Detailed Review on Gestational Diabetes Mellitus with Emphasis on Pathophysiology, Epidemiology, Related Risk Factors, and its Subsequent Conversion to Type 2 Diabetes Mellitus

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ABSTRACT

Any degree of glucose intolerance during the pregnancy of a women is termed as Gestational Diabetes Mellitus (GDM). It may further develop into Type 2 Diabetes Mellitus (T2DM) later in life. GDM affects both mother and infant in multiple ways and there are various factors that predispose the development of GDM.The primary objective of this review is to describe the various aspects related to GDM and the subsequent risk of developing T2DM later in life.We reviewed freely accessible, full-text articles, available in PubMed, Google Scholar, and MEDLINE in the English language, till August 2022 pertaining to GDM. The pathophysiology of underlying glucose intolerance has been discussed, including the various factors like β-Cell dysfunction, chronic insulin resistance, adiponectin, insulin resistance. GDM affects pregnancies world-wide, but it is higher in the South-east Asia, northern America and Caribbean, south and central America regions. Along with ethnicity, various modifiable and non-modifiable risk factors also play a major role in development of disease. Although no standard diagnostic criteria is accepted world-wide for screening of GDM, but the one-step and two-step approach has made quite a difference. The risk of developing T2DM after GDM is well documented, and it increases with age. GDM leads to an onset of diabetes in the family at a young age, it leads to poor consequences on the health of both the mother and infant. Standard diagnostic criteria, proper education and counselling of the mother is required to tackle the condition.

Introduction

Gestational diabetes mellitus (GDM) can be defined as any degree of glucose intolerance with an onset during pregnancy. Women diagnosed with GDM have a higher risk of developing type 2 diabetes mellitus (T2DM) later in their life compared to women with no GDM [1]. During pregnancy, the body of the woman adapts according to the growing fetus and its glucose requirements. Insulin secretion gets increased, which elevates maternal storage of fat and glycogen for better sufficient maternal nutrition. At the beginning of the mid- trimester, various placental hormones are produced that work as insulin antagonists. These hormones increase insulin resistance and result in the increase of maternal glucose and free fatty acids. Women with normal pregnancy produce a surplus amount of insulin to bypass this insulin resistance and insulin homeostasis falls back to non-pregnancy levels after delivery but on the contrary, women with underlying metabolic disorders and

genetic predisposition of relative insulin secretion defect fail to increase their insulin secretion during this period and develop GDM. Factors responsible for the development of GDM can be Ethnicity (Asian women are more prone to developing GDM compared to white women), lack of adequate glucose monitoring during pregnancy and follow up period, low level of patient education regarding GDM, and unwilling patient attitude towards dietary and lifestyle changes [2]. T2DM is spreading across Asia as an epidemic and one aggravating factor is GDM for the female population. Over and above GDM, other factors responsible for the development of T2DM are hereditary T2DM, multiparity, older maternal age, weight gain during pregnancy (BMI during pregnancy), and high blood sugar levels in the first pregnancy. Chances of GDM progresses to T2DM sharply within the first 5 years after delivery and then flattens after 10 years [3]. An increased risk of cardiovascular disease, T2DM, and obesity are the consequences of GDM on the maternal side and the child has a risk of developing obesity, T2DM, and cardiovascular diseases throughout their life. Furthermore, with an inherent predisposition, birth complications like stillbirth, preterm birth, overweight baby, polyhydramnios, breathing difficulty, jaundice, and hypoglycemia can result due to GDM [4]. Women with GDM have a 7-fold risk of developing T2DM post-pregnancy compared to normal women [5]. This review has been done to determine the risk of developing T2DM after having GDM in Asian women and the exact pathophysiology lying behind the conversion of GDM to T2DM and its associated factors.

Data Search and Sources

Freely accessible, full-text articles, available in PubMed and Google Scholar, and MEDLINE in the English language, till August 2022 pertaining to GDM were reviewed. The references of these articles were also scrutinized for relevant studies.

Study Selection

We included studies with a documented incidence of type 2 diabetes mellitus after GDM with the precise follow-up record, carried out on humans and were published in the English language. Studies with less than 100 patients and a low rate of follow up after 6 months post-partum were excluded to reduce the downgrading effect it can have on the study result; studies that did not fit in the criteria were excluded. Any study with an overlapping population was checked for and the one with the higher population was selected.

▶ **Fig. 1** represents the data selection and criteria on the basis of which a total of 53 articles were selected that satisfied the aim and scope of the review; the data from these articles were further used to calculate results.

Pathophysiology

GDM is a type of diabetes that develops and is diagnosed during pregnancy, as the name implies, it is a condition in which the body of a pregnant woman is unable to utilize glucose (sugar) effectively. This causes a rise in blood glucose (sugar) levels, which impacts both the mother and the fetus' health and development.

