supplementary table 4: Absolute and relative change in the proportions of individuals in each HbA_{1c} category over time, separately for each country or region (< 15 years old)

		Sample sizes		Change	
Country	**HbA_{1c}**	**Analysis 2010 – 2012**	**Analysis 2016 – 2020**	**Absolute**	**Relative**
Australia	< 58 mmol/mol (< 7.5 %)	233	284	8.4	21.7
	58 – 74 mmol/mol (7.5 – 8.9 %)	292	261	-5.2	-10.8
	≥ 75 mmol/mol (≥ 9 %)	79	60	-3.2	-24.2
Austria	< 58 mmol/mol (< 7.5 %)	465	803	9.8	21.3
	58 – 74 mmol/mol (7.5 – 8.9 %)	396	491	-5.1	-12.9
	≥ 75 mmol/mol (≥ 9 %)	147	141	-4.8	-32.6
Denmark	< 58 mmol/mol (< 7.5 %)	399	898	30.2	113.5
	58 – 74 mmol/mol (7.5 – 8.9 %)	844	590	-19.0	-33.7
	≥ 75 mmol/mol (≥ 9 %)	256	92	-11.3	-65.9
England	< 58 mmol/mol (< 7.5 %)	2,222	6,957	22.0	121.9
	58 – 74 mmol/mol (7.5 – 8.9 %)	6,053	8,026	-3.0	-6.0
	≥ 75 mmol/mol (≥ 9 %)	4,041	2,393	-19.0	-58.0
Germany	< 58 mmol/mol (< 7.5 %)	6,885	8,754	4.5	9.7
	58 – 74 mmol/mol (7.5 – 8.9 %)	5,812	6,195	-3.2	-8.1
	≥ 75 mmol/mol (≥ 9 %)	2,141	2,254	-1.3	-9.2
Italy	< 58 mmol/mol (< 7.5 %)	401	114	18.1	43.9
	58 – 74 mmol/mol (7.5 – 8.9 %)	476	53	-21.4	-43.6
	≥ 75 mmol/mol (≥ 9 %)	95	25	3.2	33.2
Latvia	< 58 mmol/mol (< 7.5 %)	44	52	-0.7	-4.6
	58 – 74 mmol/mol (7.5 – 8.9 %)	74	111	5.6	21.1
	≥ 75 mmol/mol (≥ 9 %)	163	185	-4.8	-8.4
Netherlands	< 58 mmol/mol (< 7.5 %)	158	286	19.0	60.7
	58 – 74 mmol/mol (7.5 – 8.9 %)	272	224	-14.5	-26.9
	≥ 75 mmol/mol (≥ 9 %)	76	60	-4.5	-29.9
Wales	< 58 mmol/mol (< 7.5 %)	165	385	20.2	106.8
	58 – 74 mmol/mol (7.5 – 8.9 %)	416	423	-4.7	-9.9
	≥ 75 mmol/mol (≥ 9 %)	293	178	-15.5	-46.1

Supplementary table5: Absolute and relative change in the proportions of individuals in each HbA_{1c} category over time, separately for each country or region (15 – 24 years old)

* In 2010 – 2012 analysis, data are for individuals aged 15 – 18 years. In 2016 – 2020 analysis, data are for individuals aged 15 – 21 years.

†Dataare for individuals aged 18 – 24 years.

		Sample sizes		Change	
Country	**HbA_{1c}**	**Analysis 2010 – 2012**	**Analysis 2016 – 2020**	**Absolute**	**Relative**
Australia*	< 58 mmol/mol (< 7.5 %)	92	158	8.3	33.4
	58 – 74 mmol/mol (7.5 – 8.9 %)	159	175	-6.2	-14.5
	≥ 75 mmol/mol (≥ 9 %)	118	142	-2.1	-6.5
England & Wales	< 58 mmol/mol (< 7.5 %)	3,491	8,940	5.8	34.7
	58 – 74 mmol/mol (7.5 – 8.9 %)	6,461	12,725	1.1	3.6
	≥ 75 mmol/mol (≥ 9 %)	10,987	18,140	-6.9	-13.1
France	< 58 mmol/mol (< 7.5 %)	42	47	12.7	62.3
	58 – 74 mmol/mol (7.5 – 8.9 %)	84	49	-6.3	-15.4
	≥ 75 mmol/mol (≥ 9 %)	80	46	-6.4	-16.6
Germany	< 58 mmol/mol (< 7.5 %)	2,691	4,231	5.2	15.1
	58 – 74 mmol/mol (7.5 – 8.9 %)	2,833	3,894	0.2	0.6
	≥ 75 mmol/mol (≥ 9 %)	2,240	2,484	-5.4	-18.8
Ireland	< 58 mmol/mol (< 7.5 %)	14	13	-1.1	-12.7
	58 – 74 mmol/mol (7.5 – 8.9 %)	55	83	14.6	41.9
	≥ 75 mmol/mol (≥ 9 %)	89	72	-13.5	-23.9
Italy	< 58 mmol/mol (< 7.5 %)	342	143	10.9	32.2
	58 – 74 mmol/mol (7.5 – 8.9 %)	508	120	-12.7	-25.3
	≥ 75 mmol/mol (≥ 9 %)	162	57	1.8	11.3
Latvia	< 58 mmol/mol (< 7.5 %)	72	65	-2.3	-12.6
	58 – 74 mmol/mol (7.5 – 8.9 %)	114	112	-1.4	-4.8
	≥ 75 mmol/mol (≥ 9 %)	214	236	3.6	6.8
Netherlands	< 58 mmol/mol (< 7.5 %)	176	462	8.5	32.9
	58 – 74 mmol/mol (7.5 – 8.9 %)	334	539	-8.9	-18.3
	≥ 75 mmol/mol (≥ 9 %)	174	350	0.5	1.8
Norway†	< 58 mmol/mol (< 7.5 %)	122	472	6.1	25.9
	58 – 74 mmol/mol (7.5 – 8.9 %)	218	695	1.6	3.7
	≥ 75 mmol/mol (≥ 9 %)	180	431	-7.6	-22.1
Scotland	< 58 mmol/mol (< 7.5 %)	394	768	8.9	81.0
	58 – 74 mmol/mol (7.5 – 8.9 %)	1,182	1,466	5.0	15.1
	≥ 75 mmol/mol (≥ 9 %)	2,003	1,621	-13.9	-24.9
Sweden†	< 58 mmol/mol (< 7.5 %)	1,047	2,388	20.1	74.2
	58 – 74 mmol/mol (7.5 – 8.9 %)	1,679	1,728	-9.3	-21.4
	≥ 75 mmol/mol (≥ 9 %)	1,130	934	-10.8	-36.9

