

Trends in gestational diabetes in Iceland before and after guideline changes in 2012: a nationwide study from 1997 to 2020

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Abstract

Internationally accepted diagnostic criteria recommendations for gestational diabetes (GDM) in 2010 resulted in a rise in global prevalence of GDM. Our aim was to describe the trends in GDM before and after Icelandic guideline changes in 2012 and the trends in pregestational diabetes (PGDM). The study included all singleton births ($N = 101\,093$) in Iceland during 1997–2020. Modified Poisson regression models were used to estimate prevalence ratios (PRs) with 95% confidence intervals (CIs) for risk of GDM overall and by maternal age group, as well as overall risk of PGDM, according to time period of birth. The overall prevalence of GDM by time period of birth ranged from 0.6% ($N = 101$) in 1997–2000 to 16.2% ($N = 2720$) in 2017–2020, and the prevalence of PGDM ranged from 0.4% ($N = 57$) in 1997–2000 to 0.7% ($N = 120$) in 2017–2020. The overall relative GDM prevalence rate difference before and after 2012 was 380%, and the largest difference was found among women aged <25 years at 473%. Risk of GDM increased in 2017–2020 (PR 14.21, CI 11.45, 17.64) compared to 1997–2000 and was highest among women aged >34 years with PR 19.46 (CI 12.36, 30.63) in 2017–2020. Prevalence rates of GDM and PGDM increased during the study period. An accelerated rate of increase in GDM was found after 2012, overall, and among all maternal age groups. Women aged >34 years had the greatest risk of GDM throughout all time periods, while women aged <25 years appear to have a higher relative rate difference after 2012.

Introduction

It is estimated that more than 16% of live births worldwide in 2021 were affected by some form of maternal diabetes [1]. European age-adjusted prevalence estimates for the same year were 12.2%, with 1.6 million affected live births [1]. Gestational diabetes (GDM) is characterized by inadequate insulin secretion to counteract the increased insulin resistance caused by the placenta as the pregnancy progresses and typically resolves after delivery [1]. It is well established that diabetes in pregnancy is associated with higher rates of pregnancy and delivery complications as well as adverse neonatal outcomes [1–3]. While GDM accounts for over 80% of maternal diabetes cases [1], adverse outcomes and pregnancy complications are more common among pregnancies affected by pregestational diabetes (PGDM), which includes both known type 1 and type 2 diabetes prior to pregnancy [2]. PGDM poses additional neonatal risk of congenital malformations resulting from poor glycemic control in the first trimester [2, 3]. Maternal associated risks for women with diabetes in pregnancy include hypertensive disorders of pregnancy, pre-eclampsia, assisted vaginal delivery, and cesarean delivery [2], while neonates are at increased risk of perinatal mortality, macrosomia, and preterm birth [3, 4]. Women with GDM are at seven times greater risk of developing T2DM later in life compared to women who do not have GDM [3–5]. In addition, infants born to mothers with GDM are also at higher risk for obesity and of developing T2DM later in life [5]. Increasing trends in maternal age, obesity rates, and changes to screening and diagnostic criteria are widely accepted as contributing to increasing rates of diabetes in pregnancy worldwide [1–3] due to the concurrent nature of these events.

In response to a lack of consistent and internationally accepted diagnostic screening strategies for GDM, the Hyperglycemic and Adverse

Pregnancy Outcome (HAPO) study was conducted to determine predictive diagnostic values and associated risks of adverse pregnancy outcomes in pregnancies with mild hyperglycemia [6–8]. The results of the HAPO study were reflected in the lowered diagnostic criteria and universal screening strategy for all pregnant women that was put forth in recommendations by the International Association of the Diabetes and Pregnancy Study Groups (IADPSG) in 2010 [9] and later endorsed by the World Health Organization (WHO) in 2013 [8].

