Gestational Diabetes Mellitus in Europe: A Systematic Review and Meta-Analysis of Prevalence Studies

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Background: Gestational Diabetes Mellitus (GDM) is defined as the type of hyperglycemia diagnosed for the first-time during pregnancy, presenting with intermediate glucose levels between normal levels for pregnancy and glucose levels diagnostic of diabetes in the non-pregnant state. We aimed to systematically review and meta-analyze studies of prevalence of GDM in European countries at regional and sub-regional levels, according to age, trimester, body weight, and GDM diagnostic criteria.

Methods: Systematic search was conducted in five databases to retrieve studies from 2014 to 2019 reporting the prevalence of GDM in Europe. Two authors have independently screened titles and abstracts and full text according to eligibility using Covidence software. A random-effects model was used to quantify weighted GDM prevalence estimates. The National Heart, Lung, and Blood Institute criteria was used to assess the risk of bias.

Results: From the searched databases, 133 research reports were deemed eligible and included in the meta-analysis. The research reports yielded 254 GDM-prevalence studies that tested 15,572,847 pregnant women between 2014 and 2019. The 133 research reports were from 24 countries in Northern Europe (44.4%), Southern Europe (27.1%), Western Europe (24.1%), and Eastern Europe (4.5%). The overall weighted GDM prevalence in the 24 European countries was estimated at 10.9% (95% CI: 10.0–11.8, I²: 100%). The weighted GDM prevalence was highest in the Eastern Europe (31.5%, 95% CI: 19.8–44.6, I²: 98.9%), followed by in Southern Europe (12.3%, 95% CI: 10.9–13.9, I²: 99.6%), Western Europe (10.7%, 95% CI: 9.5–12.0, I²: 99.9%), and Northern Europe (8.9%, 95% CI: 7.9–10.0, I²: 100). GDM prevalence was 2.14-fold increased in pregnant women with maternal age ≥30 years (versus 15-29 years old), 1.47-fold if the diagnosis was made in the third trimester (versus second trimester), and 6.79- fold in obese and 2.29-fold in overweight women (versus normal weight).

Conclusions: In Europe, GDM is significant in pregnant women, around 11%, with the highest prevalence in pregnant women of Eastern European countries (31.5%). Findings have implications to guide vigilant public health awareness campaigns about the risk factors associated with developing GDM.

Systematic Review Registration: PROSPERO [https://www.crd.york.ac.uk/PROSPERO/], identifier CRD42020161857.

Keywords: diabetes mellitus, Europe, Gestational Diabetes Mellitus, GDM, systematic review, meta-analysis, pregnancy complications, pregnancy hyperglycemia
INTRODUCTION

Hyperglycemia in pregnancy affects about one in every six pregnancies worldwide (1). Gestational Diabetes Mellitus (GDM) is defined as the type of hyperglycemia diagnosed for the first time during pregnancy (2, 3). This has been the widely used definition of GDM for many years, but it presents limitations in terms of the non-possible verification of the preexisting hyperglycemia (4). Hyperglycemia universal routine screening is not available for women at childbearing age before conception or in the first semester, so although GDM can take place at any time during pregnancy, it is more frequently diagnosed after the 24th week of gestation (1, 4).

GDM is highly associated with obesity. Obesity is a growing major public health problem worldwide (5). In 2016, the estimated age-standardized prevalence of obesity and overweight among adult women of the European Region was 24.5% and 54.3%, respectively (6). This prevalence is expected to continue rising in the next years (7, 8). Being overweight (body mass index [BMI] 25.0-29.9 kg/m²) or obese (BMI ≥30.0 kg/m²) is the most important modifiable risk factor for GDM. The risk is up to 5-fold higher in morbidly obese women, when compared to women with normal body weight (9). Other modifiable risk factors for GDM comprise unhealthy dietary factors, physical inactivity, and cigarette smoking (10). Moreover, the gradual increase in the mean age at childbearing of women in Europe (from 28.8 years in 2013 to 29.3 years in 2018) has an important role in the prevalence of GDM, given that advanced maternal age is a well-known risk factor for GDM (11). The chances of developing GDM increment with previous history of GDM, macrosomia, excessive gestational weight gain, spontaneous abortion, fetal anomalies, preeclampsia, fetal demise, neonatal hypoglycemia, hyperbilirubinemia, and neonatal respiratory distress syndrome family history of type 2 diabetes mellitus (T2DM), polycystic ovary syndrome, parity, non-white ancestry also increment (10, 12).

GDM has potentially serious short- and long-term consequences. The condition is associated with various adverse maternal, fetal, and perinatal outcomes, including but not limited to, preeclampsia, preterm delivery, cesarean section delivery, large for gestational age (LGA) newborns, neonatal hypoglycemia, and Neonatal Intensive Care Unit admission (13). The Hyperglycemia and Adverse Pregnancy Outcomes (HAPO) study reported a continuous association between maternal glucose levels and increased frequency of adverse outcomes, however, there was no obvious threshold at which risk increased (13). Furthermore, the gestational programming and intrauterine fetal exposure to hyperglycemia is an independent risk factor for obesity, hypertension and T2DM in the offspring (14, 15). GDM may play a crucial role in increasing the prevalence of T2DM in women. In the European Region, about 9.6% of women ≥25 years old have diabetes (16). A meta-analysis reported a 7-fold increased risk of T2DM in women with GDM compared with those without GDM (17).

Comparing data on GDM is a challenge since there is a lack of universally accepted screening standards and diagnostic criteria. Diagnostic criteria have changed over time and remain controversial, but there has been a move towards the adoption of the International Association of Diabetes in Pregnancy Study Groups (IADPSG) recommendations (18–20). Using the systematic review and meta-analysis approach to understand the regional, sub-regional, and national prevalence of GDM will help the introduction of effective public health measures and enable highlighting the gaps in evidence, following the Guidelines for Accurate and Transparent Health Estimates Reporting (GATHER) (21).

The previously published meta-analysis on the GDM prevalence in Europe was limited to only developed countries in Europe excluding immigrants who did not originate from those developed countries (22). Also, the same meta-analysis was limited to only women tested for GDM in their second or third trimesters (22). To overcome these limitations and provide a more comprehensive and informative assessment on the GDM prevalence in Europe, the present systematic review included all countries in the European region according to the definition of the United Nations (UN) geoscheme and regardless of the original of the included pregnant women. In the present review, the literature search covers a wider range of countries (51 countries) in the European continent regardless of the development status, the origin of the study population, and pregnancy trimester. Moreover, our meta-analyses considered extracting, whenever possible, stratified estimates of the GDM rather than using the overall prevalence reported in the primary studies following a prioritized one-stratification scheme. Indeed, pooling stratified estimates would provide more precise findings on the national, sub-regional, and regional prevalence of GDM. As such, this systematic review and meta-analysis method quantifies the weighted prevalence of GDM in Europe, at regional, sub-regional, and national levels, between 2014 and 2019, according to and regardless of the maternal age, trimester, maternal weight, and GDM diagnostic criteria. It is believed that this study of the 51 countries of the European region regardless of their development will complement the scientific literature, providing more insights into the prevalence of GDM at the subregional level as countries within each subregion in the European continent might have not the same development status interpreted as a limitation in the previous systematic review (22).

METHODS

Protocol and Registration

We have developed and registered our protocol on PROSPERO (registration number: CRD42020161857). This systematic review
and meta-analysis follows the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement (23). The PRISMA checklist is provided elsewhere (see Supplementary Table S1).

This systematic review and meta-analysis from prevalence studies in Europe is part of a major study that aims to estimate the prevalence of GDM in different regions in the world. From the same project, the first systematic review and meta-analysis providing findings on the prevalence of GDM in the Middle East and North Africa region has been already completed and submitted for a peer-reviewed journal (24).