Insulin resistance and β-cell dysfunction are both important factors in the pathogenesis of GDM. In the majority of cases, such abnormalities occur in the body prior to conception and progress over time as one of the key risk factors for the development of GDM and T2DM after delivery [6]. Apart from the pancreas, a variety of other organs and organ systems, such as the placenta, heart, brain, liver, kidney, eyes, skin, vascular system, neurological system, and adipose tissues play a role in the development of GDM.

β-Cell Dysfunction

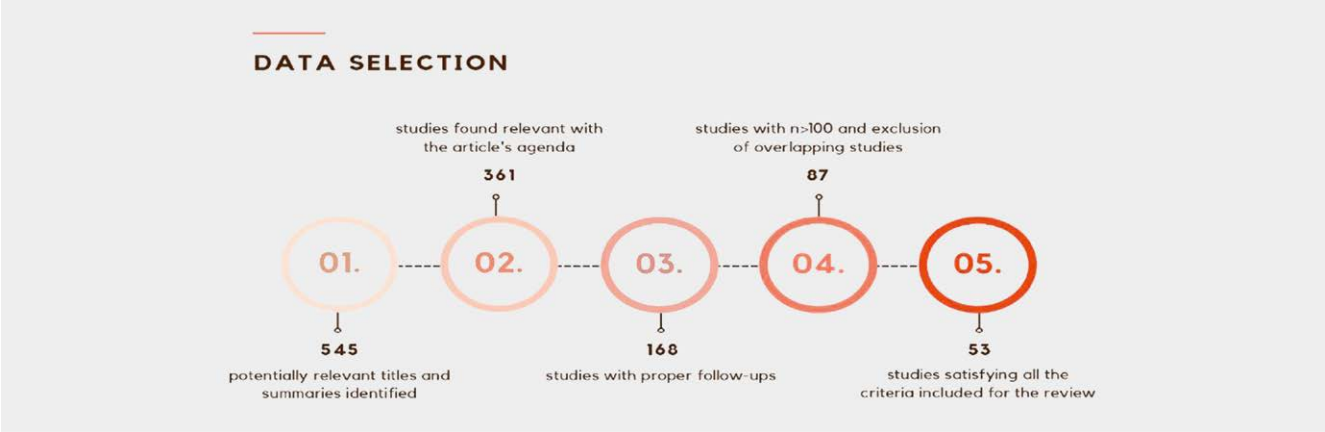
β-Cell dysfunction is a condition in which cells do not function properly. The endocrine pancreas is made up of three different types of cells: alpha, beta, and delta cells. Insulin is stored in pancreatic cells, which release it in reaction to rising glucose levels in the body. β-Cell dysfunction occurs when β-cells fail to detect glucose content in the blood and are unable to produce enough insulin in response [7]. It occurs as a result of insufficient glucose sensing to trigger insulin release, resulting in high blood glucose levels. β-Cell dysfunction can be caused by a flaw in any phase of the process. These steps include pro-insulin production, post-translational changes, insulin storage, blood glucose monitoring, and the complicated mechanism controlling granule exocytosis. GDM is linked to the majority of susceptibility genes responsible for the β-cell function. KQT-like 1 (Kcnq1), a potassium voltage-gated channel, and glucokinase are two of them (Gck) [8]. When β-cells are unable to detect glucose levels in the blood, glucose uptake is reduced, resulting in hyperglycemia. As a result, β-cells are forced to create more insulin. Glucotoxicity is the word for the destruction of β-cells caused by glucose [9]. This leads to further β-cell breakdown and a cycle of consequences, including hyperglycemia and insulin resistance.

Reduced β-cell mass and number as a result of pancreatectomy may also contribute to the development of GDM, depending on the individual.

Chronic Insulin Resistance

Insulin resistance is the result of the inability of cells to respond to insulin release. Glucose transporter 4 (GLUT4) is a glucose transport protein, which is found primarily in adipose tissues, skeletal muscles, and cardiac muscles. It facilitates the uptake of glucose molecules by the cells for its effective use and plays an important role in regulating whole-body glucose homeostasis. Inadequate translocation of glucose transporter 4 (GLUT4) to the plasma membrane due to failure of insulin signaling contributes to insulin resistance. In patients with GDM, the rate of glucose uptake due to insulin uptake is reduced by 54 % when compared with normal pregnancy. Generally, the abundance of insulin receptors is unaffected but reduced tyrosine or increased serine/threonine phosphorylation of the insulin receptor diminishes insulin signaling [10]. Apart from this, altered expression of downstream regulators of insulin signaling, including insulin receptor substrate (IRS)-1, phosphatidylinositol 3- kinase (PI3K), and GLUT4 have been associated in GDM. Most of the time these changes at the molecular level remain persistent and can contribute to the development of T2DM [11].

