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Projections of the prevalence of hyperglycaemia in pregnancy in 2019 and beyond: Results from the International Diabetes Federation Diabetes Atlas, 9th edition

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ABSTRACT

Aim: Hyperglycaemia in pregnancy (HIP) is one of the most common complications of pregnancy. This study aims to examine the projected HIP prevalence in 2030 and 2045 using multiple methods.

Methods: The International Diabetes Federation Diabetes Atlas 2019 prevalence was projected to 2030 and 2045 by: (1) carrying forward the 2019 age-adjusted prevalence rates; (2) applying a linear regression of the past four editions of the IDF Diabetes Atlas; (3) applying a regression of the previous editions with the most consistent trend, followed by extrapolation from the 9th edition HIP estimate.

Results: Respectively, for 2030 and 2045, Method 1 projected a declining HIP rate with prevalences of 14.0% and 13.3%, Method 2 projected an increasing HIP prevalence at 16.5% and 18.3%, Method 3 predicted stabilisation of the rate from 16.0% to 15.8%.

Conclusion: Assuming other factors remain unchanged, our best estimation of age-adjusted HIP will show stabilisation between 2019 and 2045 of 15.8% to 16.0%. However, this estimate is confounded by the heterogeneity of studies and the influence of different gestational diabetes mellitus diagnostic criteria. To provide accurate future comparisons we recommend standardising the diagnostic criteria to the International Association of Diabetes in Pregnancy Study Groups.

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1. Introduction

Hyperglycaemia in pregnancy (HIP) is described as the most common metabolic abnormality in pregnancy but the burden globally and the extent of a rise over time is confounded by a variety of factors including increasing population, maternal age and obesity [1–3]. In 2014, the World Health Organization (WHO) has defined HIP as *diabetes first detected at any time during pregnancy, along with pre-existing diabetes*, and are further sub-classified as diabetes in pregnancy (DIP) and gestational diabetes mellitus (GDM) [4]. Prior to this it had been defined as "any degree of glucose intolerance with onset or first recognition during pregnancy" [5].

There is a documented global rise in the prevalence of type 2 diabetes (T2D) [6–9]. We would similarly expect that prevalence of HIP would be steadily increasing, which has been reported in the past [1,10]. However, recent factors such as access to universal gestational diabetes screening and changes in diagnostic criteria have confounded these estimates and caused a substantial change in the reported prevalence rates. [11–13].

While the diagnosis of DIP is often clear cut, there has been controversy around the diagnosis of GDM without universal consensus as to the diagnostic method to best diagnose GDM. The International Association of Diabetes and Pregnancy Study Group (IADPSG) proposed a standardised strategy for the detection and diagnosis of GDM during the first antenatal visit with a fasting glucose level <5.1 mmol/L then following up with 75-g oral glucose tolerance test (OGTT) at 24 to 28 weeks' gestation with diagnostic criteria as detailed in Fig. 1. Many countries have adopted the IADPSG's interpretation of the guidelines drawn from the Hyperglycaemia and Adverse Pregnancy Outcomes (HAPO) study, and has been ratified by the World Health Organization [4] along with many other national groups [14–16]. However, there are national groups slow to adopt an alternative diagnosis of GDM due to resource, socio-economic, cultural and logistic constraints [17,18], such as Canadian Diabetes Association (CDA) [19], Diabetes in Pregnancy Study Group of India (DIPSI) [20], Finnish Medical Society Duodecin [21], New Zealand Ministry of Health [22] and National Institute for Health Care and Excellence (NICE) [23]. DIPSI recommends the pragmatic use of a non-fasting OGTT while other national groups recommend a higher fasting, and differing 2-hour glucose level thresholds. Table 1 lists the HIP diagnostic criteria currently used in the published literature to date. These differences are likely to have a significant impact on the estimation of GDM prevalence.

The International Diabetes Federation (IDF) Diabetes estimates the prevalence of diabetes worldwide and across seven Regions – Africa (AFR), Europe (EUR), Middle East and North Africa (MENA), North America and Caribbean (NAC), South and Central America (SACA), South-East Asia (SEA), Western Pacific (WP). Within the past three editions of the IDF Diabetes Atlas, the estimates of prevalence of HIP have also been published, showing the rates have been steadily increasing [8,9,24].

The 8th edition of the IDF Diabetes Atlas released in 2017 estimated that the prevalence of DIP to be 2.2% and GDM 14.0% with total prevalence of HIP at 16.2% [8]. The 9th edition released in 2019 showed a slight reduction in the overall HIP prevalence to 15.8%, with GDM at 12.8% and DIP at 2.6%, made up of hyperglycaemia first detected in pregnancy of and pre-existing diabetes both respectively at 1.3% [7]. This increase from the 8th edition may be due to a change in the study criteria scoring since the introduction of the IADPSG and may not reflect an actual increase in HIP prevalence.