Despite these recommendations, screening guidelines for GDM remain inconsistent across Europe, and many nations, including Iceland, have continued to screen based on maternal risk factors [5, 10]. In 2012, the Icelandic clinical guidelines for screening, diagnosing, and treating diabetes during pregnancy were revised to align with the diagnostic criteria set by the IADPSG [10]. It was estimated that GDM prevalence among women giving birth at Landspítali University Hospital in Iceland would increase to 16.1%; however, reported rates in 2018 were higher at 19% [11]. There remains a gap in the existing literature to include a comprehensive analysis of the overall trends of diabetes in pregnancy in Iceland and the impact the guideline changes in 2012 may have had. We aimed to examine the change in trends of GDM prevalence before and after guideline changes in 2012, overall and by maternal age, as well as to describe trends in PGDM during the same period.

Methods

Study population and data sources

This nationwide population-based cohort study included all singleton births registered in the Icelandic Medical Birth Registry from

1997 to 2020, $N=101\,093$. This centralized registry contains complete coverage of all births in Iceland for infants, both live and stillborn, weighing >500 g or having gestational age >22 weeks in addition to maternal sociodemographic characteristics.

Exposure

The primary exposure was time period of birth. We examined the following exposures: yearly, time periods before and after guideline changes in 2012 (1997–2012, 2012–2020), and time periods categorized into four-year intervals (1997–2000, 2001–2004, 2005–2008, 2009–2012, 2013–2016, 2017–2020) to account for year-to-year variation in a smaller population such as Iceland with time period 1997–2000 as the reference.

Outcome

The primary outcome was risk of GDM, and the secondary outcome was risk of PGDM. The outcomes were extracted from the database using International Classification of Diseases and Health Related Problems 10th revision (ICD-10) codes (O24.0, E10, O24.1, E11, O24.4, O24.9). In secondary analysis, we assessed the risk of GDM and PGDM by maternal age group strata, categorized by maternal age at delivery in years (<25 , 25–34, >34).

Covariates

For the association of time of birth and risk of diabetes in pregnancy, possible confounders were considered *a priori*. These included well-known factors that have been associated with changes to risk of diabetes in pregnancy including maternal age at delivery (years), parity (primipara/multipara), nationality (Icelandic/non-Icelandic), region (urban/rural), and body mass index (BMI) kg/m^2 category [underweight (<18.5), healthy (18.5–24.9), overweight (25–29.9), obese (≥ 30), unknown] [12, 13]. The Icelandic Medical Birth Registry began to collect information on maternal BMI in 2012 at the first prenatal assessment.

Statistical analysis

We calculated yearly rates of GDM and PGDM, overall and by maternal age group strata. The prevalence trend for GDM was examined before and after guideline changes in 2012. We calculated the proportionate distribution by maternal age group strata for GDM and PGDM across all six time periods.

Modified Poisson regression models were fitted for prevalence ratios (PRs) and corresponding 95% confidence intervals (CIs) for the risk of GDM according to time period of birth, overall and by maternal age group strata, with 1997–2000 as reference. We presented crude and adjusted estimates for maternal age at delivery, parity, nationality, region, and BMI category. We also fitted modified Poisson regression models for overall PRs of PGDM by time period of birth and presented crude and adjusted estimates.

Missing data

There were minimal missing values for most covariates used in our analysis. We used a data category “unknown” for missing region and BMI data as missing data for these variables was 2.3% for region and 14.9% for BMI from 2012 onward.

Ethics approval

We conducted registry-based research using administrative health data that do not require informed consent according to Icelandic regulations. The study was approved by the National Bioethics Committee in Iceland approval number VSNb2019020007/03.01.

Results

There were 101 093 singleton births in Iceland during 1997–2020. Characteristics of the study population are presented in Table 1. The overall prevalence of GDM in Iceland throughout the study period was 5.6% and ranged from 0.6% ($N=101$) in 1997–2000 to 16.2% ($N=2720$) in 2017–2020. The overall prevalence of PGDM in Iceland was 0.5% and ranged from 0.4% ($N=57$) in 1997–2000 to 0.7% ($N=120$) in 2017–2020. There were no reported cases of type 2 diabetes in 1997–2000, but increased to 36 reported cases in 2017–2020, representing 30% of PGDM in that time period. The prevalence of obesity was 1.9% in 2009–2012, 18.9% in 2013–2016, and 21.1% in 2017–2020; however, a large proportion was missing in 2009–2012.

