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Review Article

Maternal outcomes and follow-up after gestational diabetes mellitus

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Abstract

Gestational diabetes mellitus reflects impaired maternal insulin secretion relative to demand prior to pregnancy, as well as temporary metabolic stressors imposed by the placenta and fetus. Thus, after delivery, women with gestational diabetes have increased risk of diabetes and recurrent gestational diabetes because of their underlying impairment, which may be further exacerbated by fat accretion during pregnancy and post-partum deterioration in lifestyle behaviours. This hypothetical model is discussed in greater detail, particularly the uncertainty regarding pregnancy as an accelerator of β-cell decline and the role of gestational weight gain. This report also presents risk estimates for future glucose intolerance and diabetes and reviews modifiable risk factors, particularly body mass and lifestyle alterations, including weight loss and breastfeeding. Non-modifiable risk factors such as race/ethnicity and insulin use during pregnancy are also discussed. The review concludes with current literature on lifestyle modification, recommendations for post-partum glucose screening, and future directions for research to prevent maternal disease.

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Introduction

Women with histories of gestational diabetes mellitus are at increased risk for several glucose intolerant states following delivery, including gestational diabetes in future pregnancies and diabetes mellitus. In this article, I describe briefly a hypothetical model of pregnancy as a maternal stressor and follow with a review of risk and risk factors for gestational diabetes recurrence and post-partum maternal diabetes. I conclude with a discussion of how varying diagnostic guidelines for gestational diabetes affect estimates of post-partum risk and current recommendations for post-partum diabetes screening.

Hypothetical model of pregnancy as a metabolic stressor

Gestational diabetes has classically been defined as any glucose intolerance identified during pregnancy [1]. However, it has long been recognized that the diagnosis includes both (1) women who have diabetes preceding pregnancy and were not detected because of lack of screening for diabetes, as well as (2) women who had normal glucose levels prior to pregnancy, but had deterioration of glucose levels during pregnancy. Recent recommendations for gestational diabetes screening strategies attempt to distinguish between overt diabetes vs. gestational diabetes during pregnancy, i.e. glucose elevations that precede pregnancy vs. glucose elevations that occur during pregnancy [2]. While these screening strategies have not been universally adopted, the prevailing paradigm of gestational diabetes remains that of a disease state characterized by underlying defects in maternal insulin sensitivity and secretion, which are unmasked in response to the metabolic stressors of pregnancy [3]. These metabolic adaptations are informed by placental and fetal hormone production, which may vary between pregnancies [4,5].

Post-partum glucose tolerance is the end result of several factors (Fig. 1): maternal insulin sensitivity and secretion prior to pregnancy, intra-partum stresses upon β-cell function, intra-partum accretion of energy stores that persist after delivery, and post-partum behaviours. The contribution of each of these factors is determined by the degree to which temporary stresses such as placental and fetal hormone production affected glucose levels during pregnancy. It is likely that, for women with less β-cell reserve prior to pregnancy, the contribution of fetal and placental factors and pregnancy-related fat accretion is smaller than for women with greater reserve prior to pregnancy.

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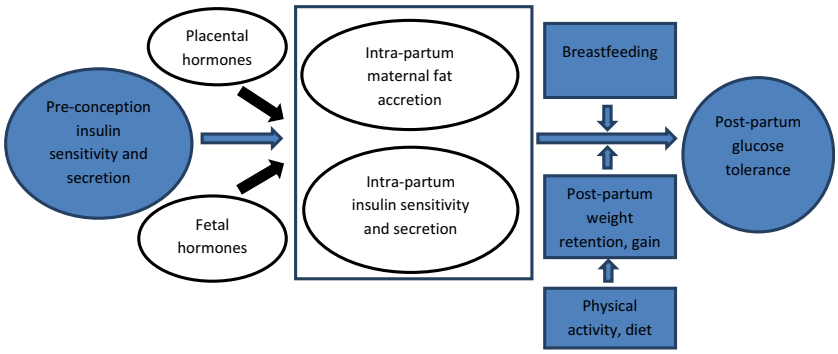

FIGURE 1 Pre-conception maternal insulin sensitivity and secretion, in conjunction with placental and fetal hormone production, influence intra-partum maternal fat accumulation as well as insulin secretion and sensitivity. Thus, post-partum glucose tolerance reflects pre-conception metabolism altered by the adipose tissue gained during pregnancy, possibly stresses upon the pancreatic β-cell possibly accelerated by the pregnancy, fat stores accumulated during pregnancy and retained after delivery and post-partum behaviours.