**Eligibility Criteria**
The search strategy was limited to English language publications between January 2006 and December 2019 and defined in accordance with our population, exposure, comparator, and outcome (PECO) criteria. The population included in this study were all pregnant women tested for GDM during their pregnancy, living in the European region according to the definition of the United Nations (UN) geoscheme (25). All included studies had at least ten pregnant women tested for GDM and reported the prevalence of GDM for their sample or have reported data that allowed us to calculate the GDM prevalence, regardless of the age, trimester, pregnancy status, or GDM ascertainment methodology. However, due to the high number of studies retrieved from databases, we restricted the inclusion criteria to only include studies published between 2014 and 2019.

All studies reporting prevalence estimates on GDM were considered eligible. For this specific systematic review and meta-analysis focusing on the European region, we have excluded studies from the other regions of the globe and studies using unclear GDM diagnostic criteria, unless studies from medical records. These decisions made by the research team were due to the high volume of eligible studies and to produce less potentially biased and more precise estimates on the GDM prevalence.

**Information Sources and Search**
A specific search strategy was developed by the principal investigators and a medical librarian expert. The initial search was developed on PubMed-MEDLINE using varied Medical Subject Headings (MeSH) and free-text terms and then translated into EMBASE, Scopus, Web of Sciences, and Cochrane Library, comprising five electronic databases (Supplementary Table S2).

**Study Selection**
We have used the Covidence software (26, 27) to perform study selection. All citations identified by our search strategy were uploaded into Covidence where duplicates were automatically removed. Two reviewers independently screened the studies for titles and abstracts and subsequently identified potential eligible full-text articles. Conflicts and discrepancies that emerged during the two stages of screening were solved by a third reviewer. The reference lists of eligible studies were also screened to identify additional studies that might have been missed.

**Data Abstraction Process and Data Items**
The data we have extracted include the study ID, article type, publication year, journal, country, city, study design, data collection period, population, sample size, sampling strategy, age, pregnancy trimester when GDM was tested, GDM criteria used for diagnosis ascertainment, strata used on the population of the study, the prevalence of GDM in the sample and by strata whenever available. Furthermore, in research reports presenting more stratified GDM prevalence and at least ten tested subjects per strata, we have extracted the stratified prevalence of GDM following a priority list to avoid double counting: comorbidity, parity, age, pre-gestational BMI, ethnicity, year, placental location, nationality, and occupation. Where there was no stratification on the prevalence of GDM, the overall prevalence was extracted. All relevant data were introduced into a predesigned Excel sheet using string codes and numerical variables. We considered a research report a single publication that might contain data from several studies (each one on a specific population group). In reports where the main study design does not report a clear prevalence, we have extracted the original study design of the report and we have calculated the prevalence of GDM accordingly. In reports where the GDM was ascertained using more than one criterion, the most sensitive and reliable assessment (e.g., fasting glucose blood test vs. self-reported) was considered as well as the most recent criteria (e.g., The American Diabetes Association ADA 2010 vs. ADA 2006).

**Summary Measures and Synthesis of Results**
To estimate the weighted pooled prevalence of GDM and the corresponding 95% confidence interval (CI), we performed meta-analyses of the extracted data. The Freeman–Tukey double arcsine transformation method was applied to stabilize the variances of the prevalence measures (28). The inverse variance method was used to weight the estimated pooled prevalence measures (29). Dersimonian–Laird random-effects model was used to estimate the overall pooled GDM prevalence (30). Cochran’s Q statistic and the inconsistency index I-squared ($I^2$), were calculated to measure heterogeneity. Along with the pooled estimates, ranges and median were also reported to describe the dispersion of the GDM prevalence measures reported in the literature. The prediction interval, which estimates the 95% interval in which the true prevalence of GDM in a new study will lie, was also quantified and reported (31).

The overall, country-level and sub-regional levels [Eastern Europe, Northern Europe, Western Europe, and Southern Europe (25)] pooled GDM prevalence was estimated. Moreover, within each sub-European region, the pooled GDM prevalence estimates were generated overall and based on age (<30, ≥30, or unclear age group), pregnancy trimester (first, second, third, or unclear trimester), BMI (normal, overweight, obese, or unclear BMI), and GDM ascertainment criteria. The provision of pooled estimates regardless of the ascertainment guidelines was justified by the fact that the women were defined...
and treated as GDM patients following each specific ascertainment guideline. We conducted a synthesis of results including the above-described meta-analysis also comprises a description of the main findings relevant to the study.

**Risk of Bias (RoB)**

To test the robustness of the implemented methodology, quality of evidence criteria was also used GDM ascertainment method, sampling methodology, and precision of the estimate. The risk of bias (RoB) tool was performed for each research report and not for individual studies, using the six-quality items adapted from the National Heart, Lung, and Blood Institute (NIH) criteria (32). From the 14 items of the NIH RoB tool we used research question/objective, studied population, participation rate, recruitment, sample size justification, and outcome measures and assessment. Reports were considered to have "high" precision if at least 100 women were tested for GDM. We computed the overall proportion of research reports with potentially low RoB across each of these nine quality criteria and the proportion (out of nine) of quality items with a potentially low RoB for each of the included research reports.

**Publication Bias**

The small-study effect on the pooled GDM prevalence estimates was explored through plotting the funnel plot. In the funnel plot, each GDM prevalence measure was plotted against its standard error. The asymmetry of the funnel plot was tested using Egger’s test (33).

Analyses were performed using the *metaprop* (34) and *metareg* packages in Stata/SE v15 (35).

**RESULTS**

**Study Selection**

After de-duplication, 15,933 records were screened and 547 full-text research reports critically assessed for eligibility, 133 research reports were deemed eligible and included in the meta-analysis (Figure 1).

**Study Characteristics**

The 133 research reports related to 24 countries in Europe and tested a total of 15,572,847 pregnant women for GDM and yielded 254 GDM prevalence studies. The majority of the research reports were reported from Northern Europe (59/133), followed by Southern Europe (36/133), Western Europe (32/133), and Eastern Europe (6/133). Across the four UN geoscheme sub-regions (25) the most studied countries were Italy (21 reports) and the United Kingdom (14 reports). Tables 1–4 summarize basic characteristics of the included research articles in the four European sub-regions.

**Eastern Europe**

From the Eastern Europe countries (Belarus, Bulgaria, Czech Republic, Hungary, Poland, Republic of Moldova, Romania, Russian Federation, Slovakia, and Ukraine), our search has just captured six reports that tested a total of 12,122 pregnant women for GDM from Hungary (two reports), Poland (three reports), and Republic of Macedonia (one report). In two out of the eight GDM prevalence studies reported in these three countries, GDM ascertainment was based on the Polish Gynecological Society Guidelines (Table 1).

**Northern Europe**

From Northern Europe sub-region (Denmark, Estonia, Finland, Iceland, Ireland, Latvia, Lithuania, Norway, Sweden, and United Kingdom), there were 59 reports presenting estimates on GDM prevalence. None of those reports were from Estonia or Latvia. Seven reports reporting 17 GDM prevalence studies were from Denmark, 10 reports with 22 GDM prevalence studies were from Finland, one report with three GDM prevalence studies were from Iceland, seven reports with 10 GDM prevalence studies were from Ireland, two reports with three GDM prevalence studies were from Lithuania, nine reports with 19 GDM prevalence were studies from Norway, nine reports with 20 GDM prevalence were studies from Sweden and 14 reports with 28 GDM prevalence studies were from the United Kingdom. In the 122 GDM prevalence studies that tested a total of 10,278,921 pregnant women reported in the Northern European countries, the IADPSG (in 15 out of 122 studies) followed by the WHO 2013 (in 14 out of 122 studies) were the most commonly used GDM diagnostic (Table 2).