The IDF Diabetes Atlas has projected the prevalence of type 2 diabetes (T2D) in previous editions [6,25,26]. What has yet to be published in previous editions is a projection of HIP. In the current edition of the IDF Diabetes Atlas, we calculated a projection of HIP prevalence to the years 2030 and 2045. Taking these factors into consideration, the aim of this article is to estimate the prevalence of HIP in 2019 and project its prevalence to 2030 and 2045.

2. Methods

The methods used for the collection of HIP prevalence have been previously described in Linnenkamp et al. [27]. In brief, studies were identified by a literature search using PubMed, Google Scholar and relevant citations from within papers. The search was conducted looking for studies between January 1990 to December 2018 using search terms: "gestational diabetes mellitus", "GDM", "prevalence", "incidence" and "screening" and < country name > or < region/continent > .

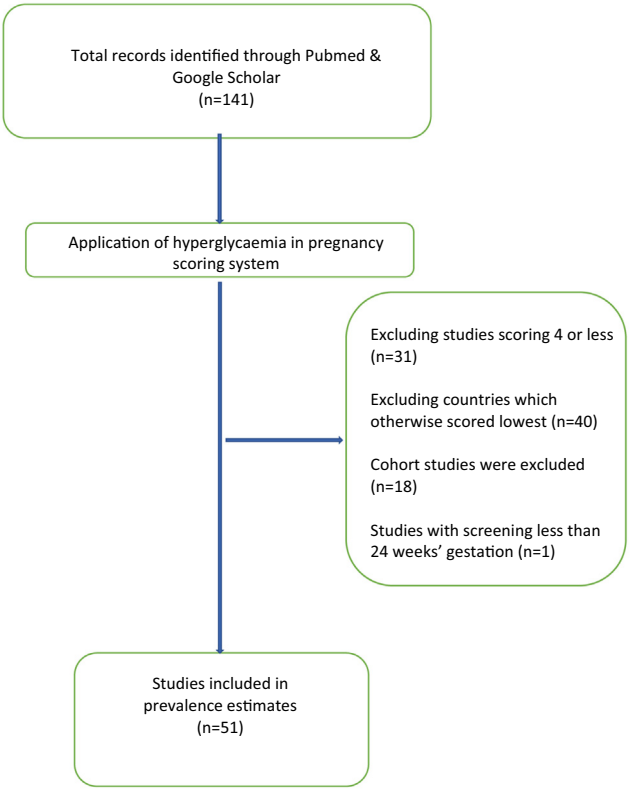

Fig. 1 – Flow diagram of studies selected for inclusion in determining hyperglycaemia in pregnancy prevalence estimates.

Table 1 – Diagnostic and screening methods currently in use for estimating gestational diabetes and hyperglycaemia first detected in pregnancy. Gestational Diabetes Mellitus. The table lists below the most commonly used screening methods for estimating gestational diabetes around the world in publications to date, based on universal screening using a fasting 75-gram oral glucose tolerance test (OGTT) with serum glucose levels measured at 0, 1, and 2 h. A 3 h 100-gram OGTT is also described but uncommonly used.

Criteria	Year & Reference	Fasting		1-hour		2-hour		3-hour		Notes
		mg/dL	mmol/L	mg/dL	mmol/L	mg/dL	mmol/L	mg/dL	mmol/L	
American Diabetes Association (ADA)/ American College of Obstetricians and Gynaecologists (ACOG)	2003, 2018 [15,42]	95	5.3	180*	10.0*	155	8.6	140	7.8	Recommends either the IADPSG one step or two-step approach; initial screening by measuring plasma or serum glucose concentration after 1-h 50-g oral glucose load (GCT). Those exceeding the cut-off perform either a 100 g OGTT or 75 g OGTT, requiring two or more venous plasma concentrations to be met or exceed the threshold.
Australian Diabetes in Pregnancy Society (ADIPS)	2014 [14]	92	5.1	180*	10.0*	153	8.5			
Diabetes Canada Clinical Practice Guidelines	2018 [19]	95	5.3		10.6		9.0			Listed is the preferred approach, the alternate approach is the IADPSG
Diabetes in Pregnancy Study Group of India (DIPSI)	2014 [20]					140	7.8			Uses a non-fasting 75 g OGTT
European Association for the Study of Diabetes (EASD)	1991 [43]	110*/126	6.1*/7.0			162*/180	9.0*/10.0			
International Federation of Gynaecology and Obstetrics (FIGO)	2015 [16]	92	5.1	180*	10.0*	153	8.5			
International Association of Diabetes and Pregnancy Society Groups (IADPSG)	**2010** [44]	**92**	**5.1**	**180***	**10.0***	**153**	**8.5**			Recommends exclusion of GDM with a fasting plasma glucose level of less than 5.1 mmol/L during the first prenatal visit on all or high risk women.
National Institute for Health and Care Excellence (NICE)	2015 [23]		5.6				7.8			
World Health Organization (WHO)	1999 [45]	110^/126	6.1^/7.0			120^/140	6.7^/7.8			
World Health Organization (WHO)	2013 [4]	92	5.1	180*	10.0*	153	8.5			