▶ **Fig. 2** [12] shows the relationship between β-cell dysfunction, insulin resistance, and GDM. During the normal gestational period, β-cells of the pancreas undergo hyperplasia and hypertrophy in order to meet the requirements of metabolic processes occurring during pregnancy and to compensate for increased blood glucose levels. β-Cells, blood glucose levels, and insulin sensitivity



▶ **Fig. 1** Data collection.

return to normal following pregnancy. However, in GDM, β-cells fail to compensate for increased blood glucose levels and, when combined with reduced insulin sensitivity, this results in hyperglycemia [8].

Adiponectin

Adiponectin is a protein hormone that is produced predominantly by adipocytes, but also by muscle and the brain. The ADIPOQ gene encodes this hormone in humans. It is involved in the regulation of glucose levels as well as the breakdown of fatty acids in the body. Its concentration in plasma, on the other hand, is inversely related to the mass of adipose tissue [13]. A reduction in adiponectin levels is also linked to GDM. Adiponectin promotes fatty acid oxidation, insulin sensitivity, and gluconeogenesis inhibition. This is accomplished via activating the transcription factor peroxisome proliferator-activated receptor alpha (PPARα) in the liver and the AMP-activated protein kinase (AMPK) within insulin-sensitive cells, which facilitates IRS-1 function [14]. Insulin secretion is stimulated by adiponectin, which increases insulin gene expression and exocytosis of insulin granules from β-cells. Adiponectin is also produced in the placenta's syncytiotrophoblast, where it is controlled by cytokines such as tumor necrosis factor alpha (TNF-α), interferon gamma (IFN-γ), interleukin (IL)-6, and leptin at low concentrations [13].

It is unclear what role placental adiponectin plays in normal and GDM pregnancy. However, new research suggests that it interferes with insulin signaling and amino acid transport through the placenta, limiting fetal growth. As a result, maternal glucose intolerance and fetal macrosomia are linked to adiponectin gene methylation in the placenta [15].

Placental Movement

The placenta, through its production of hormones and cytokines, contributes to insulin resistance throughout pregnancy. During GDM, the placenta, which serves as a barrier between the maternal and fetal surroundings, is also subjected to hyperglycemia and its effects. This can affect glucose, amino acids, and lipid transport across the placenta [16].

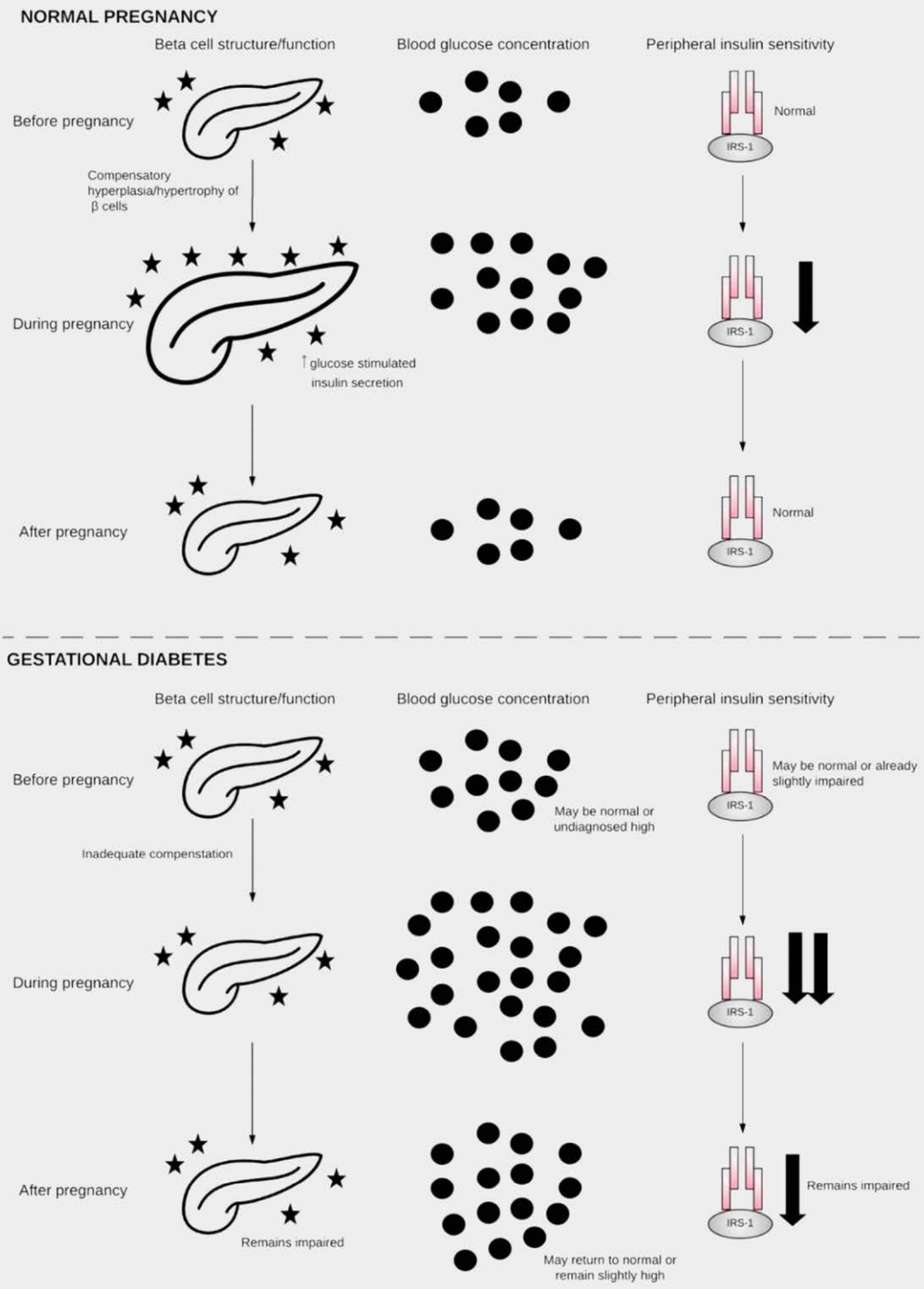
Protein: Amino acid transport across the placenta is also a key factor in fetal growth. GDM is linked to an increase in System A and L activity. Pro-inflammatory cytokines like TNF-α and IL-6 can also influence them. Excess protein consumption may potentially lead to GDM through altered amino acid transport [17].