**Western Europe**

From Western Europe sub-region (Austria, Belgium, France, Germany, Liechtenstein, Luxembourg, Monaco, Netherlands, and Switzerland). In this sub-region, the majority of the 32 research reports were in France (34.4%) followed by Germany (18.8%), Austria (15.6%), and Switzerland (15.6%). Our study did not find any prevalence studies on GDM from three countries (Liechtenstein, Luxembourg, and Monaco) in this sub-region reported between 2014 and 2019. In the 55 GDM prevalence studies that tested a total of 4,212,723 pregnant women in the Western European countries, the IADPSG (in 14 studies) was the most commonly used GDM diagnostic (Table 3).

**Southern Europe**

From Southern Europe sub-region (Albania, Andorra, Bosnia and Herzegovina, Croatia, Greece, Italy, Malta, Montenegro, North Macedonia, Portugal, San Marino, Serbia, Slovenia, and Spain), there were 36 research reports, of which, the majority were from Italy (58.3%) followed by 19.4% were from Spain. Between 2014 and 2019, there were no prevalence studies on GDM from Albania, Andorra, Bosnia and Herzegovina, Montenegro, North Macedonia, Portugal, San Marino, and Serbia. In the 69 GDM prevalence studies that tested a total of 1,069,081 pregnant women, the IADPSG was the most common GDM ascertainment criteria used (30.4%) (Table 4).

**Weighted GDM Prevalence**

In the 15,572,847 pregnant women tested for GDM the weighted GDM prevalence estimated was 10.9% (95% CI: 10.0–11.8%, I², 100%) in the 24 countries out of a total of 48 countries in Europe. Of the tested pregnant women, 76.6% were from three countries:
TABLE 1 | Baseline studies characteristics from Eastern Europe.

| Author (Ref)       | Duration of data collection | City                      | Sampling strategy | Population                     |Ascertainment method       | Tested sample | GDM Positive | Prev. (%) |
|--------------------|-----------------------------|---------------------------|--------------------|--------------------------------|---------------------------|----------------|---------------|-----------|
| Hungary            |                             |                           |                    |                                |                           |                |               |           |
| Renes L. et al.    | 01/2014 – 12/2014           | Hungary, Szeged           | Consecutive        | General population             | WHO 1999                   | 1493           | 155           | 10.1%     |
| Kun A. et al.      | 01/2009 – 12/2017           | Hungary (Western)         | Consecutive        | General population             | WHO 2013                   | 9469           | 1505          | 14.9%     |
| Mac-Marjanek K. et al. | 06-2011 – 06/2013   | Poland, Lodz              | Unclear            | Caucasian pregnant women       | PDA 2011                   | 145            | 113           | 78%       |
| Kosinska-Kaczynska K. et al. | 01/2007 – 06/2016  | Poland, Warsaw            | Unclear            | Women with dichorionic twin pregnancies at <14 weeks of pregnancy | PDA 2014                   | 104            | 71.7%         |           |
| Szymusik I. et al. | 07/2013 – 12/2016           | Poland, Warsaw            | Consecutive        | General population             | Polish                     | 201            | 27            | 13.4%     |
| Republic of Moldova |                             |                           |                    |                                | Polish                     | 368            | 31            | 8%        |

Republic of Moldova

| Author (Ref)       | Duration of data collection | City                      | Sampling strategy | Population                     |Ascertainment method       | Tested sample | GDM Positive | Prev. (%) |
|--------------------|-----------------------------|---------------------------|--------------------|--------------------------------|---------------------------|----------------|---------------|-----------|
| Brankica K. et al. | 01/2013 – 06/2013           | Republic of Moldova, Skopje | Consecutive        | General population             | IADPSG                    | 118            | 78            | 66.1%     |

IADPSG, International Association of Diabetes in Pregnancy Studies Group; PDA, Polish Diabetes Association; WHO, World Health Organization.
**TABLE 2 | Baseline studies characteristics from Northern Europe.**

| Author (Ref) | Duration of data collection | City | Sampling strategy | Population | Ascertainment method | Tested sample | GDM Positive (%) |
|--------------|----------------------------|------|-------------------|------------|----------------------|---------------|------------------|
| Denmark      |                            |      |                   |            |                      |               |                  |
| Bonnesen B. et al. (42) | 01/2009-12/2010 | Denmark, Hvidovre | Consecutive Primiparous women with a spontaneous singleton pregnancy | Medical Records | 3,440 | 43 | 1.3% |
| Medek H. et al. (43) | 05/2012 – 10/2013 | Denmark, Reykjavik | Consecutive Whole population General population | IADPSG | 117 | 22 | 12.4% |
| Holst S. et al. (44) | 01/2006 – 12/2010 | Denmark, National | Whole population Women with singleton pregnancies | Medical Records | 264539 | 5781 | 2.2% |
| Jeppesen C. et al. (45) | 01/2012 – 12/2012 | Denmark, National | Whole population Women aged 15-49 years old | Medical Records | 56894 | 1721 | 3.0% |
| McIntyre HD. et al. (10) | 01/2012 – 12/2012 | Denmark, National | Whole population General population | WHO 2013 | 1516 | 620 | 40.1% |
| Holst S. et al. (44) | 01/2006 – 12/2010 | Denmark, National | Whole population Women with singleton pregnancies | Medical Records | 264539 | 5781 | 2.2% |
| Hamann CR. et al. (46) | 01/1997 – 12/2014 | Denmark, National | Whole population Women with atopic dermatitis any time prior to birth | Medical Records | 10441 175 | 1.7% | |
|             |                            |      |                   |            |                      |               |                  |
| Finland     |                            |      |                   |            |                      |               |                  |
| Koivusalo SB. et al. (48) | 01/2008 – 12/2014 | Finland, Lappeenranta | Random selection Women with a history of GDM or pre-pregnancy obesity | ADA 2007 | 269 | 47 | 17.4% |
| Ellenberg A. et al. (49) | 01/2006 – 12/2008 | Finland, National | Whole population Women with singleton pregnancies | Medical records | 34460 | 2522 | 7.2% |
| Koivunen S. et al. (50) | 01/2006 – 12/2006 | Finland, National | Consecutive Pregnant at gestational age ≥ 22 weeks or a birthweight ≥ 500 g | The Finnish Current Care guidelines | 15682 | 5179 | 9.1% |
| Meinilä J. et al. (51) | 01/2008 – 12/2014 | Finland, Helsinki Metropolitan area and Lappeenranta | Unclear Women at high risk of GDM due to obesity, history of GDM, or both | ADA 2008 | 251 | 46 | 18.3% |
| Laine MK. et al. (52) | 01/2009 – 12/2015 | Finland, Vantaa | Whole population Primiparous women | The Finnish Current Care guidelines | 7750 | 1281 | 16.5% |
| Laine MK. et al. (53) | 01/2009 – 12/2015 | Finland, Vantaa | Whole population Primiparous women with height < 159 cm Primiparous women Primiparous women with height between 164-167 cm | The Finnish Current Care guidelines | 689 | 198 | 28.7% |
| Girchenko P. et al. (54) | 01/2011 – 12/2012 | Finland, National | Whole population General population | Medical records | 2504 | 248 | 9.9% |
| Kong L. et al. (55) | 01/2004 – 12/2014 | Finland, National | Whole population General population | Medical records | 649043 | 98668 | 15.2% |
| Ellfolk M. et al. (56) | 01/1996 – 12/2016 | Finland, National | Whole population Women exposed to antipsychotics | Medical records | 21125 | 3047 | 14.4% |
| Ijas H. et al. (57) | 01/2009 – 12/2009 | Finland, National | Whole population Women with singleton pregnancies | Medical records | 24555 | 5658 | 23.4% |
| Iceland      |                            |      |                   |            |                      |               |                  |
| Tryggvadottir EA. et al. (58) | 04/2012 – 10/2013 | Iceland, Reykjavik | Consecutive Non-smoking women and without GDM risk factors | WHO 2013 | 168 | 17 | 10.1% |
| Ireland      |                            |      |                   |            |                      |               |                  |
| Lindsay KL. et al. (59) | 03/2012 – 03/2013 | Ireland, Dublin | Random sampling Obese women | Carpenter and Cousin | 138 | 6 | 4.3% |