Conversely, pregnancy-related fat accretion and post-partum behaviours will have a greater influence upon post-partum glucose tolerance among women with greater pre-conception β-cell reserve.

Maternal metabolic adaptations, particularly in the second half of pregnancy, direct glucose and amino acids to the growing fetus. During a healthy pregnancy, increases in placental hormones, including prolactin and human placental lactogen (also known as chorionic somatomammotropin), among other hormones [6], lead to an increase in the number of pancreatic β-cells [7] and subsequent increases in insulin secretion. These increases in insulin secretion are accompanied by declines in maternal insulin sensitivity in the second half of pregnancy [8]. These declines in insulin sensitivity are concurrent with increases in other placental hormones, including human placental lactogen, progesterone and growth hormone [4], as well as adipokines such as leptin and tumour necrosis factor-alpha [5]. Compared with women with healthy pregnancies, women with gestational diabetes have relatively reduced levels of insulin secretion in relation to insulin sensitivity, resulting in higher intra-partum maternal glucose levels [9].

To what extent pregnancy depletes or 'accelerates' declines in β-cell reserve is not clear. Both animal and human studies have focused on β-cell proliferation and hypertrophy as compared with function [6]. Data conflict [10–13] as to whether parity is an independent risk factor for post-partum glucose intolerance, apart from weight gained during pregnancy. Currently, there are no studies that include precise measures of β-cell function, such as hyperinsulinaemic euglycaemic glucose clamp studies, that compare insulin secretion before and after high-risk pregnancies. Studies of insulin secretion and sensitivity in Mexican-American women [14] and Korean women [15] suggest that women with gestational diabetes have a steeper decline in insulin sensitivity and poorer β-cell compensation after delivery compared with women without gestational diabetes. These declines are independent of changes in weight and fat as measured by duel-energy x-ray absorptiometry or computed tomography scan [14]. This suggests that, once β-cell function is impaired, the natural history is for such declines to continue even after the stresses of pregnancy have ended.

Pregnancy-related hormone changes contribute to increases in body weight and changes in fat distribution that persist after pregnancy, both in healthy pregnancies as well as gestational diabetes pregnancies [16]. In other words, the placental and fetal factors impose stresses upon maternal metabolism that have lasting effects upon maternal metabolism because of these changes in fat distribution and mass. Fat accretion attributable to these factors occurs in addition to the increases in gestational weight gain that have been observed over the past decade, presumably because of interactions between lifestyle behaviours and environmental factors such as food quality, availability and facilitators and barriers to physical activity [17]. The magnitude of this 'permanent' weight gain attributable to pregnancy is directly related to the degree of gestational weight gain and persists over a decade after delivery [18]. In a meta-analysis of nine studies, women who had gestational weight gain that was below Institute of Medicine recommendations retained 3 kg less than women who had gestational weight gain within recommendations at 6 months after pregnancy (95% CI –3.72 to –2.27 kg). Women who exceeded gestational weight gain recommendations retained 3 kg more than women within recommendations at 3 years after pregnancy (95% CI 1.50–4.63 kg) as well as at 15 years post-partum (4.72 kg, 95% CI 2.94–6.50 kg) [18].

In summary, variations in underlying maternal insulin secretion and sensitivity, the degree of metabolic stress posed by factors specific to the pregnancy, including placental and fetal hormone production and gestational weight gain, and finally the adiposity retained from pregnancy and post-partum behaviours will contribute to variations in post-partum maternal risk for glucose intolerance and diabetes. The following section discusses studies of the magnitude of this risk and estimates of risk factor strength.

Risk of recurrence of gestational diabetes, post-partum diabetes and cardiovascular disease

It is well established that women with a single gestational diabetes pregnancy are at risk for gestational diabetes in their future pregnancies. Among women receiving antenatal care in one health system and who had at least two pregnancies (n = 65 132) [19], women with gestational diabetes in their first pregnancy had a 41% risk of gestational diabetes in their second pregnancy, compared with 4% among women without gestational diabetes in their first pregnancy. Among women who had three pregnancies (n = 13 096), 57% of women who had gestational diabetes in their first two pregnancies also had gestational diabetes in their third pregnancy [19]. These prevalences are similar to those reported in another health system, which noted that, among women with a gestational diabetes pregnancy, 38% had gestational diabetes in a subsequent pregnancy compared with 3.5% among women without gestational diabetes in their first pregnancy [20].