Lipids: Finally, while GDM has traditionally been thought of as a hyperglycemic condition, the growth in obesity-related GDM has forced a greater focus on the involvement of hyperlipidemia in the disease. When compared to glucose pathways (9 %), lipid pathways (67 %) account for the majority of changes in placental gene expression in GDM [18]. When compared to T1DM, GDM is related to preferential activation of placental lipid genes. GDM has been linked to various abnormalities in the placenta in addition to these changes in placental transport. GDM has been linked to global DNA hypermethylation in the placenta in recent investigations [19].

Epidemiology

Gestational diabetes mellitus (GDM) is one of the most common endocrinopathies in pregnancy that can be characterized as hyperglycemia at any time in pregnancy based on defined thresholds [20]. Placental production of diabetogenic hormones in late pregnancy such as human placental lactogen, leads to progressive insulin resistance; when β-cell hyperfunctionality adaptation during pregnancy fails to compensate maternal insulin resistance, it may lead to gestational diabetes [21]. It is well documented that GDM is linked with adverse maternal and neonatal outcomes along with lifelong risk of obesity and diabetes in both mother and child later in life.

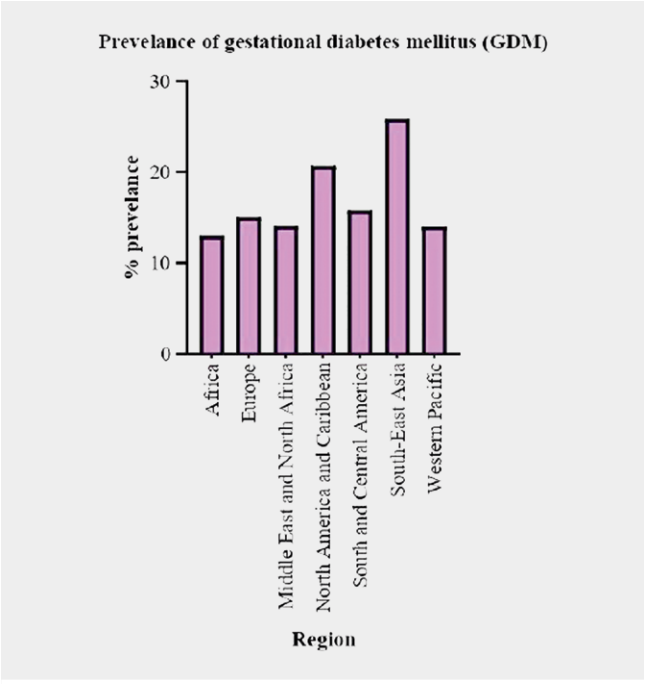
It is estimated that GDM affects around 7–10 % of all pregnancies worldwide; however, it is difficult to estimate the prevalence as rates differ between studies due to prevalence of different risk factors in the population, such as maternal age, BMI, ethnicity, lifestyle, comorbidities, socioeconomic status, substance abuse, etc. Moreover, testing methods, screening strategies, and even glycemic thresholds for GDM remain the subject of concern and thus prevalence of gestational diabetes mellitus widely varies depending on the population studied and the diagnostic criteria used. The data source used also leads to substantive divergence in the reporting