Supplementary table6:Absolute and relative change in the proportions of individuals in each HbA_{1c} category over time, separately for each country or region (≥ 25 years old)

		Sample sizes		Change	
Country	**HbA_{1c}**	**Analysis 2010 – 2012**	**Analysis 2016 – 2020**	**Absolute**	**Relative**
England & Wales	< 58 mmol/mol (< 7.5 %)	39,691	64,065	1.4	5.1
	58 – 74 mmol/mol (7.5 – 8.9 %)	57,269	86,825	-0.5	-1.3
	≥ 75 mmol/mol (≥ 9 %)	47,880	71,515	-0.9	-2.7
France	< 58 mmol/mol (< 7.5 %)	136	235	5.8	18.9
	58 – 74 mmol/mol (7.5 – 8.9 %)	188	227	-7.2	-16.9
	≥ 75 mmol/mol (≥ 9 %)	119	182	1.4	5.2
Germany	< 58 mmol/mol (< 7.5 %)	2,840	4,204	-1.2	-2.2
	58 – 74 mmol/mol (7.5 – 8.9 %)	1,499	2,495	2.8	10.0
	≥ 75 mmol/mol (≥ 9 %)	963	1,322	-1.7	-9.3
Greece	< 58 mmol/mol (< 7.5 %)	169	166	-0.3	-0.7
	58 – 74 mmol/mol (7.5 – 8.9 %)	130	136	2.1	5.8
	≥ 75 mmol/mol (≥ 9 %)	56	49	-1.8	-11.5
Ireland	< 58 mmol/mol (< 7.5 %)	160	179	-0.5	-2.2
	58 – 74 mmol/mol (7.5 – 8.9 %)	289	330	-0.1	-0.2
	≥ 75 mmol/mol (≥ 9 %)	191	223	0.6	2.1
Italy	< 58 mmol/mol (< 7.5 %)	161	972	-8.1	-16.9
	58 – 74 mmol/mol (7.5 – 8.9 %)	129	1,100	6.7	17.4
	≥ 75 mmol/mol (≥ 9 %)	46	368	1.4	10.2
Latvia	< 58 mmol/mol (< 7.5 %)	347	357	-0.7	-2.6
	58 – 74 mmol/mol (7.5 – 8.9 %)	499	543	1.2	3.0
	≥ 75 mmol/mol (≥ 9 %)	421	438	-0.5	-1.5
Netherlands	< 58 mmol/mol (< 7.5 %)	63	379	7.1	14.5
	58 – 74 mmol/mol (7.5 – 8.9 %)	56	223	-10.5	-24.2
	≥ 75 mmol/mol (≥ 9 %)	10	76	3.5	44.6
Norway	< 58 mmol/mol (< 7.5 %)	1,057	4,820	8.2	25.4
	58 – 74 mmol/mol (7.5 – 8.9 %)	1,574	5,377	-2.9	-6.1
	≥ 75 mmol/mol (≥ 9 %)	627	1,651	-5.3	-27.6
Scotland	< 58 mmol/mol (< 7.5 %)	4,305	5,528	3.8	18.6
	58 – 74 mmol/mol (7.5 – 8.9 %)	8,837	9,959	1.7	4.1
	≥ 75 mmol/mol (≥ 9 %)	7,816	7,206	-5.5	-14.9
Sweden	< 58 mmol/mol (< 7.5 %)	6,232	20,376	17.3	57.3
	58 – 74 mmol/mol (7.5 – 8.9 %)	10,193	17,383	-8.9	-18.0
	≥ 75 mmol/mol (≥ 9 %)	4,188	5,094	-8.4	-41.5