Diabetes in Pregnancy

Diabetes in pregnancy should be diagnosed by the 2006 WHO criteria for diabetes if one or more of the following criteria are met:

- fasting plasma glucose $\geq$ 7.0 mmol/L (126 mg/dL).
- 2-hour plasma glucose $\geq$ 11.1 mmol/L (200 mg/dL) following a 75 g oral glucose load.
- random plasma glucose $\geq$ 11.1 mmol/L (200 mg/ dL) in the presence of diabetes symptoms [4].

OR

- Haemoglobin A1c (HbA1c) level $\geq$ 6.5% (48 mmol/mol)# [15].

#The A1C test should be performed using a method that is certified by the NGSP and standardized to the Diabetes Control and Complications Trial (DCCT) assay.

* There are no established criteria for the diagnosis of diabetes mellitus in pregnancy based on the 1-h post-load value

^ Refers to whole blood glucose level.

Overall, studies were excluded if they were cohort studies, used populations screened at less than 24 weeks' gestation, or if the prevalence results were not categorised into three or more age ranges [27]. To increase availability of data, authors from studies which would have qualified except for the inclusion of three age-ranges were individually emailed to ascertain whether this information could be made available.

Studies that were selected underwent logistic regression to calculate an age-specific prevalence and were adjusted for diagnostic criteria if the IADPSG was not use as described in *Linnenkamp* [27].

There has been a revision to the scoring system used to grade the papers since 2013 [27], refer to Table 2 for detail. The domain of diagnostic criteria was now valued up to 2 points, and 2 points was weighted towards the WHO/IADPSG criteria for universal screening, which reflects the IDF model of care for GDM [28]. A domain for screening approach was added, with universal screening scoring 2 points, selective and/or 2-step scoring 1 point each. Further, the cut-off point was raised from 3 to 4 marks to account for these additions.

Three methods were used to project HIP: Method 1 carried forward the age-adjusted 2019 estimate, which is in line with the methods used to predict the prevalence of other diabetes sub-groups throughout the Atlas [25,26], this was consistent with the method used in other IDF Diabetes Atlas projections [6,25]. Method 2 involved performing a linear regression based on calculated age-adjusted prevalence for editions six to nine, spanning the years 2013, 2015, 2017 and 2019. This method was devised to determine whether linear regression would provide a suitable projection. However, we expected there could be large distortions in the data due to the change in our scoring method and the known increase in prevalence when using the IADPSG diagnostic criteria compared with older criteria [29–32]. Method 3 involved linear regression of only the previous IDF Diabetes Atlas HIP edition estimates that showed a consistent trend, followed by extrapolation from the age-adjusted 2019 HIP estimate. This method was devised to account for the distortions inherent in the change in scoring system between the most recent 9th edition and the prior editions' prevalence estimates, but also aimed to take factor in the projected general growth in diabetes prevalence and population.

For all three methods, the projected prevalence was then multiplied to the birth estimate for the corresponding years. This was obtained from the United Nations (UN) population estimates for women age 20–49 years multiplied by the UN fertility rate per woman for the corresponding years [33].

Countries without HIP prevalence data in 2019 were matched to the 'data region' which is a combination of IDF Region, World Bank country income group and matched by ethnicity, or the most relevant data region with available data [27]. Projected HIP cases are unadjusted for pre-existing (known or unknown) Type 1, Type 2, monogenic forms of diabetes or diabetes from other causes.

3. Results

Overall, 141 prevalence studies were identified, of which 51 fulfilled the criteria for inclusion in the analysis, representing 41 countries. Fig. 1 is a flow chart of the study selection. There were 170 countries without studies represented in the analysis. Table 3 lists the studies selected for inclusion in the calculation of the HIP for the 9th edition.

We used three methods to project regional estimates in HIP. The 9th edition of the IDF Diabetes Atlas reports on Method 1, which shows a decline from the 2019 prevalence from 15.8% to 14.0% in 2030 and 13.3% in 2045. In Method 2, we projected HIP prevalence to rise steadily to 16.5% in 2030 and again to 18.3% in 2045. In Method 3, there was an initial increase in the HIP prevalence to 16.1% in 2030 which then reverts to 15.8% in 2045. Refer to Tables 4–6 for detailed projections of regional HIP as well as an overall prevalence. Figs. 2–4 shows the change in HIP prevalence between 2030 and 2045 by Method and Region.