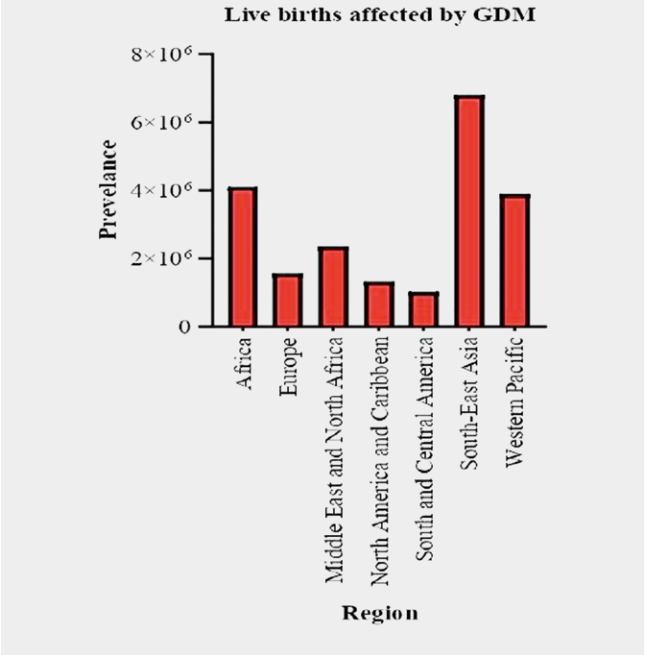
▶ **Fig. 2** Relationship between β-cell dysfunction, insulin resistance, and GDM.

of preponderance of GDM. Accurate estimate of GDM prevalence is essential for planning, evaluation, policy development, and research. We aimed to determine the prevalence of GDM using a variety of data sources and to evaluate the correspondence between different data sources, to generate common end points for the same, the information was gathered using standard sources of references, which included IDF, WHO, CDC, ADA, and national health surveys.

▶ **Fig. 3** indicates the % prevalence of GDM in the global division of 7 regions out of the total pregnancies, compiled from various



▶ **Fig. 3** Prevalence of gestational diabetes mellitus (GDM).



▶ **Fig. 4** Live births affected by GDM.

authenticated, time tested sources with the numerical percentage prevalence data.

▶ **Fig. 4** indicates the total number of live births, which are directly affected by GDM, in the global division of 7 regions out of the total pregnancies, compiled from various authenticated, time tested sources with the numerical values.

Risk Factors

On reviewing various critically acclaimed articles, the well-documented risk factors for GDM were identified and they are discussed below to help identify women at risk of gestational diabetes at an early stage, which could provide a window for preventive measures. GDM itself being a risk factor for T2DM, they share the majority of the risks involved. The risk factors stated below have differing relative risks on the development of gestational diabetes. The well-documented factors for GDM are advanced maternal age, BMI ≥ 25 kg/m^2, family history of T2DM, macrosomia, cigarette smoking, and non-Caucasian ethnicity. Advanced maternal age and obesity are well-known predictors of GDM, according to a study a pre- pregnancy BMI of > 30 kg/m^2 in women aged from 30–35 years has a stronger effect on GDM, furthermore, gain in BMI from pre-pregnancy to 15–20 weeks of gestation and advanced maternal age are strongly associated with the risk of developing GDM [22]. Heredity as a risk factor for GDM holds a strong pursuit, even though an established genetic background for diabetes mellitus remains unclear, a history of diabetes on the maternal side is quite prominent a risk factor than on the paternal side. The role of genetics on the future risk of diabetes is quite notable pertaining to the fact that phenotypes responsible for glucose homeostasis are heritable [23]. In a heritability estimate study on UK families, it was found that fasting glucose concentration and homeostasis model of pancreatic cell dysfunction has the highest heritability estimate of 0.72 and 0.78, respectively [24]. In all the findings, it is suggested that genetic as well as environmental factors play an important role in gestational diabetes. Macrosomia termed by Spellacy et al. [25], is a new-born with a birth weight of 4–4.5 kg, and a woman giving birth to a macrosomic baby has a higher chance of developing diabetes in the future compared to women giving birth to an infant that does not exceed the 90th percentile of normal gestational weight. Fetuses with higher maternal glucose receive excess glucose via the placenta and hence they develop a unique pattern of overgrowth resulting in deposition of subcutaneous fat in the abdominal and interscapular region. Among these factors, diet and physical activity also play an indispensable role, the obvious consumption of high fat and sugary food leads to increased blood glucose. Smoking and the drinking status of the parents before and during pregnancy could result in a higher risk of GDM [26]. Polycystic ovary syndrome is an endocrine disorder in females, and insulin resistance has been observed in 50 % of women with PCOS, they have a four-fold risk of T2DM than normoglycemic women and are at a higher risk of GDM. In 2012, Marshall [27] associated PCOS with hyperinsulinemia, and it has become clear hyperandrogenism and impaired glucose tolerance are correlated. GDM and T2DM are both increasing on a large scale in the Asian and Middle Eastern and African countries, resonating an endemic even. According to a combined study by WHO (World Health Organisation) and IADPSG (The International Association of Diabetes and Pregnancy Study Groups) [28], the percentage of GDM prevalence in East Asian, South Asian, and African countries is remarkably higher than European and North American region. In a study by Savitz et al. [29] conducted in New York City where ethnic diversity is increasing on the go, birth reports and hospital data collected from 1995 to 2015 show that non-Caucasian population born in their native country and then