It is also well established that women with gestational diabetes are at increased risk for future diabetes [21] and that, among women with diabetes, as many as one third of women have experienced a gestational diabetes pregnancy [22]. In a meta-analysis of 20 reports [21], women with gestational diabetes had a sevenfold increased risk of diabetes compared with women without gestational diabetes (relative risk 7.43, 95% CI 4.79–11.51). It is possible that the magnitude of risk will increase over time, as performance of post-partum diabetes screening increases. This may affect risk estimates for gestational diabetes recurrence. As background diabetes screening is not performed regularly, and as women will present for antenatal care at varying gestational ages, incidence of gestational diabetes in a future pregnancy and pre-conception diabetes affecting a future pregnancy exist in equilibrium. In other words, more women diagnosed with diabetes after an index gestational diabetes pregnancy will mean that there will be fewer women diagnosed with recurrent gestational diabetes after an index gestational diabetes pregnancy. Lawrence *et al.* noted that, between 1999 and 2005, the age- and race/ethnicity-adjusted gestational diabetes prevalence did not change significantly with time [23]. However, among all deliveries to women with gestational diabetes or pre-conception diabetes, the percentage to women with pre-conception diabetes in 1999 was 10%, which rose to 21% in 2005 [23].

Gestational diabetes is associated with increased risk of cardiovascular dysfunction, although it is unclear whether this occurs apart from a diagnosis of post-partum glucose intolerance and diabetes. Compared with women with healthy pregnancies, women with histories of gestational diabetes have elevations in cardiovascular risk factors including blood pressure [24–28] and unfavourable changes in HDL and triglyceride levels [24–29]. Women with histories of gestational diabetes had greater vascular resistance, lower stroke volume, lower cardiac output [30] and higher intimal medial thickness compared with women without histories of gestational diabetes [31]. Small cross-sectional studies conflict as to whether flow-mediated dilation is impaired among women with histories of gestational diabetes [32]. Carr and colleagues found that women with a history of gestational diabetes were more likely to experience more cardiovascular events and at earlier ages than women without a history of gestational diabetes [33]. However, gestational diabetes screening was not universal in the cohort as women with histories of gestational diabetes conceived approximately in the 1970s, and it is possible that recall bias or selective screening affected risk estimates. Moreover, the cohort examined had two affected family members with diabetes and therefore was at particularly high risk for diabetes. Other reports note that gestational diabetes is associated with increased risk of cardiovascular events and hospitalizations, although diabetes was not adjusted for in one report [34] and the association between gestational diabetes and cardiovascular event risk was attenuated by adjusting for diabetes in the other report [35].

Modifiable risk factors for future risk of glucose intolerance: body mass

In the aforementioned studies of gestational diabetes recurrence, recurrence was high, but not universal. Approximately two-thirds to half of women with a second pregnancy do not have gestational diabetes in the second pregnancy [36,37]. Thus, among the majority of women with gestational diabetes who also have a second pregnancy, gestational diabetes does not recur, despite increases in maternal age and presumed age-related declines in β-cell function. While it is unknown to what extent recurrence reflects pregnancy-specific placental and fetal factors vs. interval changes in maternal insulin secretion relative to action, there may be a role for risk factor modification prior to the second pregnancy or during the second pregnancy.

The risk factor thought to explain the greatest variance in risk, and which also is the most amenable to modification, is maternal weight before the subsequent pregnancy. While weight gain between pregnancies and at the subsequent pregnancy were inconsistently associated with gestational diabetes risk in older reports [38], more recent reports suggest that maternal weight gain in between pregnancies might play a larger role in gestational diabetes recurrence, perhaps because of the steady increase in maternal pre-conception BMI over the past decade [17]. In one recent examination of 22 351 women, women had a significant increase in their odds of gestational diabetes in their subsequent pregnancy with each unit of BMI gained between pregnancies [20]. Specifically, women who gained 1–1.9 kg/m^2 had a 1.7 increased odds of future gestational diabetes; women who gained 2.0–2.9 kg/m^2 had a 2.5 increased odds and women

who gained over 3 kg/m^2 had a 3.4 increased odds [20]. While less than 10% of women lost weight between pregnancies, women who were overweight or obese at their index pregnancy, but who then lost weight (approximately 2.0 kg/m^2) significantly lowered their risk of future gestational diabetes by almost 80% (odds ratio 0.26, 95% CI 0.14–0.47). Of note, women who were not overweight at their index gestational diabetes pregnancy, but lost weight after their index pregnancy, did not significantly reduce their odds of future gestational diabetes. This suggests that attributable risk for gestational diabetes attributable to weight was low in these women, and that weight loss may not be an ideal target for intervention in this subpopulation [20].