(Continued)
| Author (Ref) | Duration of data collection | City | Sampling strategy | Population | Ascertainment method | Tested sample | GDM Positive | Prev. (%) |
|-------------|-----------------------------|------|-------------------|------------|----------------------|--------------|-------------|----------|
| Daly N. et al. (60) | 04/2014 – 06/2014 | Ireland, Dublin | Convenience | Obese European women | WHO 2013 | 24 | 16 | 66.7% |
| Mone F. et al. (61) | 01/2011 – 09/2012 | Ireland, Dublin | Whole population | General population | WHO 2013 | 7252 | 140 | 1.9% |
| Moore R. et al. (62) | 2007 -2013 | Ireland, Dublin | Unclear | HIV women | Carpenter and Cousin | 142 | 3 | 2.1% |
| O’Dea A. et al. (63) | 01/2013 – 12/2013 | Ireland, Galway | Convenience | General population | WHO 2013 | 690 | 48 | 7.0% |
| Farren N. et al. (64) | 01/2014 – 01/2016 | Ireland, Dublin | Consecutive | Women with family history of DM | IADPSG | 240 | 40 | 16.6% |
| Daly N. et al. (65) | 11/2013 – 04/2016 | Ireland, Dublin | Consecutive | Women with BMI ≥ 30 that participated in the intervention | IADPSG | 43 | 25 | 58.1% |
| Lithuania | Ramoniene G. et al. (66) | Lithuania, Khaunas | Consecutive | Obese women with singletons | WHO 1999 | 140 | 33 | 23.6% |
| Malakauskiene L. et al. (67) | 01/2005 – 12/2015 | Lithuania, National | Whole population | Pregnant after bariatric surgery | Medical records | 130 | 3 | 2.31% |
| Norway | Rasmussen S. et al. (68) | Norway, National | Whole population | General population | Medical records | 77294 | 1086 | 1.4% |
| Sommer C. et al. (69) | 05/2008 – 05/2010 | Norway, Oslo | Unclear | General population | IADPSG | 728 | 229 | 31.5% |
| Helseth R. et al. (70) | 04/2007 – 06/2009 | Norway, Trondheim, and Stavanger | Unclear | Nordic Caucasian women | WHO 2013 | 687 | 42 | 6.1% |
| Leirgul E. et al. (71) | 01/2006 – 12/2009 | Norway, National | Whole population | General population | Medical records | 233003 | 3484 | 1.5% |
| Garnaes KK. et al. (72) | 11/2012 – 03/2013 | Norway, Trondheim | Unclear | Women with BMI ≥ 28 that participated in the intervention | WHO 2013 | 46 | 8 | 18.2% |
| Sorbye LM. et al. (73) | 01/2006 – 12/2014 | Norway, National | Whole population | Women with BMI ≥ 28 that did not participate in the intervention | Norwegian Society of Gynecology and Obstetrics | 24198 | 439 | 1.8% |
| Lehmann S. et al. (74) | 01/1967 – 12/2014 | Norway, National | Whole population | Women who trial labor after caesarean section | Medical records | 1119 | 686 | 63.0% |
| Sole KB. Et al. (75) | 01/1999 – 12/2014 | Norway, National | Whole population | Women with singleton pregnancies | Medical records | 907048 | 14200 | 1.57% |
| Magnus MA. et al. (76) | 01/2009 – 12/2013 | Norway, National | Whole population | General population | Medical records | 162343 | 5938 | 3.7% |
| Sweden | Lindqvist M. et al. (77) | Sweden, National | Whole population | General population | Medical records | 181292 | 2548 | 1.4% |
| Nilsson C. et al. (78) | 2012 - 2013 | Sweden, National | Whole population | General population | WHO 1999 | 7491 | 210 | 2.8% |
| Stokkeland K. et al. (79) | 2006 – 2011 | Sweden, National | Whole population | General population | Medical records | 578642 | 6343 | 1.0% |
| Sundelin HEK. et al. (80) | 2006 – 2014 | Sweden, National | Whole population | General population | Medical records | 877742 | 9919 | 1.1% |
| Stogianni A. et al. (81) | 2009 – 2012 | Sweden, Kronoberg | Whole population | General population | Medical records | 280 | 97 | 34.6% |
| Crump C. et al. (82) | 1973 - 2014 | Sweden, National | Whole population | General population | Medical records | 4186615 | 34255 | 0.8% |
| Hildan K. et al. (83) | 1998 – 2012 | Sweden, National | Whole population | General population | Medical records | 1294006 | 14833 | 1.0% |

(Continued)
TABLE 2 | Continued

| Author (Ref)        | Duration of data collection | City                          | Sampling strategy      | Population            | Ascertainment method | Tested sample | GDM Positive (%) | Prev. (%) |
|---------------------|-----------------------------|-------------------------------|------------------------|-----------------------|----------------------|---------------|------------------|----------|
| Khashan AS. et al.  | 1982 – 2012                 | Sweden, National              | Whole population       | General population    | Medical records      | 1292792       | 4967             | 0.4%     |
| Liu C. et al.       | 2014 – 2017                 | Sweden, National              | Whole population       | Refugees              | Medical records      | 31897         | 1148             | 3.6%     |
| United Kingdom      | 2008 – 2010                 | UK, Bradford                  | Whole population       | General population    | WHO 1999             | 11516         | 1132             | 10%      |
| West J et al.       | 03/2007 – 12/2010           | UK, Bradford                  | Consecutive            | Caucasian British/Irish women | WHO 1999             | 3503          | 172              | 4.9%     |
| Syngelaki A. et al. | 03/2006 – 07/2013           | UK, London and Gillingham    | Unclear                | General population    | Mixed methods        | 2656          | 406              | 15.3%    |
| Poston L. et al.    | 03/2009 – 06/2014           | UK, London, Bradford, Glasgow, Manchester, Newcastle, Sunderland | Random sampling       | Obese women           | IADPSG               | 1280          | 332              | 26%      |
| Sovio U. et al.     | 08/2008 – 07/2012           | UK, Cambridge                 | Unclear                | Nulliparous women     | Mixed methods        | 4069          | 171              | 4.2%     |
| Murphy NM. et al.   | 05/2007 – 02/2011           | UK, London, Manchester, Cork, Leeds | Unclear                | Women at high risk of GDM | Mixed methods        | 395           | 35               | 8.9%     |
| White SL. et al.    | 2009 – 2014                 | UK                            | Unclear                | Obese women           | IADPSG               | 261           | 20               | 7.7%     |
| Hanna FW. et al.    | 02/2010 – 12/2013           | UK                            | Unclear                | General population    | NICE 2015            | 1303          | 337              | 25.9%    |
| Panaitescu AM. et al. | 03/2006 – 11/2015          | UK, London                    | Unclear                | General population    | WHO 1999             | 6980          | 967              | 13.7%    |
| Hall E. et al.      | 05/2017 – 08/2017           | UK, London                    | Whole population       | General population    | NICE 2015            | 107788        | 2542             | 2.4%     |
| Balani J. et al.    | 2010 – 2011                 | UK, Surrey                    | Unclear                | Obese women           | WHO 1999             | 1287          | 264              | 21%      |
| Nzelu D. et al.     | 2011 – 2016                 | UK, London                    | Consecutive            | Pregnant women with pregnancy induced hypertension | NICE 2015             | 773           | 93               | 12%      |
| Vieira MC. et al.   | 03/2009 – 06/2014           | UK, London                    | Whole population       | Obese women           | IADPSG               | 824           | 241              | 29.6%    |
| Wagnild JM. et al.  | 02/2017 – 08/2017           | UK, Northeast England         | Consecutive            | Women at high risk of GDM | NICE 2015             | 326           | 31               | 16.5%    |

Sweden (48%), France (20.0%), and Norway (8.6%). From the represented countries in our analysis, Sweden (Northern Europe) shows the lowest weighted GDM prevalence of 1.8% (95% CI: 1.5–2.2, I², 99.9%) (Table 5). The highest observed national-based prevalence of 66.1% from a single study in the Republic of Moldova has contributed to the observed highest weighted GDM prevalence in the Eastern Europe sub-region (Table 5).

