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The Increasing Prevalence of Diabetes in Pregnancy

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SYNOPSIS

We review studies published in the past 10 years that examine the prevalence and trends in the prevalence of gestational diabetes mellitus (GDM). The prevalence of GDM in a population is reflective of the prevalence of type 2 diabetes in that population. In low-risk populations, such as those found in Sweden, the prevalence in population-based studies is lower than 2% even when universal testing is offered, while studies in high-risk populations, such as the Native American Cree, Northern Californian Hispanics and Northern Californian Asians, reported prevalence rates ranging from 4.9% to 12.8%. Prevalence rates for GDM obtained from hospital-based studies similarly reflect the risk of type 2 diabetes in a population with a single hospital-based study in Australia reporting prevalences ranging from 3.0% in Anglo-Celtic women to 17.0% in Indian women. Finally, of the eight studies published that report on trends in the prevalence of GDM, 6 studies report an increase in the prevalence of GDM across most racial/ethnic groups studied. In summary, diabetes during pregnancy is a common and increasing complication of pregnancy.

Keywords

gestational diabetes mellitus; prevalence; trends; diagnostic criteria

INTRODUCTION

As the incidence of diabetes continues to rise and increasingly affects individuals of all ages, including young adults and children, women of childbearing age are at increased risk of diabetes during pregnancy(1–7). The lifetime risk of diabetes among the cohort of individuals born in the United States in 2000 was estimated to be 33% in males and 39% in females based on information obtained from the National Health and Nutrition Examination Surveys (NHANES) conducted 1984–2000(8). Moreover, the estimated lifetime risk of diabetes was higher at birth and throughout life for ethnic and racial minority groups than for non-Hispanic whites and for women when compared to men(8). The estimated lifetime diabetes risk at birth ranged from 31.2% in non-Hispanic white women to 52.5% in Hispanic women and from 26.7% in non-Hispanic white men to 45.4% in Hispanic men(8).

The epidemic of diabetes is not limited to western countries, but reaches worldwide affecting individuals in countries such as India and China(9–11). A recent study estimates the global prevalence of diabetes in 2000 at 2.8%, translating into 171 million individuals with diabetes,

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and projects that in 2030 the prevalence will be 4.4%, translating into 366 million individuals with diabetes worldwide(9). The increased prevalence is attributed to the aging population structure, urbanization, the obesity epidemic and physical inactivity.

At first glance, the obesity epidemic driven by changes in lifestyle appears to be the driving force behind the increased prevalence of diabetes. The current epidemic of obesity and overweight is widespread, affecting both children and adults of many ethnic backgrounds in North America and internationally(12,13). In each consecutive NHANES survey starting with NHANES I, conducted from 1971 to 1974, through completion of the most recent NHANES survey cycle, conducted from 1999 to 2002, there has been a marked increase in the prevalence of obesity in both children and adults across all ethnic, gender, and age strata(14–18). In contrast to diabetes where both men and women of minority populations are affected disproportionately, minority women but not men tend to be disproportionately obese. The prevalence of obesity ranged from 50% in non-Hispanic black women to 30% in non-Hispanic white women in NHANES conducted 1999–2000(16). In contrast, in men the prevalence was 27% in non-Hispanic white men, 29% in Mexican American men and 28% in non-Hispanic black men(16).

Traditionally, epidemiologic studies of risk factors associated with type 2 diabetes have focused on adults and characteristics of adult study participants. However, early life exposures are emerging as potentially important risk factors. The “fetal origin of disease” hypothesis proposes that gestational programming may critically influence adult health and disease(19). Gestational programming is a process whereby stimuli or stresses that occur at critical or sensitive periods of development permanently change structure, physiology and metabolism, which predispose individuals to disease in adult life(20). Many animal studies provide support for gestational programming, as do epidemiologic studies of the Dutch Hunger Winter and the “thrifty phenotype” hypothesis which proposes that low birth weight, indicative of poor prenatal nutrition, has an effect on development that manifests itself later in life as an increased risk for a number of chronic diseases(21–37).

In contrast to times of famine, today the intrauterine environment is more likely to expose the fetus to hyperglycemia or excess energy. Obesity prior to pregnancy, and high weight gain during pregnancy, predispose women to gestational diabetes mellitus (GDM) and early onset type 2 diabetes(38–41). Maternal diabetes during gestation exposes the fetus to hyperglycemia, resulting in increased fetal insulin levels that both promote the storage of excess energy as fat and act as a growth factor. Exposure to maternal diabetes early in pregnancy is associated with birth defects, and later in pregnancy is associated with high birth weight, increased childhood and adult obesity and increased risk of type 2 diabetes(42–50). Children exposed *in utero* to maternal diabetes are at higher risk of obesity and diabetes than their unexposed siblings, suggesting that the increased risk to the exposed offspring is not exclusively genetic(51,52). In the Pima Indians, the population with the highest known rate of diabetes, a study found that the increased exposure to diabetes *in utero* and increased weight in children accounted for most of the increased prevalence of diabetes over the past 30 years in Pima Indian children(53).

If the diabetic intrauterine environment is substantially contributing to the obesity and diabetes epidemics, not only will the prevalence continue to increase across all populations, but populations with a high prevalence of diabetes, such as non-Hispanic blacks and Mexican Americans, will continue to be disproportionately affected by these epidemics, resulting in a perpetual widening of health disparities between racial and ethnic groups. For these reasons, it is imperative to understand the trans-generational epidemiology and etiology of diabetes and develop simple, economical, and effective prevention strategies. Because the prevalence of diagnosed diabetes (either type 1 or type 2) prior to pregnancy is addressed in studies of the increasing prevalence of diabetes, the current review is focused on GDM defined as glucose

intolerance with onset or first recognition during pregnancy. GDM is a common complication of pregnancy and often a precursor of type 2 diabetes. Therefore, our objectives were to review studies examining the prevalence of GDM as well as studies examining trends in the prevalence of GDM. In this context, we also review the diagnostic criteria for diabetes and GDM and their changes over time.