4. Discussion

Overall the HIP prevalence is expected to decline in Method 1, increase in Method 2, and stabilise in Method 3. The projected HIP prevalence is rising between 2019 and 2030 and 2045 for the Regions of AFR and SEA, but there are reciprocal declines in prevalence in the EUR, MENA, and WP Regions (WP includes China, the country with the largest number of HIP). The projected HIP prevalence are a reflection of variation in the regional growth in population and a decline in birth rates for AFR and SEA and WP Regions, with a mild increase in Europe but stabilising in the other Regions [33]. Depending on the degree with which this is expected to influence HIP prevalence, these factors combine to either decrease, increase or stabilise the HIP prevalence.

Recent large systematic reviews in the AFR, SEA and WP Regions have published prevalence data with mixed results. For example Gao et al. published the first systematic review GDM prevalence in China, estimated to be 14.8% [34]. While Nguyen et al. published an extensive systematic review of 48 studies from SEA and WP Region countries of China, Japan, Korea, Malaysia, Singapore, Taiwan, Thailand and Vietnam which reported a rate of 10.1% [35]. Interestingly, Li et al. found a large variation of Indian GDM estimates (0.0–41.9%) depending on the diagnostic criteria use. They conducted a *meta*-analysis of 64 studies reporting 90 prevalence estimates in India, and found using the IADPSG criteria resulted in significantly higher prevalence of 19.2% compared with WHO 1999 of 10.13% or DIPSI of 7.4% [36]. Similarly, Macaulay's systematic review published in 2014 of 6 countries in Africa estimated that the prevalence varied between 0% for Tanzania to 13.9% in Nigeria [18].

Regionally, the prevalence of HIP is highest in the SEA Region and lowest in the AFR Region in 2019, however this is expected to change with Africa's population rate rapidly rising. Nigeria, Africa's most populace country, has a higher than regional average HIP prevalence (18.0%) in 2019 and this has increased the overall prevalence for AFR Region in 2030 and 2045. For MENA, there is heterogeneity of data, with Pakistan's 2019 HIP age-adjusted prevalence estimated at 4.1% (and crude prevalence at 8.7%), compared with age-adjusted prevalence of 37.5% (crude 41.0%) in the United Arab Emirates. The projections in the MENA Region are skewed

Table 2 – Updated scoring system for hyperglycaemia in pregnancy studies for the 9th Edition of IDF Diabetes Atlas (* denotes updated criteria).

Domain	Value	Rationale for the update
*Threshold of Diagnostic Criteria**		This has been thoroughly updated to reflect the wide range of diagnostic criteria used. In 2014 there were only two items – "record based/self-reported" or "criteria based". We have added in multiple items to this domain to reflect the breadth of criteria considered. The IADPSG is the IDF model of care for GDM [28], hence studies using this approach were scored higher than other diagnostic criteria.
IADPSG*	2	
WHO	1	
EASD	1	
ADIPS	1	
ADA	1	
NDDG	1	
CDA	1	
DPSG	1	
ICD-categorization	0	
Self-reported	0	
DIPSI	0*	
Other e.g. Scandinavian	0	
Not recorded	0	
*Screening approach**	*Score*	The domain for screening approach was added to preference studies which used a universal screening approach, in line with the IADPSG recommendations. Accordingly, studies with a selective or 2-step or more approach (e.g. risk factors, use of glucose challenge test prior to the oral glucose tolerance test) were scored lower.
Universal one step	2	
Selective	1	
2 + steps	1	
Selective 2 + steps	0	
Study year	*Score*	
Later than 2006	2	
Between 2000 and 2005	1	
Before 2000	0	
No study year mentioned	0	
Study design	*Score*	
Population based	1	
Modelling	0	
Not mentioned	0	
Sample representation	*Score*	
National	3	
Regional	2	
Multi-city	2	
Community	1	
Single/tertiary level hospital	0	
Not mentioned	0	

Studies were excluded if they were cohort studies, or had data sources with the objective focused on women being screened at less than 24 weeks' gestation. Only studies scoring greater than 4 were selected.

towards Pakistan, where it has lower than regional average prevalence and is the most populous country in the Region, resulting in decline in prevalence between 2019 and 2030. China has a steadily declining birth rate and lower than regional average HIP prevalence of 8.3% (crude 8.6%) which has resulted in a sharp decline in 2030 and 2045 projections in the WP Region (Tables 2–4).

Looking at our projections, we had varying results across all three methods. For Method 1, we found a steady decline in the HIP prevalence in the SACA and WP Regions, likely reflecting a sharp decline in the fertility rates of the Regions [33]. There is also a trend of a gradual decline in the population levels of women aged 20–49 years for most Regions except the AFR. AFR has the lowest and a below average HIP prevalence in 2019 of 10.8%, but is projected to increase steadily in line with the rise in population levels.