**Sub-Regional Weighted GDM Prevalence**

The highest sub-regional weighted GDM prevalence observed in the three Eastern European countries (31.5%, 95% CI: 19.8–44.6, I², 98.9%), followed by 12.3% (95% CI:10.9–13.9, I², 99.6%) in Southern Europe, 10.7% (95% CI: 9.5–12.0, I², 99.9%) in Western Europe, and 8.9% (95% CI: 7.9–10.0, I², 100.0%) in Northern Europe.

**Sub-Group Analysis**

The weighted prevalence of GDM was significantly higher in pregnant women ≥30 years old (15.4%, I², 99.8%) compared with 15–29 years old women (7.2%, I², 99.6%), in their third (18.4%, I², 99.8%) compared with second trimester (12.5%, I², 99.9%) of pregnancy, in obese (23.1%, I², 98.3%) and overweight (7.8%, I², 99.5%) compared with normal weight (3.4%, I², 99.4%) pregnant women.

This observation was comparable in the four sub-regions, whenever data was available. In the Northern European sub-region that comprised 48.0% of the GDM prevalence studies and tested 66.0% of the pregnant women in Europe, the weighted prevalence of GDM was 1.86-time higher in pregnant women ≥30 years old (13.4%, I², 99.7%) compared with younger women (7.2%, I², 99.7%), 1.83-time higher in the third trimester (18.0%, 95% CI: 10.0–27.7, I², 99.8%) compared with the second trimester (9.8%, 95% CI: 7.6–12.2, I², 99.9%), 4.2-time and 14.1-time higher in obese (31.1%, 95% CI: 26.5–35.8, I², 0.0%) compared with overweight (7.4%) and normal weight (2.2%) women, respectively. In all sub-regions, there was a significant variation (p<0.001) in the weighted GDM prevalence between the used GDM ascertainment guidelines (Supplementary Table S3).
### TABLE 3 | Baseline studies characteristics from Western Europe.

| Author (Ref) | Duration of data collection | City | Sampling strategy | Population | Ascertainment method | Tested sample | GDM Positive | Prev. (%) |
|--------------|-----------------------------|------|-------------------|------------|----------------------|---------------|--------------|----------|
| **Austria**  |                             |      |                   |            |                      |               |              |          |
| Bozkurt L. et al. (103) | 2010 – 2014 | Austria, Vienna | Unclear | General population with OGTT at 16 weeks | IADPSG | 221 | 81 | 38.3% |
| Tramontana A. et al. (101) | 01/2010 – 11/2013 | Austria, Vienna | Whole population | General population | IADPSG | 4948 | 209 | 4.2% |
| Tramontana A. et al. (102) | 2009 – 2018 | Austria, Essen | Whole population | Women with high-risk pregnancies | IADPSG | 382 | 170 | 44.5% |
| Koning A. et al. (103) | 01/2013 – 12/2015 | Austria, Linz | Whole population | Women with polycystic ovarian syndrome | GDDD | 63 | 29 | 46% |
| Weiss C. et al. (104) |      |      |                   | Singleton pregnancies | WHO 2013 | 3293 | 553 | 16.8% |
| **Belgium**  |                             |      |                   |            |                      |               |              |          |
| Benhalima K. et al. (105) | 01/2010 – 12/2013 | Belgium, Leuven, Aalst | Whole population | General population | Carpenter-Coustan | 14661 | 601 | 4.1% |
| De Munck N. et al. (106) | 03/2010 – 08/2014 | Belgium, Brussels | Whole population | Ocyte recipient with use of closed vitrification | Mix method | 112 | 13 | 11.6% |
| **France**   |                             |      |                   |            |                      |               |              |          |
| Grunewald D. et al. (107) | 2008-2013 | France, Paris | Unclear | Pregnant women with cystic fibrosis | Medical records | 23 | 2 | 8.7% |
| Mailhe G. et al. (109) | 04/2011 – 02/2012 | France, Paris | Whole population | Singleton pregnancies | IADPSG | 2187 | 309 | 14% |
| Guessiard K. et al. (109) | 2007 – 2013 | France, National | Whole population | General population | Medical records | 1515387 | 62958 | 4.14% |
| Regnault N. et al. (110) | 2013 | France, Bondy | Whole population | General population | Medical records | 788494 | 67810 | 8.6% |
| Mortier I. et al. (111) | 01/2011 – 07/2012 | France, Marseille | Whole population | Singleton pregnancies | IADPSG | 444 | 60 | 13.5% |
| Boudet-Berquier J. et al. (112) | 01/2012 – 04/2014 | France, National | Whole population | General population | Mixed methods | 3204 | 247 | 7.7% |
| Billonnet C. et al. (113) | 2012 | France, National | Whole population | General population | Medical records | 796346 | 57629 | 7.24% |
| Mitanchez D. et al. (114) | 08/2010 – 03/2013 | France, Paris | Unclear | Singleton pregnancy in obese women | IADPSG | 226 | 99 | 43.8% |
| Marie C. et al. (115) | 2006 | Auvergne, France | Whole population | Singleton pregnancy in normal weight women | Carpenter-Coustan | 1175 | 73 | 6.2% |
| Preaubert L. et al. (116) | 01/2010 – 12/2016 | France, Paris | Whole population | Ocyte recipient with use of closed vitrification | IADPSG | 247 | 39 | 15.8% |
| Soomro MH. et al. (117) | 03/2003 – 01/2006 | France, Poitiers and Nancy | Whole population | Women with blood-biomarkers to study heavy metals | Carpenter-Coustan | 623 | 4 | 7.1% |
| Germany      |                             |      |                   |            |                      |               |              |          |
| Stuber TN. et al. (118) | 2006 – 2011 | Germany, Wurzburg | Whole population | General population | Medical records | 2810 | 264 | 9.4% |
| Beyerlein A. et al. (119) | 2008 – 2014 | Germany, Bavaria | Whole population | General population | Medical records | 173718 | 6427 | 3.7% |
| Tamayo T. et al. (120) | 07/2012 – 06/2013 | Germany, North Rhine | Whole population | Consecutive | General population | IADPSG | 153302 | 9229 | 6.0% |
| Melchor H. et al. (121) | 07/2013 – 06/2014 | Germany, National | Whole population | Consecutive | Medical records | 158839 | 10817 | 6.8% |
| Köninger A. et al. (122) | 01/2014 – 12/2015 | Germany, Essen | Whole population | Unclear | Singleton pregnancies | German Diabetes Association | 105 | 29 | 27.6% |
| Pahltzsch TMJ. et al. (123) | 2014 -2016 | Germany, Solingen | Whole population | Mothers of macrocosmic newborns | Medical records | 2277 | 87 | 3.8% |
| Netherlands  |                             |      |                   |            |                      |               |              |          |
| Lamain-de-Ruiter ML (124) | 12/2010 – 01/2014 | Netherlands | Unclear | General population | Mixed method | 3723 | 181 | 4.9% |
| Koning SH. et al. (125) | 01/2011 – 09/2016 | Netherlands, Groningen | Whole population | Pregnant women with at least one risk factors for GDM | WHO 2013 | 10642 | 3364 | 31.6% |
| De Wilde MA. et al. (126) | 04/2008 – 04/2012 | Netherlands | Unclear | General population with polycystic ovarian syndrome | ADA 2004 | 188 | 43 | 23.9% |
| Kölner A. et al. (127) | 12/2012 – 12/2013 | Germany, National | Whole population | Singleton pregnancies | WHO 1999 | 2889 | 129 | 4.5% |