METHODS

Literature Search

A literature search was conducted in MEDLINE using the following search criteria: "gestational diabetes" as a MeSH term or text word, combined with "epidemiology" as a subheading or MeSH term, "prevalence" as a MeSH term, or "trend" or "screening" as a text word. In addition the search was limited to English language articles published in the last 10 years (July 1st, 1996 through October 1st, 2006). Using these search criteria yielded 1025 articles. The lead author (KJH) reviewed either the abstract or title of these articles to determine if they were suitable to asses either the current prevalence of GDM or trends in the prevalence of GDM. The review was limited to population-based studies that included at least 500 pregnant women or hospital-based studies that included at least 1000 pregnant women with at least 70% of the population being screened for GDM. In addition, articles that assessed GDM trends were required to span at least 3 years. When multiple articles were published on a single population the article containing the most recent information was retained. In addition to conducting the literature search in MEDLINE, reference lists of review articles obtained from the MEDLINE search were reviewed for additional pertinent studies.

Diabetes and GDM, screening and definitions

The definition of diabetes has changed over the past 10 years. Table 1 summarizes the definitions of diabetes commonly employed in recent epidemiologic literature. While the 1985 and 1999 World Health Organization (WHO) criteria require a 2-hour 75g oral glucose tolerance test (OGTT), the 1997 American Diabetes Association (ADA) criteria are focused on fasting glucose, but also recognize a casual or 2-hour 75g OGTT glucose level greater than or equal to 200 mg/dL as diagnostic of diabetes. Therefore, epidemiologic studies based on the ADA criteria may be based exclusively on fasting glucose levels or include information from an OGTT.

The recommended definition of GDM and criteria identifying who should be screened for GDM has varied widely across populations and over time; therefore, we review both screening criteria and diagnostic criteria for GDM employed in recent epidemiologic literature. Table 2 summarizes screening criteria, while Table 3 summarizes widely accepted GDM diagnostic criteria. In summary, recommended screening ranges from selective screening of average and high risk individuals to universal diagnostic testing of the entire population dependent on the risk of diabetes in the population.

The diagnostic criteria for GDM have evolved over time and are not agreed upon internationally; therefore, definitions of GDM utilized in the epidemiologic literature vary considerably. Notably, at the 4th International Workshop Conference on GDM it was agreed that the Carpenter and Coustan(54) (C & C) criteria should replace the National Diabetes Data Group(55) (NDDG) criteria, resulting in a significant lowering of the thresholds and an increase in the prevalence of GDM. Because a number of organizations currently endorse the C & C criteria(56–58), for consistency throughout the review we refer to the C & C criteria or to the NDDG criteria when they are utilized in different references.

RESULTS

Population-based studies

For purposes of this review, population-based studies were defined as studies which attempted to include a representative sample of the general population in a defined geographical area. Moreover, because the focus for population-based studies was having a representative study population, universal screening or testing for GDM was not required for inclusion in the review. Population-based studies of more than 500 individuals are summarized in Table 4. The prevalence of GDM varied depending upon the diagnostic criteria employed in the study, whether the study was retrospective or prospective, the source of the study data, as well as the country of residence, ethnicity and racial group of the study participants. In general, we observed lower prevalence rates in retrospective studies utilizing preexisting databases or routinely collected health statistics where a clear screening policy for GDM was not in place (59–64), compared to retrospective or prospective studies which report universal screening for GDM.

In studies conducted in North America, the observed prevalence was higher in Asians, African Americans, Native North Americans from Canada, and Hispanics than in non-Hispanic whites (39,60,61,65–69). In a retrospective cohort study of the Kaiser Permanente Medical Care Group of Northern California, where 93.5% of the population was screened for GDM, the prevalence ranged from 2.5% in white women to 5.7% in Asian women using the NDDG criteria and from 3.9% in white women to 8.3% in Asian women using the C & C criteria (65). In the Nurses Health Study II, which relied on self-reported diagnosis, the observed prevalence was over 10% in African Americans (10.6%) and Asians (10.5%), and around 5% in whites (4.8%) (39). Finally, in retrospective studies conducted in Native North Americans in Canada, the prevalence based on NDDG criteria ranged from 8.4% to 12.8%(61,67–69). The single study conducted in South America was a prospective study conducted in Brazil in a diverse population and reported a prevalence of 2.4% based on ADA(56) criteria using the 2-hour 75g OGTT diagnostic criteria and 7.2% based on WHO criteria(70).

Population-based studies conducted in northern Europe used a 2-hour 75g OGGT to diagnose GDM; however, varying diagnostic cutpoints were employed. Using the 2-hour 75g OGTT, observed prevalence rates in the United Kingdom, Holland, Sweden and Denmark ranged from 0.6% in Dutch women to 3.6% using local criteria in a Danish population(62,63,71–75). In two studies conducted in Italy, a 3-hour 100g OGTT using the C & C criteria following universal screening was employed to diagnose GDM. In the earlier study conducted in north-west Tuscany the prevalence was 6.3%(76), while in the later study conducted in a volunteer population in Sardinia the prevalence was 22.3%(77).

Reported prevalence rates in population-based studies in Turkey, Iran, Bahrain, Ethiopia and India ranged from 1.2% in Turkey (NDDG criteria following universal screening) to 15.5% in Bahraini women (C & C with a 3-hour 75g OGTT following universal screening) (78–83). In a retrospective study in Australia, which included all singleton deliveries in Victoria in 1996 and utilized routinely collected information in two databases, the prevalence was 3.6% in non-Aboriginal women and 4.3% in Aboriginal women(64). In a study conducted in 6 urban districts in Tianjin, China, using 1999 WHO diagnostic criteria and universal screening, the prevalence was 2.3%(84). Finally, in a study conducted in Japan, using the Japanese Society of Obstetrics and Gynecology (JSOG) criteria for GDM and universal screening, the prevalence was 2.9% (85).