In Method 2, there was a linear increase in HIP prevalence, however the change in scoring criteria resulted in a much higher HIP prevalence in the NACB Region in the 9th compared to the 8th edition. There were adjustments in the studies included from the 8th to the 9th editions, due to the new scoring criteria applied for study inclusion, which distorted the HIP prevalence, predominantly in the MENA and NAC Regions. This resulted in a higher than expected prevalence for NACB from 23.4% in 2019 to 40.0% in 2030 and 68.4% in 2045. There was also a sharp decline in MENA HIP prevalence from 11.3% in 2019 to 2.39% in 2045.

Overall we felt the best projection is that of Method 3, which predicts stabilising of the rate around 16.0%. There is initially a mild increase of the prevalence of HIP from 15.8% in 2019 to 16.0% in 2030, but then stabilises to 15.8% in 2045. This method aims to eliminate the distortions created by

Table 3 – Data sources for estimates of hyperglycaemia in pregnancy for the 51 countries which met selection criteria for inclusion.

IDF Region & Country	Year	Sample Size	Study Design	Sampling Frame	Diagnostic Criteria
Africa					
Cameroon [46]	2011	235	Population-based	Single hospital	ADA 2003
Kenya [47]	2013	886	Modelling	Local	IADPSG
Nigeria [48]	2009	1460	Population-based	Single hospital	WHO 1999
Rwanda [49]	2015	288	Population-based	Local	WHO 1999
South Africa [50]	2017	1906	Population-based	Single hospital	WHO 1999
United Republic of Tanzania [51]	2011	910	Population-based	National	WHO 1999
Europe					
Belgium [52]	2010	6727	Population-based	Single hospital	IADPSG
Croatia [53]	2011	40,641	Population-based	National	IADPSG
France [54]	2012	796,346	Population-based	National	WHO 1999
Hungary [55]	2000	1835	Population-based	Regional	WHO 1999
Ireland [32]	2009	5500	Population-based	Multi-city	IADPSG
Israel [56]	2010	1818	Population-based	Local	IADPSG
Israel [56]	2010	1631	Population-based	Single hospital	IADPSG
Netherlands [57]	2009	471	Population-based	Single hospital	WHO 1999
Norway [58]	2010	759	Population-based	Local	IADPSG
Poland [59]	2006	2130	Population-based	Single hospital	WHO 1999
Slovakia [60]	2013	1,353,608	Population-based	National	ICD-categorisation
Spain [61]	2010	1454	Population-based	Single hospital	IADPSG
Spain [30]	2011	1750	Population-based	Single hospital	IADPSG
Sweden [62]	2010	16,907	Population-based	Regional	EASD
Turkey [63]	2013	1434	Population-based	National	IADPSG
United Kingdom [56]	2010	2376	Population-based	Local	IADPSG
United Kingdom [56]	2010	1671	Population-based	Local	IADPSG
Middle East and North Africa					
Islamic Republic of Iran [64]	2015	1010	Population-based	Local	IADPSG
Pakistan [65]	2014	1210	Population-based	Local	IADPSG
Qatar [66]	2016	2000	Population-based	Single hospital	IADPSG
United Arab Emirates [67]	2008	10,283	Population-based	Local	IADPSG
North America and Caribbean					
Barbados [56]	2010	2093	Population-based	Single hospital	IADPSG
Canada [56]	2010	2028	Population-based	Single hospital	IADPSG
United States of America [56]	2010	797	Population-based	Single hospital	IADPSG
United States of America [56]	2010	757	Population-based	Single hospital	IADPSG
United States of America [56]	2010	753	Population-based	Single hospital	IADPSG
United States of America [56]	2010	1981	Population-based	Single hospital	IADPSG
South and Central America					
Argentina [68]	2008	1702	Population-based	Local	WHO 1999
Brazil [69]	1995	4998	Population-based	Multi-city	WHO 1999
Cuba [70]	2008	1003	Population-based	Regional	WHO 1999
South-East Asia					
Bangladesh [71]	2002	147	Population-based	Regional	WHO 1999
Bangladesh [72]	2012	3480	Population-based	Local	WHO 1999
Bangladesh [72]	2013	3480	Population-based	Local	ADA 2003
India [73]	2006	12,056	Population-based	Regional	WHO 1999
Sri Lanka [74]	2010	419	Population-based	Regional	IADPSG
Western Pacific					
Australia [56]	2010	1444	Population-based	Single hospital	IADPSG
China [75]	2015	1555	Population-based	Regional	IADPSG
China [76]	2016	64,931	Population-based	Regional	IADPSG
Hong Kong China [56]	2010	1654	Population-based	Single hospital	IADPSG
Japan [78]	2001	3003	Population-based	Local	ADA 2003
Malaysia [79]	2008	616	Population-based	Single hospital	IADPSG
Singapore [56]	2010	1786	Population-based	Single hospital	IADPSG
Thailand [56]	2010	2499	Population-based	Single hospital	IADPSG
Vietnam [77]	2010	2772	Population-based	Local	IADPSG

Table 4 – Method 1 – projection of HIP prevalence in women aged 20–49 years for 2030 and 2045 by IDF region by carrying forward the 2019 estimates.