The overall trend in prevalence of GDM increased over the study period, with a marked increase after 2012 (Fig. 1). The overall prevalence of GDM increased from 2.5% between 1997 and 2012 to 12% between 2013 and 2020, representing a 380% difference between the two time periods (Supplementary Table S1). When we stratified by maternal age group, increased trends in GDM prevalence were found among all strata (Fig. 1). When comparing before and after 2012, women aged <25 years had the highest relative prevalence rate difference of 473%, from 1.1% to 6.3% (Supplementary Table S1). This was followed by relative prevalence rate differences of 362% for women aged 25–34 years, from 2.4% to 11.1%, and 312% for women aged >34 years, from 4.7% to 19.4% (Supplementary Table S1).

Proportionate distribution of maternal age groups for GDM showed increasing trends among all maternal age groups throughout the study period, with larger proportions seen with increasing maternal age (Fig. 2). Proportionate distribution of maternal age groups for PGDM was found to be unstable, but with increasing trends to all age group in the two time periods after 2009–2012 (Fig. 2).

When we estimated the relative risk of GDM by time period of birth, we found an increase in PR 14.21 (CI 11.45, 17.64) in 2017–2020 compared to 1997–2000 (Table 2). Stratified estimates were highest among women aged >34 years with PR 19.46 (CI 12.36, 30.63) in 2017–2020, while the risk for women aged <25 years was PR 12.20 (CI 6.47, 22.99) and the risk for women aged 25–34 years was PR 12.84 (CI 9.78, 16.85) (Supplementary Table S2). Similar estimates were found overall and in age-stratified adjusted models 1 and 2 before 2012. After 2012, the estimates were lower in model 2, indicating an effect for adjustment for BMI which was missing prior to 2012. The overall relative risk of PGDM by time period was PR 1.49 (CI 0.94, 2.36) in 2017–2020, compared to 1997–2000 (Supplementary Table S3).

Discussion

Principle findings

In this nationwide register-based cohort study of all singleton births in Iceland from 1997 to 2020, we found increased trends in prevalence rates of GDM and PGDM overall. GDM was more than 14 times more prevalent overall in 2017–2020 compared to 1997–2000, while PGDM was one-and-a-half times more prevalent in 2017–2020 compared to 1997–2000. A marked increase in GDM prevalence trend was found after 2012, overall, and among all maternal age group strata. Women aged >34 years had the largest proportionate distributions of GDM and highest risk of GDM throughout all time periods. Women aged <25 years had the largest relative GDM prevalence rate difference when comparing the time periods before and after the guideline changes.

With already increasing trends in maternal age and rates of obesity, the increasing trend in GDM and, to a smaller extent, PGDM, was not surprising. It was also inevitable to expect that implementing internationally accepted, lowered diagnostic thresholds for GDM would increase GDM global prevalence rates. However, research that examines the effect of the practice shift toward the IADPSG