(Continued)
### TABLE 3 | Continued

| Author (Ref) | Duration of data collection | City | Sampling strategy | Population | Ascertainment method | Tested sample | GDM Positive (%) | Prev. (%) |
|--------------|----------------------------|------|-------------------|------------|----------------------|--------------|------------------|----------|
| Switzerland  |                            |      |                   |            |                      |              |                  |          |
| Mosimann B. et al. (127) | 01/2014 – 12/2014 | Switzerland, Bern | Consecutive | General population | Mixed method | 328 | 51 | 15.5% |
| Amylidi S. et al. (128) | 06/2011 – 11/2012 | Switzerland, Bern | Whole population | Pregnant women with at least one risk factor for GDM | ADA 2016 | 218 | 32 | 14.7% |
| Ryser Rietschi J. et al. (129) | 10/2010 – 04/2012 | Switzerland, Geneva and Basel | Whole population | Consecutive | IADPSG | 2298 | 251 | 10.9% |
| Horsch A. et al. (130) | 11/2012 * 07/2013 | Switzerland, Lausanne | Whole population | General population | Mixed method | 203 | 39 | 19.2% |
| Savopol H. et al. (131) | 01/2014 – 12/2015 | Switzerland, Bern | Whole population | General population | IADPSG | 502 | 159 | 31.7% |

ADA, American Diabetes Association; DM, diabetes mellitus; GDDD, Deutsche Gesellschaft fur gynakologie und Geburtshilfe; HBV, Hepatitis B virus; HIV, Human Immunodeficiency virus; IADPSG, International Association of the Diabetes and Pregnancy Study Groups; OGTT, oral glucose tolerance test; WHO, World Health Organization.

### Risk of Bias (RoB)

The results of the four RoB domains assessed and the six quality of evidence items from NIH are presented in (Figure 2). Overall, the RoB and quality of evidence showed a significant low RoB with domains like the study population and research question having 100% of high quality of evidence. Recruitment and outcomes measurement were also rated with high quality of evidence in 97%, while sample size justification was unclear for 70% of the studies. Regarding RoB, GDM ascertainment and precision were low for 4% and 5%, respectively. While the response rate and sampling methodology were considered high for 14% and 10%, respectively (Figure 2).

### Publication Bias

Graphically, the funnel plot shows a potential of publication bias and small-study effect (Egger’s test, p < 0.001) on the estimated pooled prevalence (Supplementary Figure S1).

### DISCUSSION

#### Summary of Evidence

This systematic review and meta-analysis research summarizes the prevalence of GDM in Europe based on 133 reports comprising data of 254 single studies reported between 2014 and 2019 in 24 countries. Most of these studies were from Italy and the United Kingdom. The overall estimated prevalence of GDM in the 24 countries from the entire European Region was lower (10.9%, 95% CI: 10.0–11.8, $I^2$: 100%) than the estimates reported by the International Diabetes Federation (IDF) for 2019 (16.3%) (168) and higher than a previous meta-analysis (5.4%, 95% CI: 3.8–7.8) conducted by Eades and colleagues (22). Differences in the population estimates (and countries) might explain the variation between the reports. IDF has included data of 39 countries and only for women aged 20-45 years old (168) and Eades and colleagues included only 12 countries (22). A descriptive study revising the global GDM prevalence points to Europe as the region with the lowest GDM prevalence with a median of 6.1 (range 1.8%-31.0%) (169), in our study, the median estimate was 9.9 (range 0.2%-78%).

Considering the four sub-regions of Europe, the Eastern region presented the highest GDM prevalence (31.5%, 95% CI: 19.8–44.6, $I^2$: 98.9%), followed by Southern Europe (12.3%, 95% CI: 10.9–13.9, $I^2$: 99.6%), Western Europe (10.7%, 95% CI: 9.5–12.0, $I^2$: 99.9%), and Northern Europe (8.9%, 95% CI: 7.9–10.0, $I^2$: 100). A review of the literature from 2000–2009 is consistent with these results presenting the lowest GDM prevalence for the European northern or Atlantic seaboard countries in comparison with the Southern or Mediterranean countries (170). The Eastern (and Southern regions were also the two regions with the smallest number of studies included, 4.5% and 27.1% respectively, due to the lack of identified reports from these countries. These results highlight the need for good quality and standardized epidemiological studies in these two regions, not to mention the 25 countries that are not represented in our study. We have assessed full-text studies from some countries like Albania and Portugal that were potentially eligible to be considered but as the GDM ascertainment criteria was not clear, therefore they were excluded for not meeting our criteria.

The Republic of Moldova has the highest GDM prevalence across the entire region (66.1%, 95% CI 19.8–44.6, $I^2$: 98.9%), followed by Poland, Austria, Cyprus, and Malta. Sweden has the lowest GDM prevalence followed by Belgium, Norway, Croatia, and Denmark. The IDF 2019 Diabetes Atlas presents GDM prevalence for 12 countries in the region and their estimated prevalence is within our confidence interval for France, Ireland, Netherlands, Poland, and Sweden (168). For Norway, Spain, and the UK their estimates are higher than ours. These findings may suggest the recent higher reported rates for GDM prevalence compared with previous years as our review comprises data from 2014-2019 and there is just for 2019.