REGION	TOTAL BIRTHS 2030	TOTAL PROJECTED HIP 2030	CALCULATED AGE-ADJUSTED PREVALENCE 2030 %	TOTAL BIRTHS 2045	TOTAL PROJECTED HIP 2045	CALCULATED AGE-ADJUSTED PREVALENCE 2045 %
AFRICA (AFR)	39,341,842	4,049,767	10.29%	47,723,278	4,892,668	10.39%
EUROPE (EUR)	9,438,885	1,181,371	12.52%	9,855,635	975,228	9.90%
MIDDLE EAST AND NORTH AFRICA (MENA)	16,245,212	1,005,127	6.19%	17,272,493	1,067,500	6.18%
NORTH AMERICA AND CARRIBEAN BARBADOS (NACB)	6,831,860	1,464,441	21.44%	6,713,811	1,435,807	21.39%
SOUTH AND CENTRAL AMERICA (SACA)	6,439,990	673,681	10.46%	6,063,395	634,393	10.46%
SOUTH-EAST ASIA (SEA)	26,547,383	7,284,296	27.44%	23,321,899	6,399,408	27.44%
WESTERN PACIFIC (WP)	25,752,070	2,624,657	10.19%	24,798,582	2,524,615	10.18%
OVERALL PREVALENCE	**130,597,242**	**18.283,340**	**14.00%** [95% Confidence Interval (CI): 13.998, 14.000]	**135,750,094**	**17,993,464**	**13.25%** [95% CI: 13.254,13.256]

Table 5 – Method 2 – regression of IDF HIP prevalence estimates between 2013 and 2019 to provide projection of HIP prevalence for women aged 20–49 years for 2030 and 2045.

REGION	TOTAL BIRTHS 2030	TOTAL PROJECTED HIP 2030	CALCULATED PREVALENCE 2030 %	TOTAL BIRTHS 2045	TOTAL PROJECTED HIP 2045	CALCULATED PREVALENCE 2045 %
AFRICA (AFR)	39,341,842	4,687,034	11.91%	47,723,278	6,850,857	14.36
EUROPE (EUR)	9,438,885	1,099,506	11.65%	9,855,635	1,065,470	10.81%
MIDDLE EAST AND NORTH AFRICA (MENA)	16,245,212	828,126	5.10%	17,272,493	413,674	2.39%
NORTH AMERICA AND CARRIBEAN BARBADOS (NACB)	6,831,860	2,738,022	40.08%	6,713,811	4,590,911	68.38%
SOUTH AND CENTRAL AMERICA (SACA)	6,439,990	817,896	12.70%	6,063,395	828,726	13.67%
SOUTH-EAST ASIA (SEA)	26,547,383	8,281,395	31.19%	23,321,899	7,559,312	32.41%
WESTERN PACIFIC (WP)	25,752,070	3,107,923	12.07%	24,798,582	3,490,114	14.07%
OVERALL PREVALENCE	**130,597,242**	**21,559,903**	**16.51%** [95% CI: 16.507, 16.511]	**135,750,094**	**24,799,064**	**18.27%** [95% CI: 18.266, 18.271]

Table 6 – Method 3 – regression of previous IDF HIP prevalence estimates with a consistent trend and extrapolated from 2019 to provide HIP projection in women aged 20-49 years between 2030 and 2045.

REGION	TOTAL BIRTHS 2030	TOTAL PROJECTED HIP 2030	CALCULATED PREVALENCE 2030 %	TOTAL BIRTHS 2045	TOTAL PROJECTED HIP 2045	CALCULATED PREVALENCE 2045 %
AFRICA (AFR)	39,341,842	4,924,707	12.52%	47,723,278	6,781,245	14.21%
EUROPE (EUR)	9,438,885	1,321,060	14.00%	9,855,635	1,373,888	13.94%
MIDDLE EAST AND NORTH AFRICA (MENA)	16,245,212	1,112,534	6.85%	17,272,493	1,106,440	6.41%
NORTH AMERICA AND CARRIBEAN BARBADOS (NACB)	6,831,860	1,704,227	24.95%	6,713,811	1,945,734	28.98%
SOUTH AND CENTRAL AMERICA (SACA)	6,439,990	769,055	11.94%	6,063,395	712,596	11.75%
SOUTH-EAST ASIA (SEA)	26,547,383	8,288,856	31.22%	23,321,899	6,864,159	29.43%
WESTERN PACIFIC (WP)	25,752,070	2,788,697	10.83%	24,798,582	2,696,788	10.87%
OVERALL PREVALENCE	**130,597,242**	**21,050,497**	**16.01%** [95% CI: 16.01, 16.012]	**135,750,094**	**21,650,077**	**15.82%** [95% CI: 15.822, 15.825]

the change in scoring criteria and factors in the aforementioned population and fertility changes. Although there is a general trend of increasing diabetes prevalence projected by Cho et al. [6], this method has predicted a stabilising HIP trend. This may be related to a stabilisation of the factors of average maternal body mass index, particularly in Western Countries [37–39]. However, this is partially offset by the expected rise in HIP prevalence of AFR Regions.