Table 1. Characteristics of singleton births in Iceland during 1997–2020

| | 1997–2000 (N = 16 201) | 2001–2004 (N = 15 969) | 2005–2008 (N = 17 536) | 2009–2012 (N = 18 383) | 2013–2016 (N = 16 240) | 2017–2020 (N = 16 764) | Overall (N = 10 1093) |
|--------------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|--------------------------|
| Diabetes status in pregnancy | | | | | | | |
| No diabetes | 16 043 (99.0%) | 15 540 (97.3%) | 16 989 (96.9%) | 17 546 (95.4%) | 14 911 (91.8%) | 13 924 (83.1%) | 94 953 (93.9%) |
| Gestational | 101 (0.6%) | 370 (2.3%) | 485 (2.8%) | 755 (4.1%) | 1225 (7.5%) | 2720 (16.2%) | 5656 (5.6%) |
| Pregestational | 57 (0.4%) | 59 (0.4%) | 62 (0.4%) | 82 (0.4%) | 104 (0.6%) | 120 (0.7%) | 484 (0.5%) |
| Type 1 | 57 (100%) | 51 (86.4%) | 41 (66.1%) | 63 (76.8%) | 73 (70.2%) | 84 (70.0%) | 369 (76.2%) |
| Type 2 | 0 (0%) | 8 (13.6%) | 21 (33.9%) | 19 (23.2%) | 31 (29.8%) | 36 (30.0%) | 115 (23.8%) |
| Maternal age (years) | | | | | | | |
| Mean (SD) | 28.1 (5.72) | 28.7 (5.61) | 28.9 (5.51) | 29.3 (5.46) | 29.6 (5.47) | 29.9 (5.27) | 29.1 (5.54) |
| Median [Min, Max] | 28.0 [14.0, 47.0] | 28.0 [13.0, 48.0] | 29.0 [15.0, 55.0] | 29.0 [14.0, 48.0] | 29.0 [14.0, 51.0] | 30.0 [14.0, 53.0] | 29.0 [13.0, 55.0] |
| Maternal age group (years) | | | | | | | |
| <25 | 4644 (28.7%) | 3971 (24.9%) | 3955 (22.6%) | 3650 (19.9%) | 3028 (18.6%) | 2531 (15.1%) | 21 779 (21.5%) |
| 25–34 | 9160 (56.5%) | 9358 (58.6%) | 10 631 (60.6%) | 11 361 (61.8%) | 9973 (61.4%) | 10 846 (64.7%) | 61 329 (60.7%) |
| >34 | 2397 (14.8%) | 2640 (16.5%) | 2950 (16.8%) | 3372 (18.3%) | 3239 (19.9%) | 3387 (20.2%) | 17 985 (17.8%) |
| Parity | | | | | | | |
| Primipara | 6493 (40.1%) | 6429 (40.3%) | 7112 (40.6%) | 7309 (39.8%) | 6438 (39.6%) | 7414 (44.2%) | 41 195 (40.7%) |
| Multipara | 9708 (59.9%) | 9540 (59.7%) | 10 424 (59.4%) | 11 074 (60.2%) | 9802 (60.4%) | 9350 (55.8%) | 59 898 (59.3%) |
| Nationality | | | | | | | |
| Icelandic | 15 803 (97.5%) | 15 302 (95.8%) | 15 984 (91.1%) | 16 101 (87.6%) | 14 195 (87.4%) | 14 109 (84.2%) | 91 494 (90.5%) |
| Non-Icelandic | 398 (2.5%) | 667 (4.2%) | 1552 (8.9%) | 2282 (12.4%) | 2045 (12.6%) | 2655 (15.8%) | 9599 (9.5%) |
| Region | | | | | | | |
| Urban | 9087 (56.1%) | 9432 (59.1%) | 11 258 (64.2%) | 12 079 (65.7%) | 10 644 (65.5%) | 5285 (31.5%) | 57 785 (57.2%) |
| Rural | 6157 (38.0%) | 5674 (35.5%) | 5987 (34.1%) | 6240 (33.9%) | 5517 (34.0%) | 11 386 (67.9%) | 40 961 (40.5%) |
| Unknown | 957 (5.9%) | 863 (5.4%) | 291 (1.7%) | 64 (0.3%) | 79 (0.5%) | 93 (0.6%) | 2347 (2.3%) |
| BMI kg/m ² category | | | | | | | |
| Underweight (<18.5) | — | — | — | 83 (0.5%) | 401 (2.5%) | 295 (1.8%) | 779 (0.8%) |
| Healthy (18.5–24.9) | — | — | — | 1430 (7.8%) | 7618 (46.9%) | 6920 (41.3%) | 15 968 (15.8%) |
| Overweight (25–29.9) | — | — | — | 488 (2.7%) | 3771 (23.2%) | 3851 (23.0%) | 8110 (8.0%) |
| Obese (≥30) | — | — | — | 351 (1.9%) | 3065 (18.9%) | 3536 (21.1%) | 6952 (6.9%) |
| Unknown | 16 201 (100%) | 15 969 (100%) | 17 536 (100%) | 16 031 (87.2%) | 1385 (8.5%) | 2162 (12.9%) | 69 284 (68.5%) |