Hospital-based studies

Hospital-based studies of more than 1000 unselected individuals, where universal screening or testing was employed and at least 70% of the population was screened for GDM, are summarized in Table 5. Similar to the population-based studies, in the hospital-based studies the prevalence of GDM varied depending upon the diagnostic criteria employed in the study, whether the study was retrospective or prospective as well as the country of residence, ethnicity and racial group of the study participants. Three of the hospital-based studies directly compare GDM prevalence rates based on NDDG and C & C criteria(86–88). In these three studies, NDDG rates range from 3.2% in a study conducted in Mexico(86) to 8.8% in a study conducted in Spain(87) with corresponding C & C rates ranging from 4.1% to 11.6%(86–88).

The hospital-based studies conducted in the United States diagnosed GDM based on a 3-hour OGTT and report prevalence rates ranging from 2.7% using the NDDG criteria to 6.8% in a largely Mexican American population using the C & C criteria(89–91). In a Canadian study at the Saskatoon Royal University Hospital, using the NDDG criteria, the prevalence was 11.5% in the Aboriginal population and 3.5% in the non-Aboriginal population(92). In a study conducted at the University Hospital in Monterrey, Mexico which compared a number of diagnostic criteria the prevalence was 3.2%, 4.1%, and 8.7% based on NDDG, C & C and 1999 WHO diagnostic criteria, respectively(86). In Europe, hospital-based studies were conducted in Spain and Italy. Three studies in Spain reported prevalence rates ranging from 3.3% to 8.8% using NDDG criteria(87,93,94). The two Italian studies report prevalence rates of 4.6% and 8.7% based on C & C criteria(88,95).

Reported prevalence rates in hospital-based studies in Turkey, Iran, Pakistan, India and Sri Lanka are between 4.1% and 4.7%, with the exception of the study conducted in India, which used the 1999 WHO diagnostic criteria and reports a prevalence of 18.9%, as well as the study conducted in Turkey, which reports a prevalence of 6.6% using the C & C criteria(96–100). Both hospital-based studies conducted in Australia employed the Australasian Diabetes in Pregnancy Society (ADIPS) criteria, with one reporting an overall prevalence of 5.2%(101) and the second reporting prevalence rates as low as 3.0% in Anglo-Celtic participants and as high as 10.0, 15.0 and 17.0% in Aboriginal, Chinese and Indian participants, respectively (102). A single hospital-based study conducted in Japan reported a prevalence of 1.8% based on the JSOG diagnostic criteria(103).

Trends in the prevalence of GDM

Eight retrospective studies conducted in the past 10 years in the United States, Canada and Australia examine trends in the prevalence of GDM (Table 6) (104–111). Three of the four studies conducted in the United States report either universal screening criteria in place and/or evidence of consistent screening in the population, with a screening rate of 96 to 98% in the Kaiser Permanente of Colorado study and 86.8% in the Northern California Kaiser Permanente study(104–106). Each of the four studies conducted in the United States reports a statistically significant increase in the prevalence of GDM or diabetes during pregnancy during the study period(104–107). The Kaiser Permanente study conducted in a population representative of the Denver metropolitan area reports a prevalence increase from 2.1% in 1994 to 4.1% in 2002, based on the NDDG diagnostic criteria throughout the study(104). In addition, they report a greater increase for minorities than whites(104). Similarly, the Kaiser Permanente study conducted in a population representative of Northern California reports a prevalence increase from 5.1% in 1991 to 7.4% in 1997, which leveled off through 2000 at 6.9% based on the C & C diagnostic criteria(105). A study conducted on all women with singleton deliveries in New York city, where universal screening criteria have been practiced since the 1980s, reports a prevalence of 2.6% in 1990 increasing to 3.8% in 2001, with significantly increasing rates of GDM in all major racial/ethnic groups except non-Hispanic whites(106). The final study

conducted in the United States utilized birth records of American Indian and white mothers in Montana and North Dakota for the years 1989 through 2000(107). In both states a statistically significant increase in prevalence of GDM was identified in whites, from 1.8 to 2.6% in Montana and from 1.6 to 3.2% in North Dakota(107). In contrast, in the smaller population of American Indians within each state, a statistically significant increase in prevalence of GDM was reported for Montana (from 3.1 to 4.1%), but not North Dakota (from 3.8 to 4.8%)(107).

The study conducted in Canada included over 100,000 perinatal records from 39 hospitals in Northern and Central Alberta and used NDDG criteria and universal screening throughout the study period(108). The study reports a prevalence ranging between 2.2 and 2.8% between 1991 and 1997 with a non-significant test for linear trend for the duration of the study(108). One of the three studies conducted in Australia is the only study to report a decrease in the prevalence of GDM over time(110). The study was conducted in far North Queensland using a hospital database with 7,567 entries(110). Using ADIPS diagnostic criteria and universal screening, with 78 to 85% of the population being screened throughout the study period, prevalence was 14.4% in 1992 and had dropped to 5.3% by 1996(110). Improvement in medical care and a dietary intervention were given as potential explanations for the decline in GDM during the study period(110). A second study conducted in Australia included all deliveries in South Australia between 1988 and 1999 and reports an annual rate increase of 4.7% in the non-Aboriginal population, but not in the Aboriginal population (non-statistically significant annual rate increase of 0.5%)(109). Finally, using information on over 40,000 women attending Mercy Hospital for Women in Melbourne, Australia, a statistically significant increasing prevalence from 2.9% (1971–1980) to 8.8% (1991–1994) is reported(111).

DISCUSSION

In this study, we review studies published in the past 10 years that examine the prevalence and trends in the prevalence of GDM. In summary, the prevalence of GDM in a population is reflective of the prevalence of type 2 diabetes in that population; therefore, ethnic and racial populations with a high prevalence of type 2 diabetes are at higher risk of GDM. In low-risk populations such as those found in Sweden the prevalence in population-based studies is lower than 2% even when universal testing is offered (71–73), while studies in high-risk populations such as the Native American Cree, Northern Californian Hispanics and Northern Californian Asians reported prevalence rates based on NDDG diagnostic criteria following universal screening ranging from 4.9% to 12.8%(61,65,67–69). Prevalence rates for GDM obtained from hospital-based studies similarly reflect the risk of type 2 diabetes in a population. A single hospital-based study in Australia using ADIPS diagnostic criteria and universal screening reports prevalences ranging from 3.0% in Anglo-Celtic women to 17.0% in Indian women (102). Finally, of the eight studies published in the past 10 years that report on trends in the prevalence of GDM(104–111), one study reports a significant decline in the prevalence of GDM(110), one study reports no significant change in the prevalence of GDM(108), and 6 studies report an increase in the prevalence of GDM across most racial/ethnic groups studied (104–107,109,111).