There were limitations in our approach. The first limitation is the number of small studies overall that qualified for inclusion, and the absence of high quality HIP studies in some of the low to middle income Regions, even though globally around 79% of people living with diabetes live in these Regions [6]. While we found increasing numbers of high quality population-based studies reporting on the prevalence of HIP, the scoring criteria for study inclusion into the IDF Diabetes Atlas meant some of these studies were excluded from age-specific HIP estimation due to not reporting three age groups. Although effort was made to contact the authors for this information, many studies did not or were not able to provide this data. This has inevitably meant a loss of these studies into the estimation of HIP, and makes it unclear whether there is inherent bias in the data used, or whether we are over or understating the estimate, further research in this area is needed. We would encourage future HIP prevalence studies, where possible, to report on age-stratified data.

There appears to be few high-quality HIP prevalence studies from low-income countries (LIC) in AFR, MENA and SACA, and middle-income countries (MIC) in AFR, MENA, EUR, NACB, SACA, and SEA. This has led to an approximation of the estimates from aggregation of data from nearby Regions of similar, but are often higher-income countries. This method can skew the estimates, as within a Region, there can be great variation in prevalence. For instance, in 2019, the AFR-LIC prevalence was estimated at 7.4%, but almost doubled to 14.5% for the AFR-MIC Region; high income countries (HIC) in MENA had an average prevalence of 33.5% in 2019, but this declined sharply to 4.8% for the MIC. There were no LIC studies that qualified in the MENA, SACA, SEA and WP Regions. In time, as more high quality data become available, we hope to attain more specific HIP estimates within each Region.

Furthermore, clear data on the prevalence of pre-existing DIP versus GDM are not always available. In the calculation of age-adjusted HIP, we predicted DIP from the age- and sex-specific diabetes prevalence rates for women aged 20–49 from the IDF Diabetes Atlas 9th edition [6,7]. Many studies used in our GDM calculation reported solely on GDM prevalence rates, without estimation of undiagnosed DIP, there could be a component of undiagnosed pre-existing DIP which is under-represented by our data. We know from our IDF diabetes atlas estimates that AFR has the highest rates of undiagnosed diabetes at 69.2%, but SEA and WP Regions also have over 50% of diabetes undiagnosed [6].

As discussed in *Linnenkamp*, there are limited data on the fertility rates of women affected by HIP, and we have assumed these are in line with the country's fertility rates [27].

In addition, the reporting of HIP in the age range of 15–19 years was not accounted for, and looking at the UN's fertility rates, there is a significant portion of women from the less

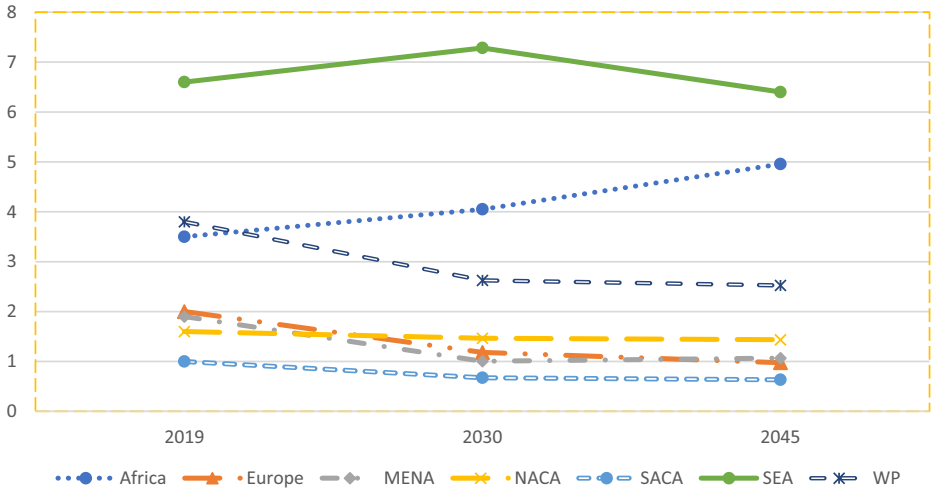

Fig. 2 – Method 1 – Hyperglycaemia in pregnancy prevalence by region between 2019 and 2045 (millions).