recommendations is inconsistent and varied. Results from a meta-analysis of 35 studies, including 13 studies from the USA and Canada, 9 from Northern Europe, 7 from China and Japan, 6 from India, Bangladesh, and Sri Lanka, 5 from Australia, and 10 from other countries, examining the effect of various diagnostic thresholds on the prevalence of GDM among pregnant women worldwide, regardless of geographical region, reported a 6- to 11-fold increase in identified women with GDM when using the IADPSG recommendations compared to other guidelines [14]. In 2021, another systematic review and meta-analysis consisting of 31 studies from most regions around the world apart from North America, including seven (22.6%) conducted in Europe (England, Croatia, Norway, Hungary, Ireland, Turkey), found that the number of women with GDM increased by only 75% after the implementation of IADPSG recommendations [15]. Our results are more in line with the former, where a more marked increase was observed.

The International Diabetes Federation released global and regional raw prevalence estimates for all hyperglycemia in pregnancy for 2021, of which 80.3% were attributed to GDM [1]. Global raw prevalence estimates were 16.7%, regional estimates for Europe were 15.0%, and the highest raw prevalence reported was for Southeast Asia at 25.9% [1]. In a meta-analysis of GDM prevalence in Europe that included studies reported between 2014 and 2019, sub-regional European prevalence estimates were lowest in Northern Europe (including Iceland) at 8.9% and highest in Eastern Europe at 31.5%. These results highlight the importance of considering regional differences in risk factors for GDM as well as the impact of varying diagnostic and screening strategies which can exist between countries. Our results indicate that Iceland is following similar overall global and European trends in GDM prevalence with 16.5% in 2020 but that they are higher than the European sub-regional prevalence estimates for Northern Europe.

Increased BMI is associated with increased risk for GDM [16]. The higher GDM prevalence estimates in our study compared to European sub-regional estimates could also be explained by high

obesity rates in Iceland. The prevalence of obesity is higher in Iceland than in any other Nordic country [17], and obesity trends have been increasing since the 1980s [17]. In 2018, 27% of adults in Iceland were obese based on self-reported height and weight, results that were well above the average of 17% among OECD nations [18]. Later in 2022, the WHO European Regional Obesity Report indicated the prevalence of obesity among Icelandic women was around 20% [19]. Our study was able to demonstrate the impact of increasing obesity trends on GDM prevalence among pregnant women in Iceland from 2012 onward.

Advanced maternal age has been well established in the literature as a risk factor for GDM [1, 20, 21]. Trends in maternal age at delivery in Iceland have been increasing overall for decades [22]. A systematic review and meta-analysis published in 2020 aimed to quantify the change in risk for GDM according to maternal age using 24 studies from Asia, Europe, North America, and Oceania, including more than 120 million pregnant women [23]. The study found a linear increase in risk of GDM with maternal age, with an overall increase in GDM risk of 7.9% for every one-year increase in maternal age after 18 years [23]. Statistics Iceland reports that the mean maternal age at delivery in 2022 among primiparous women was 28.9 years, compared to under 22 years in the 1970s. According to the OECD Family Database, in 2021, the mean maternal age at delivery for primiparous women in most OECD was 30 years or above [24]. A lower mean of 28–30 years was only seen in seven of the OECD countries, including Poland and the United States [24]. Our study found that the overall mean maternal age at delivery is consistent with these trends.