A number of factors influence the prevalence of GDM identified in a population and make it difficult to compare prevalences across populations. In the United States the definition of GDM and screening policies concerning GDM have changed considerably in the past 20 years and still vary substantially. Despite four international conferences aimed at developing a consensus definition for GDM worldwide, the definition and screening criteria for GDM continue to vary, making it difficult to compare prevalences between countries. A critical change in the definition of GDM occurred at the 4th International Workshop conference on GDM in 1997, endorsed by the ADA, when it was largely agreed that the C & C criteria should replace the NDDG criteria, significantly lowering the accepted cutpoints and therefore raising the prevalence of

GDM(58). Finally, because GDM encompasses undiagnosed type 2 diabetes prior to pregnancy, the definition, screening strategies and awareness of type 2 diabetes in a population ultimately influences the observed prevalence of GDM in a population. This is of particular importance during the past decade because the diagnostic criteria for diabetes and recommended screening practices have changed in the United States and internationally, namely the threshold for a fasting glucose level diagnostic of diabetes was lowered from 140 mg/dL to 126 mg/dL(112,113).

In addition to the varied definitions and screening policies for GDM and diabetes there are a number of factors which make it difficult to compare GDM prevalence rates across populations and over time. Increased maternal age at delivery is a strong risk factor for GDM. Hence, a contributing factor to increased prevalence rates of GDM in a given population over time, or differences observed between populations, is increased maternal age at delivery. Because we are unable to age standardize our prevalence rates across studies, we are unable to determine the impact of maternal age at delivery on prevalence rates across studies. However, increasing maternal age at delivery is one factor likely influencing the increasing prevalence of GDM in developed countries. Maternal age at delivery is also likely to vary and affect prevalence differences when comparing developed and undeveloped countries. Because the prevalence of GDM in a population reflects the prevalence of type 2 diabetes in a population, and certain racial and ethnic groups are at increased risk of type 2 diabetes, a second factor which may influence changes in prevalence overtime in a given population is a change in the racial/ethnic composition of that population. While racial/ethnic group specific prevalences of GDM reflect the prevalence within a specific segment of the population, they may fail to reflect the broader public health impact of GDM as the overall population prevalence increases.

Changes in lifestyle including decreased physical activity and increased caloric consumption continue to fuel the obesity epidemic. Obesity, often accompanied by insulin resistance, is a strong risk factor for GDM and likely contributes to the increasing prevalence of GDM. The National Longitudinal Survey of Youth, a prospective cohort study of children aged 4 to 12 years carried out between 1986 and 1998 in the United States, indicated that the prevalence of overweight children increased significantly and steadily throughout the study(114). By the end of the study in 1998, obesity affected an estimated 21.5% of African American children, 21.8% of Hispanic children and 12.3% of non-Hispanic white children(114). In the 2003–2004 NHANES, 17.1% of individuals ages 2 to 19 years were overweight; more than triple the percent in 1980(115). In adults of childbearing age the prevalence of obesity also continues to rise; in 18- to 29-year olds the prevalence of obesity rose from 7.1% in 1991 to 12.1% in 1998 in the Behavioral Risk Factor Surveillance System survey (116).

As obesity and diabetes increasingly affect young adults and women of childbearing age, understanding the public health impact of diabetes during pregnancy and its affect on infant health becomes important. Exposure to maternal diabetes later in pregnancy is associated with high birth weight, increased childhood and adult obesity and increased risk of type 2 diabetes (42,44,45,48,117–121); therefore, the diabetic intrauterine environment may not only be a result of the obesity and diabetes epidemics, it may be partially responsible and currently fueling the epidemics. Moreover, because both obesity and diabetes disproportionately affect minority women including minority women of childbearing age(8,16), if the intrauterine environment is contributing to the epidemics, it perpetuates and widens health disparities between racial and ethnic groups.

The population health impact of GDM is not limited to exposed offspring, but affects maternal health as well. Once diagnosed with GDM, a woman has a substantial chance of developing type 2 diabetes following delivery, with some studies reporting a 5 year cumulative incidence rate of over 50%(122). Moreover, because childbearing women are relatively young, women

with GDM who develop overt diabetes acquire it at a young age, substantially increasing their lifetime risk of developing complications from diabetes. The Diabetes Prevention Program was one of several clinical trials which indicates that either through diet and exercise, or with the aid of a pharmacological agent, it is possible to lower the incidence or delay the onset of diabetes among individuals at high risk of the disease(123–126). Women with GDM, because of their high diabetes risk and young age, are ideally suited to be targeted for lifestyle or pharmacological interventions to delay or prevent the onset of overt diabetes(123–126). Moreover, because women with GDM are of childbearing age, preventing or delaying the onset of overt diabetes not only improves the woman's health, but protects future offspring from the harmful effects of elevated glucose levels in pregnancy(127,128).

In summary, diabetes during pregnancy is a common and increasing complication of pregnancy that differentially affects racial and ethnic minority populations dependent upon their underlying risk of diabetes. Hence, an important public health priority, consistent with reducing health disparities between racial and ethnic groups, is prevention of diabetes, starting with maternal health pre- and post-conception.

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Table 1

Definitions of diabetes commonly employed in recent epidemiologic literature.

WHO, 1985(129)	Fasting glucose ≥ 140 or a 2hr 75g OGTT glucose ≥ 200
WHO, 1999(113)	Fasting glucose ≥ 126 or a 2hr 75g OGTT glucose ≥ 200
ADA, 1997(112)	Focused on a fasting glucose ≥ 126, but also recognizes a casual or 2hr 75g OGGT ≥ 200; therefore, epidemiologic studies based on the ADA criteria may be based exclusively on fasting glucose levels or include information from a 2hr 75g OGTT.