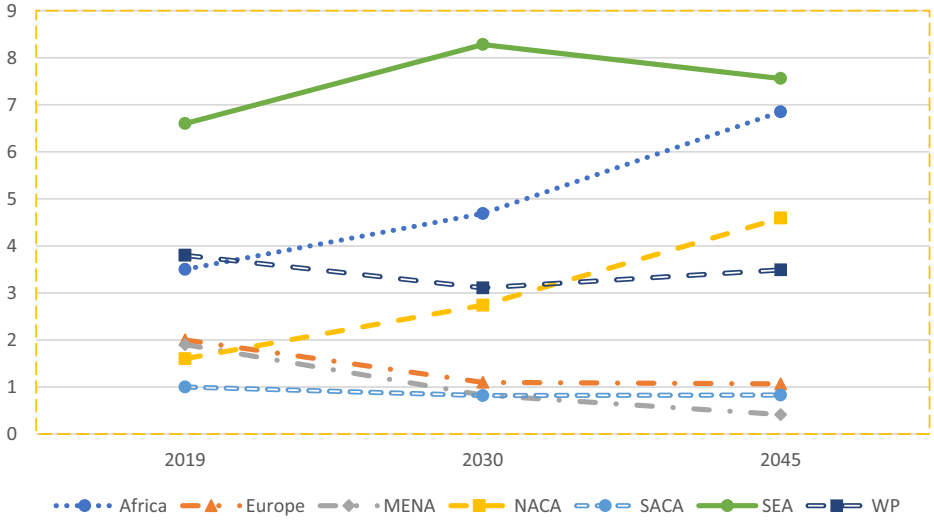

Fig. 3 – Method 2 – Hyperglycaemia in pregnancy prevalence by region between 2019 and 2045 (millions).

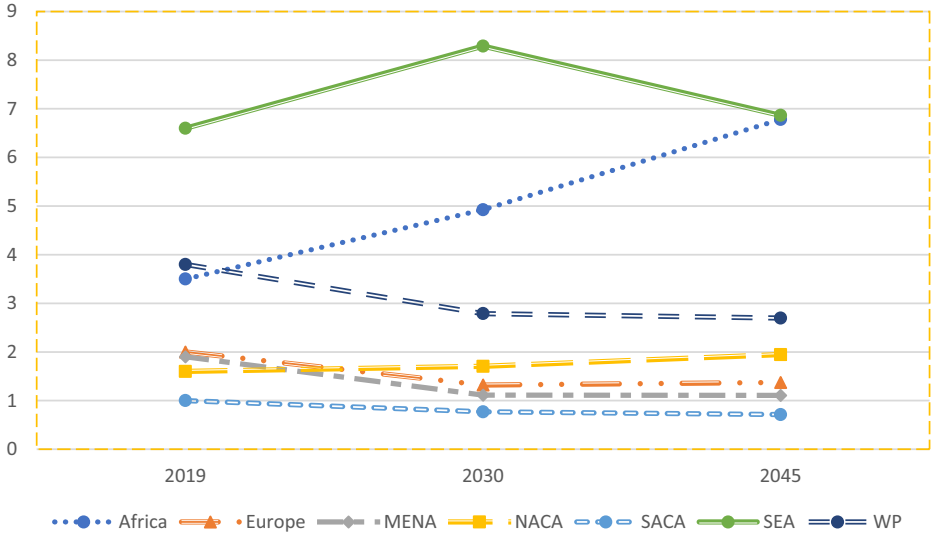

Fig. 4 – Method 3 – Hyperglycaemia in pregnancy prevalence by region between 2019 and 2045 (millions).

developed and low- to middle-income regions that give birth at this age bracket [33]. There is undoubtedly a much smaller proportion of GDM and DIP diagnosed in the 15–19 years' age bracket than in the older age ranges. What is not known is the rate of impaired glucose tolerance and fasting glucose levels in the women aged 15–19 years.

Moreover, the UN predicts that much of the population change will be a result of migration to nations like Europe, North America and Oceania [33]. The rates of net migration will be heavily influenced by political, economic and social factors within these regions. It will be interesting to see the effects these will have on the population levels and future rates of HIP.

Lastly, there is inherent uncertainty around prediction of a prevalence based on different diagnostic criteria. It is our view that standardisation of the diagnostic criteria to IADPSG as ratified by the IDF, WHO, International Federation of Gynaecology and Obstetrics, American Diabetes Association, Australian Diabetes in Pregnancy Society and many other countries and regional bodies will allow for better understanding and comparison of HIP worldwide. Describing the potential worldwide public health burden caused by HIP can inform policy to create interventions that can prevent the poor maternal and foetal outcomes caused by HIP [40,41].

5. Conclusion

Using our best estimation of HIP per the IDF Diabetes Atlas method, and assuming factors stay the same, we expect the worldwide prevalence of HIP to stabilise around 15.8% to 16.0% between 2019 and 2045. However, the results are largely confounded by the heterogeneity of data, and the use of different GDM diagnostic criteria and approaches. It would be beneficial to have a uniform criterion for GDM screening and diagnosis across all countries and Regions, similar to that which currently exists for DIP.

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Declaration of Competing Interest

The authors declare no conflict of interest.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.diabres.2019.107841.

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