Due to a lack of high-quality data among many countries around the world for pre-existing T1DM and T2DM in pregnancy, true global estimates of PGDM are limited [25]. Previous trends for PGDM mainly consisted of T1DM; however, the increases in maternal age at delivery and maternal BMI have contributed to a growing number of T2DM cases seen among pregnant women [25]. A meta-analysis of studies published between 2010 and 2020 found

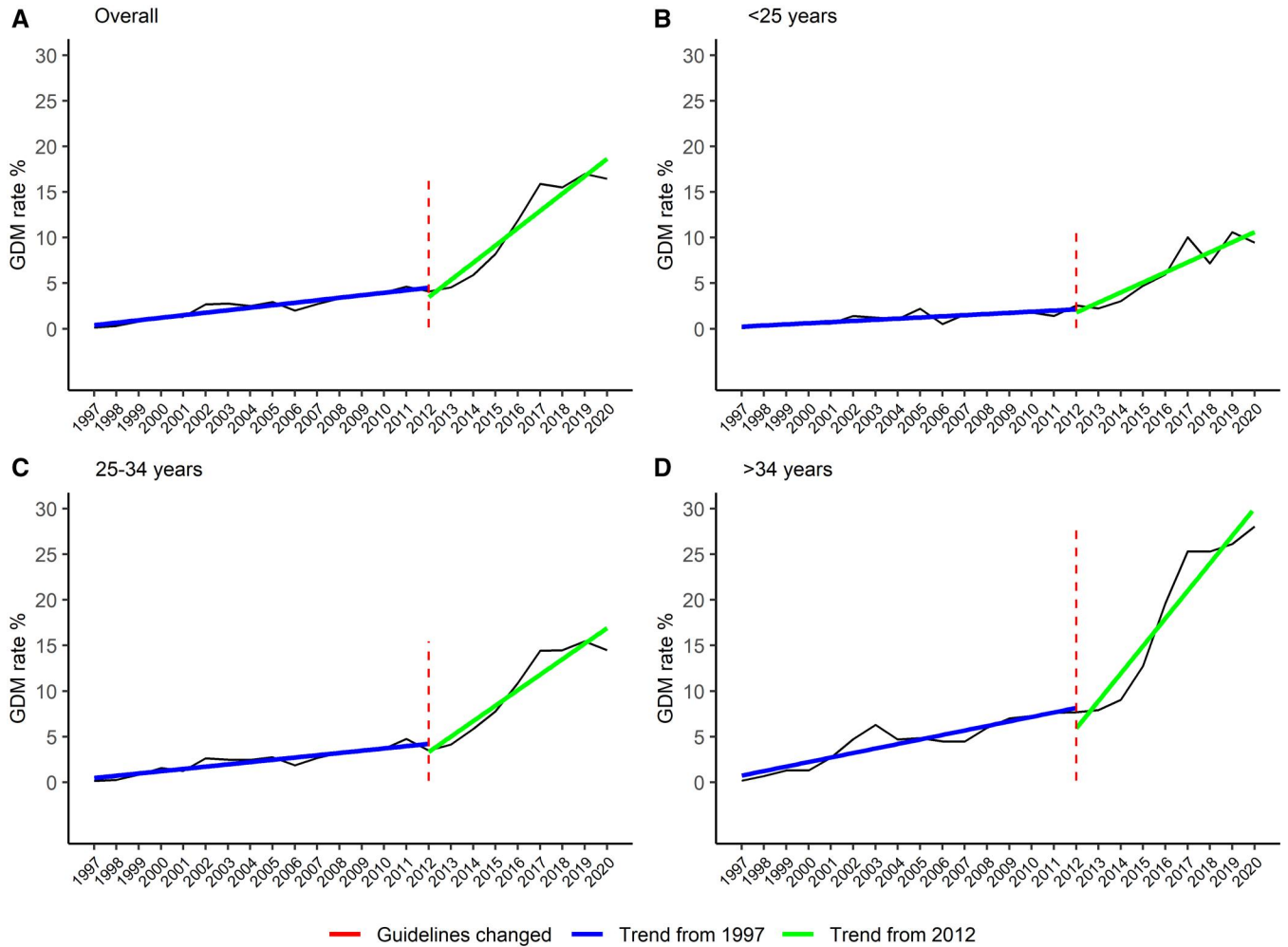


Figure 1. Trends in gestational diabetes prevalence in Iceland during 1997–2020, before and after guideline changes in 2012, overall and by maternal age group.