All criteria are stated in mg/dL and use venous plasma. WHO, World Health Organization; ADA, American Diabetes Association; OGTT, oral glucose tolerance test

Table 2

Gestational diabetes mellitus screening criteria.

	Target Population	Recommended Screening Test
WHO, 1985 and 1999 Reports of the WHO Consultation on the Diagnosis and Classification of Diabetes Mellitus(113,129)	Not specified	**Non-High Risk:** diagnostic 2hr 75g OGTT at 24th–28th week of gestation **High Risk:** Also test early in pregnancy.
EASD, 1991(130)	Universal	A random blood glucose ≥ 108 when fasting or 2 hours after food or ≥ 126 when within 2 hours of food at initial prenatal visit and 28 weeks gestation
ACOG, 1994(131)	From universal to selective, dependent upon the risk of diabetes in the population	**Non-High Risk:** 1hr 50g GCT ≥ 140 or ≥ 130 **OR** diagnostic 3hr 100g OGTT at 24th–28th week of gestation **High Risk:** Also screen as early as possible in pregnancy.
ADA, 1997(112)	'Low Risk*' women do not need to be screened	1hr 50g GCT ≥ 140 at 24th–28th week of gestation
ADA(56) and ACOG(57), post 1997 4th International Workshop Conference on GDM(58)	**Selective:** 'Low Risk†' women do not need to be screened	**Average Risk:** 1hr 50g GCT ≥ 140 or ≥ 130 at 24th–28th week of gestation **OR** diagnostic 2hr 75g OGTT **High Risk:** Also screen as early as possible in pregnancy.
ADIPS, 1998(132)	Universal	1hr 50g GCT ≥ 140 **OR** 1hr 75g GCT ≥ 144 at 26th–28th week of gestation

All criteria use venous plasma. ADA, American Diabetes Association; ACOG, ;WHO, World Health Organization; EASD, European Association for the Study of Diabetes; ADIPS, Australasian Diabetes in Pregnancy Society; GCT, glucose challenge test; OGTT, oral glucose tolerance test;

*The ADA (1997) initially defined 'Low Risk' as women meeting the four following criteria: (1) Age less than 25, (2) Not a member of an ethnic group with a high prevalence for DM (e.g., not Hispanic, Native American/Alaskan, Asian/Pacific Islander, African American), (3) Normal prepregnancy body weight (not 20% or more over desired body weight or BMI 27 kg/m2 or more), and (4) No family history of diabetes in first-degree relatives.

†At the 1997 4th International Workshop Conference on GDM, the following two criteria were added to the 'Low Risk' definition: (5) No history of poor obstetric outcome and (6) No history of abnormal glucose tolerance.

Table 3

Gestational diabetes mellitus diagnostic criteria.

	Load (g)	Duration (hours)	Abnormal Values (n)	Fasting, 1-, 2- and 3-hour OGTT Thresholds (mg/dL)
O'Sullivan and Mahan*, 1964 (133)	100	3	≥ 2	90, 165, 145, 125
NDDG, 1979(55) ACOG,1994(131) ADA, 1997(112)	100	3	≥ 2	105, 190, 165, 145
Carpenter and Coustan, 1982 (54)	100	3	≥ 2	95, 180, 155, 140
JSOG, 1984(134)	75	2	≥ 2	100, 180, 150
WHO, 1985(129)	75	2	≥ 1	140, N/A, 140
EASD, 1991(130)	75	2	≥ 1	108, N/A, 162
ADA(56) and ACOG(57), post 1997 4th International Workshop Conference on GDM (58)	75 or 100	2 3	≥ 2 ≥ 2	95, 180, 155 95, 180, 155, 140
WHO, 1999(113)	75	2	≥ 1	N/A, N/A, 140
ADIPS, 1998(132)	75	2	≥ 1	99, N/A, 144

OGTT, oral glucose tolerance test; NDDG, National Diabetes Data Group, WHO, World Health Organization; ADA, American Diabetes Association; ADIPS, Australasian Diabetes in Pregnancy Society; EASD, European Association for the Study of Diabetes; JSOG, Japanese Society of Obstetrics and Gynecology;

* All criteria use venous plasma except for O'Sullivan and Mahan which was defined using whole venous blood.

Table 4

Prevalence of GDM in Population-based studies.