migrating to the U.S. had an elevated risk at developing GDM compared to the ones born in the U.S.

Diagnostic Criteria

Usually, any woman with a family history of diabetes or hyperglycemia will be screened for an IGT (impaired glucose tolerance) during 24–36 weeks of pregnancy period because hormonal changes during pregnancy can lead to impaired insulin production in the body, which is tolerated well by some women but could result into gestational diabetes in others. Glycosuria, polyuria, frequent thirst, obesity are the early signs of gestational diabetes, and any women showing these symptoms should be checked for hyperglycemia. In 2014, the USA Preventive Service Task Force recommended screening every woman post 24 weeks of pregnancy for GDM as only screening women with a symptom and history of hyperglycemia failed to identify half of the women with GDM [30]. The GDM screening guidelines of the USA and Canada agree on a two-step approach, including an initial test with 50 g 1-hour plasma glucose test (positive test if > 140 g/dl). Women with a positive result are f ollowed up on the 100 g OGTT, the women having 2 or more than 2 abnormal values of plasma glucose are diagnosed with GDM. The guidelines followed by the UK and Australia include an initial test with 75 g 2-hour OGTT and a fasting blood glucose ≥ 126 mg/dl and a 2- hour ≥ 140 g/dl is taken as a diagnosis for GDM. The WHO recommends a 75 g OGTT irrespective of the last meal with a threshold value of 2-hour PG > 140 mg/dl for GDM [31]. The ADA has recommended the use of either the one or two-step approach at 24–28 weeks of gestation in pregnant women without the diagnosis of diabetes.

The 75 g 2-hour test is a widely accepted standard because of convenience, it has also shown more sensitive results in predicting pregnancy complications like gestational hypertension, preeclampsia, and macrosomia compared to the 100 g 3-hour test [32]. The fact behind its increased sensitivity is that it requires only one elevated glucose value to diagnose GDM but the 100 g 3-hour test requires two abnormal glucose values. In this group of gravida at 24–28 weeks' gestation, the one-step strategy entails doing a 75 g OGTT with plasma glucose measurement when the patient is fasting and at 1 and 2 hours. After an overnight fast of at least 8 hours, perform the OGTT in the morning. When any of the following criteria are met or surpassed, GDM is diagnosed, 92 mg/dl (5.1 mmol/l) fasting, 180 mg/dl (10.0 mmol/l) after 1 hour, 153 mg/dl (8.5 mmol/l) after 2 hours. A 1-hour (nonfasting) plasma glucose measurement following a 50 g oral glucose load is used in women between 24–28 weeks of pregnancy who have never been diagnosed with diabetes, then perform a fasting 100 g OGTT if the plasma glucose level after 1 hour is 130 mg/dl, 135 mg/dl, or 140 mg/dl (7.2 mmol/l, mmol/l, or 7.8 mmol/l, respectively). If at least two of the following four plasma glucose values are attained or exceeded, GDM is diagnosed: 95 mg/dl (5.3 mmol/l) while fasting 180 mg/dl (10.0 mmol/l) after 1 hour, 155 mg/dl (8.6 mmol/l) after 2 hours, 140 mg/dl (7.8 mmol/l) after 3 hours [33].