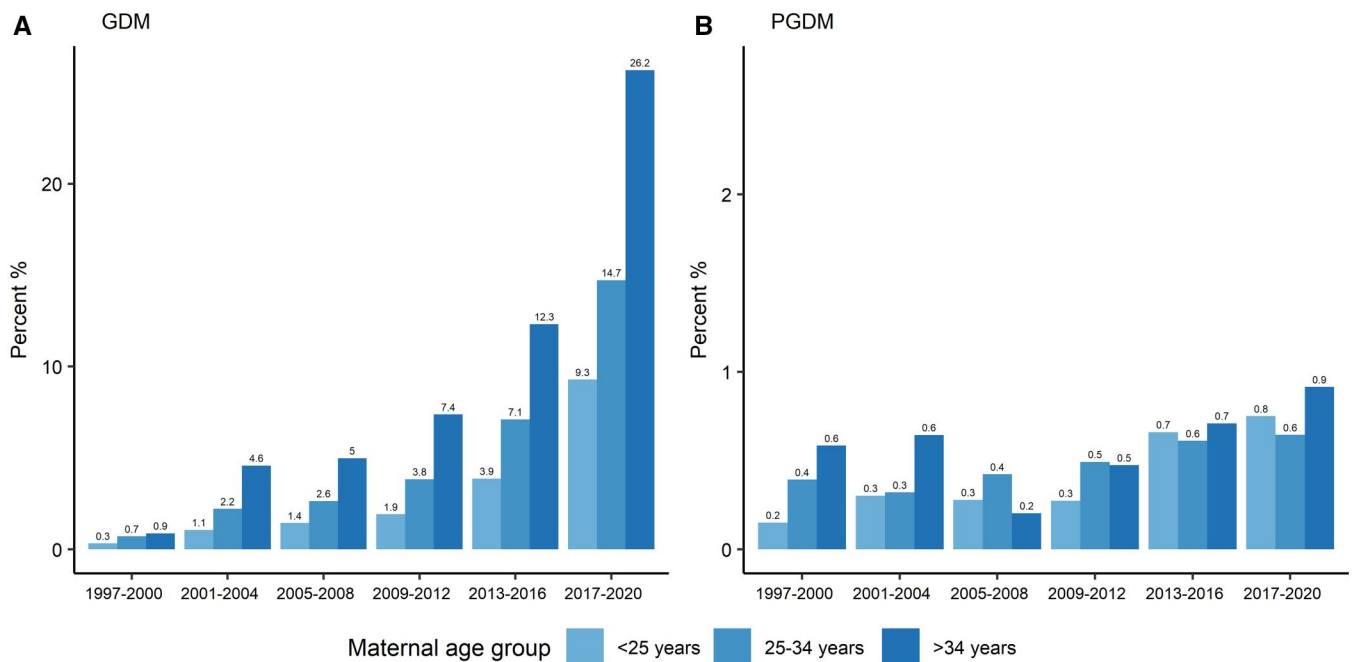


Figure 2. Proportional distribution of gestational diabetes (GDM) and pregestational diabetes (PGDM) among maternal age groups in Iceland during 1997–2020.

Table 2. Relative risk of gestational diabetes by time period of birth, in Iceland during 1997–2020

| Predictors | Crude | | | Adjusted model 1 ^a | | | Adjusted model 2 ^b | | |
|--------------|-------------------|-------------|---------|-------------------------------|-------------|---------|-------------------------------|-------------|---------|
| | Prevalence ratios | CI 95% | P value | Prevalence ratios | CI 95% | P value | Prevalence ratios | CI 95% | P value |
| Intercept | 0.01 | 0.01 – 0.01 | <.001 | 0.00 | 0.00 – 0.00 | <.001 | 0.00 | 0.00 – 0.00 | <.001 |
| 2001–2004 | 3.72 | 2.99–4.63 | <.001 | 3.57 | 2.87–4.45 | <.001 | 3.55 | 2.86–4.42 | <.001 |
| 2005–2008 | 4.44 | 3.58–5.49 | <.001 | 4.16 | 3.36–5.15 | <.001 | 4.07 | 3.29–5.04 | <.001 |
| 2009–2012 | 6.59 | 5.36–8.10 | <.001 | 5.99 | 4.87–7.37 | <.001 | 5.53 | 4.49–6.82 | <.001 |
| 2013–2016 | 12.10 | 9.89–14.80 | <.001 | 10.72 | 8.76–13.13 | <.001 | 6.68 | 5.37–8.31 | <.001 |
| 2017–2020 | 26.03 | 21.36–31.71 | <.001 | 23.45 | 19.22–28.61 | <.001 | 14.21 | 11.45–17.64 | <.001 |
| Observations | | 101 093 | | | 101 093 | | | 101 093 | |