Author	Screening criteria	GDM criteria	Time Frame	Source Population	Country	Ethnic group; n	Prevalence
Rosenberg (59)	Varied depending upon prenatal care received.		Retrospective; 1991–2001	Live singleton New York City births with birth certificate data on prepregnancy weight and weight gain	USA	NHB; 86,908 NHW; 96,581 NHA; 38,570 Hispanic; 107,612	3.7%, Total 3.7%, NHB 2.6%, NHW 6.6%, NHA 3.5%, Hispanic
Ferrara (65)	Universal screening at 24–28 weeks; 1hr 50g GCT ≥ 140; 93.5% screened	C & C NDDG	Retrospective; 1996	Kaiser Permanente Medical Care Group of Northern California; computerized hospitalization records	USA	White; 13,714 AA; 2,345 Hispanic; 5,026 Asian; 4,121	NDDG and C & C: 3.2 and 4.8%, Total 2.5 and 3.9%, White 2.6 and 3.4%, AA 3.4 and 4.9%, Hispanic 5.7 and 8.3%, Asian
Kieffer (66)	Universal screening at 24–28 weeks; 1hr 50g GCT ≥ 140 98.9% of Latinas and 96.6% of AA screened	NDDG	Retrospective; 1995 – 1998	Latina and AA women who received at least 4 prenatal care visits in large Detroit health system; medical record surveys	USA	Latina; 653 AA; 552	5.4%, Latina 3.9%, AA
Williams (60)	Varied depending upon prenatal care received.		Retrospective; 1987–1995	Mothers born in Washington State since 1949 delivering a singleton birth between 1987–1995; vital records and hospital discharge summaries.	USA	NHW; 21,528 AA; 6,359 Native American; 7,456 Hispanic; 6,496	2.8%, NHW 2.6%, AA 2.7%, Native American 3.0%, Hispanic
Solomon (39)	Varied depending upon prenatal care received. Self-reported Diagnosis		Prospective; 1989–1994	Nurses' Health Study II women with singleton pregnancies and no history of diabetes or GDM.	USA	White; 13,771 AA; 113 Hispanic; 224 Asian; 248	4.9%, Total 4.8%, White 10.6%, AA 7.6%, Hispanic 10.5%, Asian
Rodrigues (67,68)	Universal screening at 24–30 weeks; 1hr 50g GCT ≥ 140	NDDG	Retrospective; 1995–1996	**Cree:** 9 communities in James Bay, Quebec; maternal medical charts **Non-Native**: Royal Victoria Hospital, Montreal; McGill Obstetric and Neonatal Database	Canada	Cree; 579 Non-Native; 7,718	12.8%, Cree 5.3%, Non-Native
Godwin (61)	Varied depending upon prenatal care received. GDM was defined according to NDDG criteria or a fasting or 1hr 50g GCT ≥ 140 with physician diagnosis.		Retrospective; 1987 – 1995	Weeneebayko Hosptial, Moose Factory, James Bay, Ontario; chart review	Canada	Native Swampy Cree; 1,298	8.5%
Harris (69)	Universal screening at 24–28 weeks; 1hr 50g GCT ≥ 14090% screened	NDDG	Retrospective; 1990–1993	Sioux Lookout Zone, Northwestern Ontario; medical records	Canada	Native Ojibwa-Cree; 741	8.4%
Schmidt (70)	Universal Testing at 24–28 weeks; 2hr 75g OGTT; ADA, post 1997 and		Prospective; 1991–1995	General prenatal care clinics in the National Health Service	Brazil	White; 2,234 AA; 679 Mixed; 2,042	2.4%, ADA 7.2%, WHO

Author	Screening criteria	GDM criteria	Time Frame	Source Population	Country	Ethnic group; n	Prevalence
	WHO, 1999 including 0hr ≥ 126					Other; 21	
Janghorbani (62)	Universal screening at 26–28 weeks or high risk testing; random plasma glucose ≥ 117	2hr 75g OGTT 0hr ≥ 108 2hr ≥ 140	Retrospective; 1996–1997	Plymouth, southwest U.K.; databases and midwifery care notes	UK	NHW; 4,942	1.8%
Weijers (63)	Varied depending upon prenatal care received. Medical history of physician-diagnosed GDM.		Retrospective; 1992 – 1997	Town borough of Amsterdam; physician diagnosed GDM reported in hospital registration	Holland	Dutch; 483 Non-Dutch; 1,157	0.6%, Dutch 2.6%, Non-Dutch
Ostlund (71, 72)	Universal testing offered at 28–32 weeks; 73.5% accepted; EASD (0hr ≥ 121 cut-point)		Prospective; 1994 – 1996	Defined geographical area of Sweden	Sweden	Nordic; 3,211 Non-Nordic; 405	1.7%
Aberg (73)	Universal testing offered at 27–28 weeks with additional testing in high risk patients; not clear what %age of the population accepted; 2hr 75g OGTT ≥ 162 whole-blood		Prospective; 1995–1997	Lund University Hospital	Sweden	Not specified; 12,382	1.2%
Jensen (74)	Universal testing offered, high risk - early in pregnancy and at 28–32 weeks; EASD (0hr ≥ 111 and 2hr ≥ 164 whole-blood)		Prospective; 1999–2000	Four Danish healthcare centers	Denmark	Not specified; (5,235 using 56.2% imputed values)	2.4%
Kvetney (75)	High risk[†] testing at 24–28 weeks; 2hr 75g OGTT ≥ 121 or WHO, 1999; 19.5% tested		Prospective; 1995 – 1997	Ribe county prenatal care patients	Denmark	Not specified; 6,158	3.6%, Local Criteria 2.8%, WHO
Murgia (77)	Universal screening at 16–18, 24–26 and 30–32 weeks; 1hr 50g GCT ≥ 130	C & C	Prospective; 2006[*]	Sardinian volunteers	Italy	Sardinian; 1,103	22.3%
Di Cianni (76)	Universal screening at 24–28 weeks or earlier when high risk; 1hr 50g GCT ≥ 140	C & C	Prospective; 1997[*]	8 healthcare districts in north-west Tuscany	Italy	Not specified; 2,000	6.3%
Erem (78)	Universal screening at 24–28 weeks; 1hr 50g GCT ≥ 140	NDDG	Prospective; 2003[*]	Central Province of Trabzon City: seven health stations	Turkey	Not specified; 807	1.2%
Keshavarz (79)	Universal screening high risk - initial visit and at 24–28 weeks; 1hr 50g GCT ≥ 130	ADA, post 1997	Prospective; 1999 – 2001	Fatemiyeh Hospital in Shahrood City	Iran	Not specified; 1,310	4.8%
Hadaegh (80)	Universal screening at 24–28 weeks; 1hr 50g GCT ≥ 130	C & C and NDDG	Prospective; 2002 – 2004	All pregnant women referred to the obstetrics clinics in various parts of Bandar Abbas city	Iran	Not specified; (800 using 12.5% imputed values)	8.1%, NDDG 11.4%, C & C
Al Mahroos (81)	Universal screening at 24–28 weeks; 1hr 50g GCT ≥ 140	C & C with a 3hr 75g OGTT	Prospective; 2001 – 2002	Antenatal clinics at health centers and at Salmaniya Medical Complex	Bahrain	Bahraini; 7,575 Expatriate; 2,920	13.3%, total 15.5%, Bahraini 7.5%, Expatriate