As with recurrent gestational diabetes, anthropometric factors have a strong association with future risk of diabetes. In a systematic review conducted in 2009, body fat measures had the most consistent associations with diabetes risk compared with other types of factors including age, parity and family history of diabetes [39]. Specifically, pre-pregnancy BMI was associated with significantly increased risk of future diabetes after a gestational diabetes delivery; for every 1 kg increase in pre-pregnancy weight, there was a 40% increase in odds of developing Type 2 diabetes (odds ratio 1.40, 95% CI 1.20–1.60). Intra-partum and post-partum weight measures were also associated with increased diabetes risk [39]. In an examination of weight change post-partum, Peters *et al.* reported that, for every 4.5-kg increase in weight, there was a twofold increase in the risk of Type 2 diabetes, even after adjustment for other factors including post-partum BMI, oral glucose tolerance test results and breastfeeding [10]. In a cohort of Korean women, Cho *et al.* compared the strength of association between post-partum BMI, weight, skin thickness, waist–hip ratio and waist circumference and diabetes risk [24]. All of the body mass measures were associated with risk of diabetes, but waist circumference as characterized by quartiles and body fat measures had the strongest associations, suggesting that adipose tissue as opposed to other tissue compartments and visceral fat deposition as opposed other types of fat deposition conferred the highest risk for diabetes.

Altering body mass through lifestyle changes including diet and exercise has proven to be challenging among women with histories of gestational diabetes. The most successful intervention was among women who were overweight and glucose intolerant and enrolled in the Diabetes Prevention Program, a multi-centre randomized trial that concluded in 2001 [40]. Among the 350 women with histories of gestational diabetes, intensive lifestyle change targeting 7% reduction in enrolment weight and increased physical activity led to significant reductions in diabetes incidence compared with placebo [40]. The incidence of diabetes in women with gestational diabetes randomized to lifestyle was 7.4 per 100 person-years, compared with an incidence of diabetes in the placebo group of 15.2 per 100 person years, for a 53% reduction in incidence.

Several Diabetes Prevention Program study characteristics underline how difficult behaviour change in the population with gestational diabetes can be. Women with histories of gestational diabetes in the Diabetes Prevention Program were approximately 43 (± 7.6) years of age and the date of their prior gestational diabetes pregnancy specifically was not known, although they were approximately 12 years from their last pregnancy. Presumably, the Diabetes Prevention Program population would be more amenable to behaviour change than women with more recent gestational diabetes deliveries who may face barriers to lifestyle change because of caregiving demands imposed by young children. In addition, women who were at extremely high risk for diabetes, and perhaps with the greatest barriers to lifestyle change, would have already converted to diabetes in their first decade post-partum. However, women with gestational diabetes had the greatest weight loss at 6 months post-randomization (5.1 kg) and steadily increased weight thereafter, so that their mean weight loss at 3 years was only 1.6 kg. This weight pattern was significantly worse than in the women in the Diabetes Prevention Program without gestational diabetes, who had a mean weight loss at 3 years of 4.0 kg. These weight patterns corresponded with decreases in physical activity by the end of the study; women with gestational diabetes had increased their activity by approximately 1.5 h per week from baseline during the first year, but by the third year, they reported less than 30 min of physical activity a week [40]. As a randomized trial, the Diabetes Prevention Program undoubtedly selected for a highly motivated group of participants; previous Diabetes Prevention Program reports have noted that approximately 158 000 persons were screened and recruitment protocols emphasized a history of gestational diabetes because of the high prevalence of glucose intolerance among women with gestational diabetes post-partum. However, 29 000 were excluded because of lack of participant interest and, among participants who underwent the screening oral glucose tolerance test, the majority were excluded because of lack of elevation in the 2-h post-prandial value (approximately 20 000 individuals), resulting in the 3800 participants eventually randomized [41]. Women with histories of gestational diabetes randomized to metformin also had similar reductions in incident diabetes, although it is unclear whether metformin would have similar benefit among women with gestational diabetes who did not have elevations in both their fasting and 2-h values at baseline, as Diabetes Prevention Program participants had to have impaired fasting glucose as well as significant elevations in their 2-h postprandial values.