a: Adjusted for maternal age, parity, nationality, and region.

b: Adjusted for maternal age, parity, nationality, region, and BMI category (missing prior to 2012).

that the global prevalence of PGDM appears to have doubled between 1990 and 2020 and has a varied regional prevalence of 0.5% to 2.4% [25]. Our study found similar trends where reported cases of T2DM diabetes increased from 0 to 36 between the first and last time periods, with an overall increase in PGDM prevalence from 0.4% to 0.7%.

Strengths of the study

A major strength of our study is the use of national registry data which include complete, nationwide coverage of all births in Iceland. The data are highly reliable due to its prospective collection with limited missingness. We were able to provide prevalence rates for GDM and PGDM over a long time period, examine the changes to trends in GDM prevalence before and after guideline changes in 2012, as well as provide age-stratified estimates of relative risk for GDM over time.

Limitations of the data

We acknowledge the limitation of lack of validation in the use of ICD-10 codes within the registry data. Nordic countries, such as Denmark, Norway, and Finland, have undergone validation studies of their medical birth registers with varying results [26]. Denmark showed high validity for diagnostic, surgical, and procedural codes, Finland showed more reliable data collection using check-box variables compared to the use of codes, and only a few selected variables were examined Norway [26]. Although extensive validation investigations have yet to be conducted for the birth register in Iceland, one study examining the validity of recorded chronic diseases in other Icelandic healthcare registries had very positive results for accuracy and validity [27]. Our study was also limited by low completeness of BMI data within the birth register, which was not collected until 2012, and there is a lack of other lifestyle and socioeconomic indicators within the registry which could contribute to possible residual confounding in our analysis. Despite this limitation, we were able to provide an estimate of the effect of BMI in time periods where this information was made available and provide evidence to support the inclusion of this important covariate in our regression modeling. Our PR estimates were lower following adjustment for BMI, indicating that BMI has contributed to the increase in the prevalence of GDM.

Conclusion

While PRs indicated that women aged >34 years had a higher risk of GDM throughout the time periods, the higher relative rate difference after 2012 among women aged <25 years could suggest a changing pattern where GDM is becoming more prevalent in this age group. These findings emphasize the need for targeted strategies for public health interventions, especially for women aged <25 years to address and manage the increase in GDM cases among this age

group in a relatively short period of time, and for women aged >34 years who continue to have higher risk for GDM and in the greatest proportions. Our GDM PR estimates were sharply decreased after adjusting for BMI, especially in the maternal age group < 25 years. A primary prevention strategy for overweight and obesity aimed at younger women could potentially benefit the youngest age group, with lasting effects as these women get older. Further investigation into other specific factors influencing GDM in each age group may provide additional insights to help guide targeted public health strategies.

Supplementary data

Supplementary data are available at *EURPUB* online.

Conflict of interest

None declared.

Funding

The study was funded by the Icelandic Centre for Research.

Data availability

Research data are not shared.

Key Points

- Markedly increasing trends in prevalence for GDM occurred in Iceland after changes in 2012 to the guidelines for the diagnosis and treatment of diabetes in pregnancy.
- In Iceland, women aged >34 years have higher risk for GDM and in the greatest proportions, while women aged <25 years appear to have a higher relative GDM rate difference after 2012.
- Targeted primary prevention strategies for overweight and obesity aimed at younger women could potentially reduce the impact of gestational diabetes among the youngest age group with lasting effects as these women age over the long term.

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