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Author	Screening criteria	GDM criteria	Time Frame	Source Population	Country	Ethnic group; n	Prevalence
Seyoum (82)	Universal testing after 24 weeks; WHO, 1999		Prospective; 1999*	Women over 24 weeks gestational age; community-based, eastern zone of Tigray	Ethiopia	Not specified; 890	3.7%
Zargar (83)	Universal screening 2nd or 3rd trimester; 1hr 50g GCT ≥ 140	Group A: C & C Group B: WHO, 1999	Prospective; 1999 – 2002	Six districts of Kashmir valley	India	Not specified; Group A; 1,000 Group B; 1,000	3.1%, Group A 4.4%, Group B
Stone (64)	Varied depending upon prenatal care received.		Retrospective; 1996	Singleton pregnancies for Victoria in 1996; Routinely collected data in Victoria from Perinatal Morbidity Statistics System and Victorian Inpatient Minimum Dataset Data	Australia	Aboriginal; 438 Non-Aboriginal; 59,962	3.6%, Total 4.3%, Aboriginal 3.6%, Non-Aboriginal
Yang (84)	Universal screening at 26–30 weeks; 1hr 50g GCT ≥ 140	WHO, 1999 including 0hr ≥ 126	Prospective; 1998–1999	6 urban districts in Tianjin	China	Not specified; 9,471	2.3%
Maegawa (85)	Universal screening during first trimester; 1hr 50g GCT ≥ 130	JSOG	Prospective; 1999 – 2001	11 hospitals in Mie prefecture or Hiroshima Municipal Asa Hospital	Japan	Japanese; 749	2.9%

OGTT, oral glucose tolerance test; GCT, glucose challenge test; C & C, Carpenter and Coustan; NDDG, National Diabetes Data Group, WHO, World Health Organization; ADA, American Diabetes Association; EASD, European Association for the Study of Diabetes; JSOG, Japanese Society of Obstetrics and Gynecology;

*Indicates that calendar time for participant enrollment was not provided; therefore, the publication date is substituted for the study time frame.

†Women with previous GDM, history of fetal macrosomia, glucosuria, BMI > 29, family history, prior stillbirth, age > 35yrs)AA, African American; NHW, non-Hispanic white; NHB, non-Hispanic black; NHA, non-Hispanic Asian

Table 5

Prevalence of GDM in hospital-based studies.

Author	Screening criteria	GDM criteria	Time Frame	Population/Data Source†	Country	Ethnic group; n	Prevalence
Yogev (89)	Universal screening at 24–28 weeks; 1hr 50g GCT ≥ 130	C & C	Prospective; 1995–1999	St. Luke's Roosevelt Hospital Center and University of Texas Health Sciences Center at San Antonio	USA	Mexican American (85%), African American, Caucasian, other; 6,857	6.8%
Stamilio (90)	Universal screening at 24–28 weeks; 1hr 50g GCT ≥ 135	NDDG With 0h ≥ 100	Retrospective; 1995–1997	University of Pennsylvania Medical Center Triple marker screen perinatal database	USA	Not specified; 1,825	2.7%
Danilenko-Dixon (91)	Universal screening at 24–30 weeks; 1hr 50g GCT ≥ 140	NDDG	Retrospective; 1986–1997	Mayo Clinic, Rochester, NY; perinatal database	USA	White, African American, Asian, Hispanic, other; 18,504	3.0%
Dyck (92)	Universal screening; 1hr 50g GCT ≥ 140	NDDG	Prospective; 1998	Saskatoon Royal University Hospital	Canada	Aboriginal; 252 Non-Aboriginal; 1,360	11.5%, Aboriginal 3.5%, Non-Aboriginal
Santos-Ayarzagoitia (86)	Universal screening; 1hr 50g GCT ≥ 140 (initial visit) WHO Diagnostic (second visit)	NDDG C & C WHO, 1999	Prospective; 2002–2003	University Hospital Monterrey, Mexico	Mexico	Does not specify; 1,092	3.2%, NDDG 4.1%, C & C 8.7%, WHO
Ricart (87)	Universal screening at 24–28 weeks; 1hr 50g GCT ≥ 140	NDDG C & C	Prospective; 2002	16 general hospitals of the Spanish National Health Service	Spain	Caucasian, African, Asian, Caribbean, and other; 9,270	8.8%, NDDG 11.6%, C & C
Jimenez-Moleon (93)	Universal screening; 1hr 50g GCT ≥ 140	NDDG	Retrospective; 1995	Hospital Clinico San Cecilio; abstracted from medical records	Spain	Not specified; 1,962	3.3%
Bartha (94)	Universal screening at initial visit and 24–28 weeks; 1hr 50g GCT ≥ 140	NDDG	Prospective; 2000*	University Hospital of Puerto Real	Spain	Not specified; 3,986	5.9%
Di Cianni (95)	Universal screening high risk - initial visit and at 24–28 weeks; 1hr 50g GCT ≥ 140	C & C	Retrospective; 1995 – 2001	University of Pisa; data source not given, likely to be medical records	Italy	Italian; 3,950	8.7%
Corrado (88)	Universal screening; 1hr 50g GCT ≥ 135	NDDG C & C	Prospective; 1989 – 1995	University of Messina and 5 private practices	Italy	Italian; 1,000	3.4%, NDDG 4.6%, C & C
Yalcin (96)	Universal screening at 24–32 weeks; 1hr 50g GCT ≥ 140	C & C	Prospective; 1996	Tahir Burak Women's Hospital	Turkey	Turkish; 1,000	6.6%
Larijani (97)	Universal screening high risk - initial visit and at 24–28 weeks; 1hr 50g GCT ≥ 130	C & C	Prospective; 2003*	4 university teaching hospitals in Tehran	Iran	Not specified; 2,416	4.7%
Hassan (98)	Universal screening at 24–36 weeks; 1hr 50g GCT ≥ 130	NDDG	Prospective; 1997	Lady Reading Hospital	Pakistan	Not specified; 1,000	4.3%
Seshiah (99)	Universal screening 2nd or 3rd trimester; 1hr 50g GCT ≥ 130	WHO, 1999 including 0h ≥ 126	Prospective; 2001	Raja Sir Ramaswamy Mudhaliar Hospital	India	Not specified; 1,251	18.9%
Wagaarachchi (100)	No screening; Universal testing at 24–28 weeks	WHO, 1985	Prospective; 2001*	Castle Street Hospital for Women	Sri Lanka	Not specified; 1,004	4.1%