In women with a history of GDM, lifestyle interventions and medical treatment decreased the progression of T2DM by up to 40% (171). Therefore, GDM becomes a public health priority issue as it poses a significant health burden, not only to these pregnancies but also to the future health of both mothers and offspring. In this way, the diagnosis and management of GDM can represent an opportunity for intervention to reduce the...
| Author (Ref) | Duration of data collection | City | Sampling strategy | Population | Ascertainment method | Tested sample | GDM Positive | Prev. (%) |
|-------------|----------------------------|------|-------------------|------------|----------------------|--------------|--------------|----------|
| Croatia     |                            |      |                   |            |                      |              |              |          |
| Djakovic I. et al. (132) | 2011 – 2012 | Croatia, Zagreb | Consecutive | General population | HAPO study guidelines | 6407 | 593 | 9.3% |
| Djelmis J. et al. (133) | 2012 -2014 | Croatia | Unclear | Singleton pregnancies | IADSPG, WHO 1999 | 4646 | 1074 | 23.1% |
| Erjavec K. et al. (134) | 2010 | Croatia, National | Consecutive | General population | IADSPG | 4646 | 826 | 17.8% |
| Vince K. et al. (133) | 2011 | Croatia, National | Consecutive | General population | IADSPG | 39092 | 1829 | 4.6% |
| Cyprus      |                            |      |                   |            |                      |              |              |          |
| Inancli SS et al. (136) | 11/2013 – 04/2014 | Cyprus, National | Consecutive | Turkish Cypriot | National Diabetes Data Group | 230 | 45 | 19.6% |
| Greece      |                            |      |                   |            |                      |              |              |          |
| Vassilaki M. et al. (137) | 02/2007 – 02/2008 | Greece, Crete | Convenience | General population | Carpenter-Coustan | 1122 | 102 | 9.1% |
| Italy       |                            |      |                   |            |                      |              |              |          |
| Trotta F. et al. (138) | 10/2009 – 09/2010 | Italy, Lombardy | Whole population | General population | Medical records | 86171 | 1921 | 2.3% |
| Pietrauci B. et al. (139) | 05/2010 – 10/2011 | Italy, Messina | Whole population | Caucasian women | IADSPG | 1015 | 113 | 11.1% |
| Cassa D. et al. (140) | 01/2007 – 06/2011 | Italy, Rome | Whole population | Twin pregnancies | Medical records | 207 | 6 | 2.9% |
| Laceria E. et al. (141) | 01/2012 – 13/2013 | Italy, Pisa and Livorno | Whole population | Twin pregnancies with assisted conception | IADSPG | 138 | 14 | 10.1% |
| D’Anna R. et al. (142) | 01/2011 – 04/2014 | Italy, Messina and Modena | Random sampling | Obese women | IADSPG | 241 | 51 | 23.8% |
| Pinzauti S. et al. (143) | 01/2010 – 12/2014 | Italy, Florence and Siena | Whole population | Twin pregnancies with assisted conception | Mixed method | 430 | 30 | 6.9% |
| Capula C. et al. (144) | 08/2011 – 01/2015 | Italy, Catanzaro | Convenience | Healthy pre-pregnancy women | IADSPG | 3974 | 1066 | 26.8% |
| Santamaria A. et al. (145) | 01/2012 – 12/2014 | Italy, Messina and Modena | Convenience | Overweight Caucasian | ADA 2011 | 102 | 28 | 27.5% |
| Bianchi C. et al. (146) | 01/2010 – 03/2015 | Italy, Pisa | Unclear | General population | Medical records | 1198 | 476 | 39.7% |
| Di Cianni G. et al. (147) | 01/2015 – 12/2015 | Italy, Tuscany | Whole population | General population | Medical records | 17606 | 2000 | 11.4% |
| Bordi et al. (148) | 01/2001 – 06/2015 | Italy, Rome | Whole population | Twin pregnancies with assisted conception | Medical records | 450 | 38 | 8.4% |
| Chiefari E. et al. (149) | 08/2011 – 12/2016 | Italy, Catanzaro | Whole population | Twin pregnancies | Italian Minister Guidelines | 5473 | 1559 | 28.5% |
| Cozzolino M. et al. (150) | 01/2010 – 01/2016 | Italy, Florence | Whole population | Multiple pregnancies | IADSPG | 656 | 99 | 15.1% |
| Bruno R. et al. (151) | 02/2013 – 06/2014 | Italy, Modena | Unclear | Singleton pregnancies of overweight/obese women with prescribed personalized dietary intervention | IADSPG | 62 | 23 | 37.1% |
| Bianchi C. et al. (152) | 01/2013 – 12/2015 | Italy, Pisa | Whole population | General population | Italian National Guidelines | 69 | 13 | 18.8% |
| Mercreaglia M. et al. (153) | 01/2014 – 12/2014 | Italy, National | Whole population | General population | Medical records | 1338 | 534 | 39.95% |
| Quaresima P. et al. (154) | 01/2015 – 12/2016 | Italy, Catanzaro | Consecutive | General population | IADSPG | 1413 | 451 | 31.8% |
| Gerli S. et al. (155) | 01/2011 – 12/2013 | Italy, National | Whole population | Women in Robson class 1 according to the Ten Group Classification System | IADSPG | 7693 | 132 | 1.7% |

(Continued)
burden of T2DM. Strategies to prevent T2DM may incorporate hyperglycemia screening 4 to 12 weeks after the post-partum as recommended by the most recent guidelines from ADA (12).

Differences in the GDM criteria used in the different countries and sub-regions also play an important role in the differences of prevalence reported and most importantly in the heterogeneity of our meta-analysis estimations. It is known that there is a poor consensus and uniformity in the diagnosis of GDM, as our study demonstrates, by having 24 different criteria used. This fact is to be considered as well with the recent criteria updates, specifically from the WHO in 2013. The differences in GDM criteria allied with the different countries’ screening guidelines (e.g., universal GDM screening vs screening for women with risk factors) introduce heterogeneity to the meta-analysis and increases the challenge of comparing the prevalence across countries and regions. Standardized studies and policies across the European region would help to tackle the GDM public health burden.

**Strengths, Implications, and Limitations**

This study has used a comprehensive search strategy to review all the studies of GDM in Europe at the regional, sub-regional, and national levels. The study includes a huge number of reports and single estimates that were combined. Estimating a weighted GDM prevalence based on a huge number (over 15 million) of tested pregnant women provides the best-precise estimation of the burden of GDM in the included European countries. Additionally, estimating the pooled GDM prevalence among various pregnant women population groups according to age, trimester of GDM diagnosis, maternal body weight, also provides specific estimates in this population group to priorities action and screening strategies. As mentioned above, the range of GDM per country varied widely therefore we are not able to extrapolate the reported GDM prevalence for the European countries not represented in our estimates, the sub-regions itself and even within the countries, as the case of the Republic of Moldova, Iceland, and Malta that are included in our analysis with one single report. Another potential limitation is the lack of or small number of studies from specific countries which might not reflect the reality of the region. Therefore, interpreting the present findings should be exercised in the light of this important potential limitations.

**CONCLUSIONS**

The overall GDM prevalence in Europe is considerable, particularly for pregnant women in Eastern European countries. Epidemiological studies focusing on GDM and using standardized

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**TABLE 4 | Continued**

| Author (Ref) | Duration of data collection | City | Sampling strategy | Population | Ascertainment method | Tested sample | GDM Positive | Prev. (%) |
|-------------|-----------------------------|------|------------------|------------|----------------------|---------------|-------------|----------|
| Masturzo B. et al. (156) | 01/2011 – 12/2015 | Italy, Turin | Whole population Consecutive | Singleton pregnancies | Medical records | 27807 | 2308 | 8.3% |
| Visconti F. et al. (157) | 08/2011 – 12/2016 | Italy, Calabria | Whole population | Singleton pregnancies | IADPSG | 2424 | 596 | 24.7% |
| Marzoio L. et al. (158) | 2009 - 2015 | Italy, Turin | Whole population | Pregnant women < 40 years old | ADA 2014 | 52413 | 1430 | 2.7% |
| | | | | Pregnant women between 40-44 years old | | 3541 | 203 | 5.7% |
| | | | | Pregnant women > 45 years old | | 257 | 21 | 8.2% |
| Malta | 01/2009 – 12/2009 | Malta, National | Consecutive | General population | WHO 2006 | 203 | 43 | 21.2% |
| | | | | | | | | |
| Slovenia | 05/2013 – 09/2015 | Slovenia, Ljubljana | Unclear | General population | Self-reported | 450 | 43 | 10.0% |
| Kek T. et al. (160) | Spain | | | | | | | |
| | | | | | | | | |
| Goni L. et al. (161) | 11/2009 – 03/2010 | Spain, Navarra | Convenience | General population | Medical records | 5987 | 397 | 7.8% |
| Ruiz-Gracia T. et al. (162) | 04/2011 – 03/2012 | Spain, Madrid | Consecutive | General population | Carpenter-Coustan | 1750 | 185 | 10.5% |
| Berglund SK. et al. (163) | 2008 - 2012 | Spain, Granada | Convenience | Overweight and Obese women | Spanish Society of Gynecology and Obstetrics | 333 | 46 | 13.8% |
| Benaiges D. et al. (164) | 04/2013 – 09/2015 | Spain, Barcelona | Consecutive | Singleton pregnancies | National Diabetes Data Group | 1158 | 152 | 13.1% |
| Assaf-Balut C. et al. (165) | 01/2015 – 12/2015 | Spain, Madrid | Consecutive | Single pregnancy following standard Med-Diet supplemented with EVOO and pistachios | IADPSG | 434 | 74 | 17.1% |
| Gortazar L. et al. (166) | 2006 – 2015 | Spain, Catalonia | Whole population | Singleton pregnancies | | | | |
| | | | | | | | | |
| Mane L. et al. (167) | 2010 - 2013 | Spain, Barcelona | Whole population | General population | Self-reported | 5633 | 572 | 10% |