The different criteria used for GDM screening bring out individual outcomes. O'Sullivan and Mahan were the first ones to identify a need for diagnostic criteria for GDM and create one, based on their study on 752 women by performing a 3-hour 100 g OGTT on them. Further, O'Sullivan suggested a 50 g 1-hour OGTT for GDM. O'Sullivan and Mahan's test used whole blood instead of plasma for measuring glucose concentration [34]. NDDG (National Diabetes Data Group) identified this drawback and suggested using plasma instead of whole blood pertaining to the fact that plasma has 11 % more glucose concentrations than whole blood [35]. Following this, Carpenter and Coustan replaced the calorimetric assays with enzyme assays which further brought down the NDDG cut-offs and if any two or more values exceeded the cut-off, it would result in the diagnosis of GDM [36]. In 1999, WHO suggested that the diagnosis of GDM was made on a single cut-off value of 140 gm/dl after a 2-hour 75 g post glucose concentrations were measured after overnight fasting. This test became inconvenient as it required antenatal women to fast on the day of testing and it was against the belief system at that time. Therefore, in 2016 DIPSI (Diabetes in Pregnancy Study Group in India) came out with an upgraded version of WHO, which included a 75 g 2-hour OGTT plasma glucose that was measured in a non-fasting state during the 24–28 weeks of pregnancy irrespective of the last meal [37]. The WHO also claimed it as an efficacious test similar to the fasting test. This was followed by the HAPO (Hyperglycemia and Adverse Pregnancy Outcomes) study in 2008, which explained that varying degrees of maternal hyperglycemia can result in adverse outcomes from the pregnancy but they were not as severe as in overt diabetes [1]. Soon, in 2010, IADPSG (International Association of Diabetes and Pregnancy Study Group) after reviewing the HAPO study, formed international guidelines to unify the diagnostic criteria for GDM globally, but soon it was criticized as the HAPO study was based mainly on the Caucasian population and left out other ethnicities, especially Asian [38].

▶ **Table 1** [39] shows comparison of different diagnostic criteria for GDM (NDDG: National diabetes data group, ADA: American diabetic association, WHO: World Health Organisation, ADIPS: Australian Diabetes in Pregnancy).

Risk of Subsequent T2DM after GDM

GDM occurs in women with a genetic or historical predisposition of glucose intolerance, it leads to the fact that the affected women have the inability to maintain the required plasma glucose concentration in the body, so this leads to future diabetes mellitus with increasing age, glucose intolerance also advances. With advancing maternal age and a sedentary lifestyle, GDM has become more common. Studies have found out that GDM prevalence is 7 % worldwide and it has increased up to 30 % in recent decades, becoming one of the most common complications of pregnancy. Women with GDM have a 7-fold risk of developing T2DM later in life which institutes the fact that increasing prevalence of GDM can fuel the T2DM epidemic [40]. In a study by Ornoy, Asher et. al. [41], the probability of development of diabetes was 3.7 % at 9 months, 4.9 % at 15 months, and 13.1 % at 5.2 years, women with GDM had a higher rate of developing overt diabetes in the early 9 months compared to after years. This led to the fact that most of these women had undiagnosed T2DM, which was identified during pregnancy. Women with diagnosed diabetes before pregnancy suffer from lower birth complications than women with undiagnosed diabetes. GDM has been associated with various short and long-term health complications, both fetal and maternal. It increases the short-term maternal risk of polyhydroamnios, pre-eclampsia,

▶ **Table 1** Comparison of different diagnostic criteria for GDM.

Criteria	NDDG	Carpenter and Coustan	ADA	WHO	ADIPS
Glucose	100	100	75	75	75
FPG (mg/dl)	105	95	95	126	99
OGTT (mg/dl)					
1 h level	190	180	180	–	–
2 h level	165	155	155	140	144
3 h level	145	140	–	–	–
Diagnostic criteria	2 of 4	2 of 4	2 of 3	1 of 2	1 of 2

prolonged labor, obstructed labor, caesarean section, uterine prolapse, postpartum hemorrhage, and infections [31]. Even though serum glucose levels return to normal after delivery it can also lead to the fetal risk of spontaneous abortion, intrauterine death, stillbirth, congenital malformation, shoulder dystocia, birth injuries, neonatal hypoglycemia, infant respiratory distress syndrome, and macrosomia [42]. On top of T2DM, it can further lead to long-term health complications for both mother and offspring. These long-term complications include metabolic syndrome, malignancies, cardiovascular disorders, renal diseases, and gestational diabetes in the subsequent pregnancy. The long-term complications on the offspring can be T2DM, obesity, and neuropsychiatric disorders like sleep apnea, autistic spectrum disorders, cerebral palsy, and infantile spasms [43].

Prevention of GDM

Prevention of GDM can simultaneously prevent the complications for both mother and the fetus and helps them lead a healthy life.