Author	Screening criteria	GDM criteria	Time Frame	Population/Data Source†	Country	Ethnic group; n	Prevalence
Davey (101)	Universal screening at 26–28 weeks; 1hr 50g GCT ≥ 140	ADIPS	Retrospective; 1996–1998	Sunshine Hospital, Melbourne; abstracted from medical records	Australia	Not specified; 6,032	5.2%
Yue (102)	Universal screening at 24–28 weeks; 1hr 50g GCT ≥ 140	ADIPS	Prospective; 1996*	Royal Prince Alfred Hospital	Australia	Anglo-Celtic, Chinese, Vietnamese, Indian, Arab, Aboriginal; 5,243	3.0%, Anglo-Celtic 15.0%, Chinese 9.0%, Vietnamese 17.0%, Indian 7.0%, Arab 10.0%, Aboriginal 1.8%
Miyakoshi (103)	Universal screening at 24–27 weeks; 1hr 50g GCT ≥ 130	JSOG	Retrospective; 1996–2000	Keio University Hospital; data source not given, likely to be medical records	Japan	Japanese; 2,651	

OGTT, oral glucose tolerance test; GCT, glucose challenge test; C & C, Carpenter and Coustan; NDDG, National Diabetes Data Group, WHO, World Health Organization; JSOG, Japanese Society of Obstetrics and Gynecology;

*Indicates that calendar time for participant enrollment was not provided; therefore, the publication date is substituted for the study time frame;

†Data source is provided for retrospective studies only.

Table 6

Trends in the prevalence of GDM

Author	Screening criteria	GDM criteria	Time Frame*	Population/ Data source	Country	Ethnic group; n	Outcome
Dabelea (104)	Universal screening at 24–28 weeks; 1hr 50g GCT ≥ 140; (96–98% screened)	NDDG	1994–2002	Kaiser Permanente of Colorado perinatal database, Denver metropolitan area	USA	NHW, Hispanic, AA, Asian; 36,403	From 2.1% in 1994 to 4.1% in 2002; GDM prevalence increase was greater for minorities than whites
Thorpe (105)	Screening and GDM criteria varied depending upon prenatal care received; however, universal screening has been practiced since the 1980s.		1990–2001	Residents of New York City with a singleton delivery; Birth certificate records from the New York City Department of Health and Mental Hygiene	USA	Diverse population; 1990; 125,663 2001; 110,340	From 2.6% in 1990 to 3.8% in 2001; GDM increased significantly in all major racial/ethnic groups except Non-Hispanic whites
Ferrara (106)	Considered screened if a 1hr 50g GCT (98.2% of those screened); 3hr 100g OGTT (C & C); 2hr 75g OGTT (≥ 140); fasting glucose (≥ 126); 2hr postprandial or random glucose measured (≥ 200); 86.8% screened; GDM defined by above cutpoints or a hospital discharge diagnosis		1991–2000	Northern California Kaiser Permanente Medical Care Program screened pregnancies; Gestational Diabetes Registry	USA	White, AA, Hispanic, Asian; 267,051	From 5.1% in 1991 to 7.4% in 1997; leveled off through 2000 at 6.9%
Moum (107)	Screening and GDM criteria varied depending upon prenatal care received.		1989–2000	American Indian and white mothers in Montana and North Dakota (ND); birth records	USA	Montana; 133,991 ND; 102,232	Increasing rate of diabetes in pregnancy 1989 to 2000. 3.1 to 4.1%, Montana Indian 1.8 to 2.6%, Montana white 3.8 to 4.8%, ND Indian (NS) 1.6 to 3.2%, ND white
Xiong (108)	Universal screening at 24–28 weeks; 1hr 50g GCT ≥ 140;	NDDG	1991–1997	39 hospitals in Northern and Central Alberta; Perinatal Audit and Education Program records	Canada	Canadian; 111,563	GDM prevalence ranged between 2.2 –2.8% with a mean of 2.5% between 1991 and 1997; NS test for linear trend
Ishak (109)	Unclear	ADIPS or WHO, 1999	1988–1999	All deliveries in South Australia; Pregnancy Outcome Unit of the Department of Human Services	Australia	Aboriginal; 4,843 Non-Aboriginal; 225,168	4.3%, Aboriginal 2.4%, Non-Aboriginal Increasing trend in non-Aboriginal (annual rate increase of 4.7%), but not in Aboriginal population (0.5%).
Kim (110)	Universal testing at 26–28 weeks; 1hr 50g GCT ≥ 140; (78–85% screened)	ADIPS	1992–1996	Far North Queensland; Cairns Base Hospital database	Australia	Aboriginal, Torres Strait Islanders, Australian-born Caucasian, others; 7,567	14.4%, 1992; 13.4%, 1993; 11.1%, 1994; 7.3%, 1995; 5.3%, 1996
Beischer (111)	Universal testing 3hr 50g OGTT; 1971 to 1980 at 30–34 weeks (64.5% screened); 1981 and after at 30–34 weeks (79.9%		1971–1994	Mercy Hospital for Women, Melbourne; either abstracted from	Australia	Not specified; 1971–1980; 27,111 1991–1994; 16,820	Of screened pregnancies from 2.9% in 1971–1980 to 8.8% in 1991–1994 (X^2 for trend, $p<0.00001$).

Author	Screening criteria	GDM criteria	Time Frame*	Population/ Data source	Country	Ethnic group; n	Outcome
	screened); GDM defined by a 1hr ≥162 and a 2hr ≥126			medical records or a database			

OGTT, oral glucose tolerance test; GCT, glucose challenge test; C & C, Carpenter and Coustan; NDDG, National Diabetes Data Group, WHO, World Health Organization; JSOG, Japanese Society of Obstetrics and Gynecology; NHW, non-Hispanic white; AA, African American; ND, North Dakota; NS, not significant;

*All studies were retrospective.

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