ADA, American Diabetes Association; EVOO, extra virgin olive oil; HAPO, Hyperglycemia and Adverse Pregnancy Outcomes; IADPSG, International Association of the Diabetes and Pregnancy Study Groups; WHO, World Health Organization.
### TABLE 5 | Weighted national, sub-regional, and regional GDM prevalence in Europe.

| Country            | No. of studies | Tested sample | GDM Range (%) | Median (%) | Weighted prev. (%) | 95% CI       | Q statistic (p-value) | I² (%) | 95% Pl (p-value) | P-value (fixed) |
|--------------------|----------------|---------------|---------------|------------|-------------------|-------------|----------------------|--------|----------------|-----------------|
| **Eastern Europe** |                |               |               |            |                   |             |                      |        |                |                 |
| Hungary            | 2              | 10,982        | 1,660         | 10.1–14.9  | 12.5              | 15.1        | 14.4–15.8            |        |                |                 |
| Poland             | 5              | 1,042         | 298           | 8.0–78.0   | 13.4              | 34.1        | 8.8–65.8             | 427.8  | 99.1           | 0.00–100        |
| Republic of Moldova| 1              | 118           | 78            | –          | –                 | 66.1        | 57.2–74.0            | –      | –              | –               |
| Overall Eastern    | 8              | 12,122        | 2,036         | 8.0–78.0   | 14.2              | 31.5        | 19.8–44.8            | 665.8  | 98.9           | 0.8–79.0        |
| **Northern Europe**|                |               |               |            |                   |             |                      |        |                |                 |
| Denmark            | 17             | 474,094       | 19,350        | 0.9–40.1   | 12.0              | 6.3         | 3.7–9.3              | 22,782.0 | 99.9          | 0.00–24.1       |
| Finland            | 22             | 749,342       | 129,062       | 4.9–36.3   | 17.3              | 18.4        | 16.7–20.2            | 6,728.1 | 99.7          | 10.6–27.8       |
| Iceland            | 3              | 168           | 17            | 2.3–28.9   | 9.1               | 11.0        | 0.6–29.7             | 17.5   | 88.6          | –               |
| Ireland            | 10             | 8,572         | 309           | 1.8–68.4   | 9.3               | 18.9        | 10.0–29.9            | 376.6  | 97.6          | 0.0–64.1        |
| Lithuania          | 3              | 3,377         | 196           | 2.3–23.6   | 5.1               | 8.5         | 1.4–20.2             | 45.1   | 95.6          | –               |
| Norway             | 19             | 1,332,092     | 25,092        | 1.1–63.0   | 2.0               | 4.6         | 3.8–5.5              | 6,904.2 | 99.7          | 1.6–8.9         |
| Sweden             | 20             | 7,479,062     | 74,073        | 0.2–34.6   | 1.5               | 1.8         | 1.5–2.2              | 18,241.0 | 99.9         | 0.6–3.8        |
| United Kingdom     | 28             | 232,214       | 10,113        | 1.9–29.8   | 11.2              | 11.7        | 9.4–14.4             | 6,947.8 | 99.6          | 1.8–28.6        |
| Overall            | 122            | 10,278,921    | 258,212       | 0.2–63.0   | 7.5               | 8.9         | 7.9–10.0             | 365,513.4 | 100.0        | 1.0–23.4       |
| **Western Europe** |                |               |               |            |                   |             |                      |        |                |                 |
| Austria            | 5              | 8,897         | 1,042         | 4.2–46.0   | 38.3              | 27.3        | 13.0–44.3            | 796.0  | 99.5          | 0.0–90.4        |
| Belgium            | 2              | 14,773        | 614           | 4.1–11.6   | 7.9               | 3.9         | 3.6–4.3              | –      | –              | –               |
| France             | 16             | 3,109,492     | 189,173       | 1.2–43.8   | 7.5               | 8.0         | 5.9–10.4             | 22,936.1 | 100.0        | 2.7–17.0       |
| Germany            | 18             | 1,058,242     | 101,724       | 3.4–27.6   | 7.0               | 7.3         | 5.1–9.9              | 61,693.8 | 99.9          | 0.8–21.3       |
| Netherlands        | 4              | 17,442        | 3,717         | 4.5–31.6   | 14.0              | 13.9        | 1.9–34.1             | 2,340.4 | 99.9          | 0.0–100.0      |
| Switzerland        | 10             | 3,877         | 583           | 10.0–31.7  | 16.1              | 17.0        | 11.3–23.4            | 120.3  | 92.5          | 1.7–41.4       |
| Overall Western    | 55             | 4,212,723     | 296,853       | 1.2–46.0   | 8.6               | 10.7        | 9.5–12.0             | 73,439.9 | 99.9          | 3.4–21.4       |
| **Southern Europe**|                |               |               |            |                   |             |                      |        |                |                 |
| Croatia            | 13             | 88,086        | 4,676         | 1.1–23.1   | 4.7               | 5.8         | 3.2–9.2              | 3,635.5 | 99.7          | 0.0–24.0       |
| Cyprus             | 1              | 230           | 45            | –          | –                 | 19.6        | 15.0–25.2            | –      | –              | –               |
| Greece             | 4              | 1,122         | 102           | 7.6–17.0   | 9.3               | 10.0        | 6.4–14.3             | 69.6   | 9.9           | 0.1–31.3       |
| Italy              | 32             | 222,809       | 13,497        | 1.7–47.6   | 11.5              | 14.5        | 11.1–18.1            | 13,663.2 | 99.8         | 0.9–39.8       |
| Malta              | 1              | 203           | 43            | –          | –                 | 21.2        | 16.1–27.3            | –      | –              | –               |
| Slovenia           | 1              | 450           | 43            | –          | –                 | 9.6         | 7.2–12.6             | –      | –              | –               |
| Spain              | 17             | 756,181       | 37,786        | 4.8–39.6   | 11.4              | 15.0        | 11.0–19.4            | 1,838.4 | 99.1          | 1.7–37.6       |
| Overall Southern   | 69             | 1,069,081     | 56,192        | 1.1–47.6   | 10.7              | 12.3        | 10.9–13.9            | 19,346.8 | 99.6          | 3.0–28.0       |

(Continued)
GDM criteria would be crucial to better estimate the national, subregional, and regional GDM of Europe as GDM has serious public health implications for the life of the mothers and newborns. This systematic review and meta-analysis findings highlight these implications and aim to contribute to the vigilant public health awareness campaigns about the risk factors associated with developing GDM in Europe and globally.

**DATA AVAILABILITY STATEMENT**

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

**ETHICS STATEMENT**

There are no primary data used in this review. There is no need for any ethical approval or an exemption letter according to the United Arab Emirates University-Human Research Ethics Committee.

**AUTHOR CONTRIBUTIONS**

RHA conceptualized and designed the study. MSP assessed the eligibility of the retrieved citations in the titles/abstracts and full-text screening phases. RHA, NA, and MSP critically assessed the eligible studies and extracted data. RHA and NA performed the
analysis. MSP and RB-S wrote the initial draft of the manuscript. All authors contributed to the article and approved the submitted version.

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**SUPPLEMENTARY MATERIAL**

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fendo.2021.691033/full#supplementary-material
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