Diet

Just like any other pregnancy complications, GDM can also be prevented by leading a healthy life and leading a healthy life starts with a healthy diet. A healthy diet comprises of different varieties of food like proteins, carbohydrates, fats and vitamins in a specific quantity, also termed as balanced diet. Higher intake of fruits/fruit fiber pre-pregnancy is associated with decreased risk of GDM. Higher intake of potato is associated with increased risk of GDM due to its high glycemic index. Replacing two potato servings per week with other vegetable types, legumes or wholegrain foods resulted in a 9 %, 10 % and 17 % of reduction in GDM risk respectively. Higher consumption of sugar sweetened beverage (SSB) was associated with risk of GDM. Intake of protein from animal origin increased the risk of GDM by 50 % when compared to intake of protein sourced from vegetables which was protective by 30 %. Replacing 5 % energy of animal protein for protein of plant origin reduced the risk of GDM by 51 % [44]. Increased instances of fast food intake pre pregnancy was associated with a significant increased risk or incidence of developing GDM. Luoto et al. [45], explained in their article the protective role of probiotics in pregnancy by modifying intestinal microbiota, altering the fermentation of dietary polysaccharides, improving the function of intestinal barrier and their capability to regulate the inflammatory pathways resulted in a reduced risk of maternal and fetal heperglycemia, the gut microbiota is recently associated with setting the tone of inflammation in the body, which modulated the host's sensitivity towards insulin. Mediterranean diet was the most consistently reported protective diet for protection against GDM [46]. Complying with a diet with higher AHEI 2010 score was associated with a decreased risk of GDM by 19 % or 46 % [47]. A greater adherence to Dietary Approaches to Stop Hypertension (DASH diet) was linked with a 34 % reduction in GDM risk. A randomized control trial compared the pregnancy outcomes of normal diet and DASH diet mothers, DASH diet mothers not only required low insulin therapy post-delivery, but also resulted in normal birth weight infants, lower caesarean sections and lower HbA1c levels pre and postgestation in mothers. Lowering the intake of foods rich in high heme iron, sugar sweetened cola, potatoes, fatty foods, and sweets can reduce the risk of GDM, especially among the high-risk population and before getting pregnant [48].

Maintaining a Healthy Lifestyle

Lifestyle adjustment, in addition to diet, is an equally essential element in reducing the incidence of GDM. Exercising or engaging in a physical activity is a vital part of maintaining a healthy body weight. Exercise helps the body to become more sensitive to the insulin and helps regulate blood sugar levels effectively. At least 30 minutes of moderate-intensity exercise 4–5 days a week reduces the risk of developing GDM [49]. Moderate-intensity exercise is an exercise that causes sweating. For a person living sedentary lifestyle, try starting with brisk-walking, climbing stairs, active leisure activities like hiking, gardening, or playing with children outdoors and swimming. Cardio exercises can also be involved. A study by Badon and colleagues [47] stated that engaging in Leisure Time Physical Activity (LTPA) pre and during pregnancy was associated with 46 % reduction in GDM risk. Indulging in healthy diet, physical activity, not smoking, and maintaining a low stress level were associated with a lower risk of GDM. The study also stated that women without any of the four healthy lifestyle outcomes were at 4.43 times higher risk of GDM. Women with all 4 healthy lifestyle outcomes were 35 % less likely to develop GDM compared to women with 3 or less components. Out of all the four components, non-smoking was the most significant factor associated with

development of GDM. Education and counselling of the mother regarding lifestyle changes, fetal health evaluation, diet, exercise and diabetes screening plays a crucial role in its prevention, although there are no standard guidelines for the same.

Post-Delivery Care

Post-delivery care is as important as care taken before and during pregnancy. Some of the same risk factors that put you in risk of getting GDM can also increase your chances of develop T2DM later in life. And if you have GDM, the risk of developing T2DM after your pregnancy rises. Following the same healthy diet and exercise plan post pregnancy and getting back to a healthy weight will lower your risk of developing T2DM in future.

Conclusion

With the current amount of knowledge, GDM can be addressed as a multifactorial and complex process that can evolve from various mechanisms. Diabetes in developing and developed nations is on a rise and leading up to become an epidemic, the prevalence of GDM is increasing in populations worldwide. The Asian, Middle Eastern, North African, and Western pacific regions are at a higher prevalence of diabetes compared to Europe and America but due to lack of uniform assessing techniques worldwide, it becomes complicated to compare data worldwide. Screening of diabetes antepartum provides an insight into the women's future risk of overt diabetes. Given the established association between GDM and T2DM, GDM is a vicious cycle that leads to the onset of diabetes in the family at a young age. G DM leads to poor consequences on the health of the mother and offspring as well. Half of the women are not aware of their glucose intolerance until they have their index pregnancy and glucose screening inform them about it; also with early intervention, proper treatment, and diet, many of the short and long-term effects of GDM can be avoided. The subsequent risk of T2DM after GDM can be reduced with regular follow-ups postpartum. Future studies should look for an internationally accepted diagnostic pattern for GDM.

Conflict of Interest

The authors declare that they have no conflict of interest.

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