As of yet, lifestyle interventions that successfully target women with gestational diabetes closer to their delivery have not been published [42]. Ferrara *et al.* randomized approximately 100 women with gestational diabetes to a Diabetes Prevention Program-like intervention vs. 100 women to control and, at 1 year post-partum, women randomized to intervention reduced their dietary fat intake [43]. Physical

activity, breastfeeding and proportion that reached dietary weight goals were not statistically significant between study arms, although between-arm differences in these outcomes were close to meeting statistical significance ($P < 0.10$ but > 0.05) and women randomized to intervention were more likely to meet their dietary fat goals than women randomized to usual care; a larger trial is currently underway. In another randomized controlled trial of 450 Chinese women with histories of gestational diabetes that also advised on diet and exercise, there were no difference in diabetes incidence between the intervention and control group at 3 years, nor were there differences in glucose or insulin sensitivity [44].

As in women without gestational diabetes, healthier diets may be associated with decreased risk of diabetes among women with histories of gestational diabetes, although such studies are few. Among women with histories of gestational diabetes in the Nurses' Health Study II cohort [45], women's dietary patterns were scored by several scales examining degree of adherence to the Mediterranean diet, Dietary Approaches to Stop Hypertension (DASH) diet and the Healthy Eating Index. Women who were the most adherent to or in the highest quartile of the Mediterranean diet scale had a 40% lower risk of Type 2 diabetes compared with women in the lowest quartile (hazard ratio 0.60, 95% CI 0.44–0.82). Similar reductions in risk were observed in women who were in the highest quartile of the DASH diet and the Healthy Eating Index compared with the lowest quartile. The risk reduction was partially mediated by body mass changes. Among Korean women, greater animal fat intake was associated with the presence of pre-diabetes and diabetes in the early post-partum [46].

In general, women with histories of gestational diabetes have similarly poor health behaviours compared with women without such histories [47]. One recent report from the Coronary Artery Risk Development in Young Adults Study compared post-pregnancy weight and behaviours between women with and without gestational diabetes pregnancies [48]. Women were examined at mean of approximately 1.4 years after delivery. Women with and without gestational diabetes were similar regarding their degree of post-partum weight retention, which averaged 3–4 kg, with an increase in waist circumference of approximately 4 cm compared with pre-pregnancy [48]. Women with and without gestational diabetes reported similar declines in total physical activity and increases in caloric intake, including an increase in the percentage of calories from fat. An earlier report from Canada noted that women with gestational diabetes increased their leisure-time activity (although not other types of physical activity) by 1 year after pregnancy compared with women without such histories, indicating there may be some variation in health behaviours by region or service area [49]. To our knowledge, there are no longitudinal reports of physical activity in women with histories of gestational diabetes and reports of associated risk reductions in future diabetes.

Modifiable behaviours: breastfeeding and contraception choice

Breastfeeding is a behaviour that has been reported to have favourable effects upon glucose both in the early and late post-partum. Two reports, each examining approximately 500 women, noted that those who breastfed compared with those who did not breastfeed had lower fasting plasma glucose and insulin, and a lower prevalence of diabetes and impaired glucose tolerance, at 6–9 weeks post-partum [50,51]. Women with histories of gestational diabetes who breastfed had a median time to diabetes of 12.3 years, compared with 2.3 years among women who did not breastfeed [52]. Longer periods of breastfeeding, i.e. greater than 3 months, were associated with the lowest risks of diabetes. This reduction in risk did not seem to be mediated entirely through post-partum BMI, as duration of lactation and the degree of change in post-partum BMI was not significant [52]. Unfortunately, women with gestational diabetes are less likely to breastfeed than women without diabetes (odds ratio 0.75, 95% CI 0.66–0.85) after a delivery in hospital, perhaps attributable to management of these women by specialists less focused upon breastfeeding than other issues [53].

The lactational amenorrhoea associated with exclusive breastfeeding may induce a relatively progestogenic state and, combined with progestin-only contraceptive medication, may increase risk of diabetes in high-risk women. Among Latinas with gestational diabetes, users of progestin-only oral contraception and who breastfed had higher risks of Type 2 diabetes compared with women who used combination oestrogen–progestin contraceptives (relative risk 2.87, 95% CI 1.57–5.27) [54]. Diabetes risk is also increased among Latinas [29] and Navajos [55] who used injectable progestins, in part through the weight gain associated with injectable progestins as well as interactions with lactation. Thus, while breastfeeding may improve glucose, there may be interactions with contraception that are detrimental for glucose in women in racial/ethnic groups at high risk for glucose intolerance. While combination oral contraception has been reported to decrease breast milk to a greater extent than progestin-only use, study quality was limited [56]; recent reports indicate no difference in breastfeeding or maternal perception of breast milk production in women randomized to contraception type [57].

Non-modifiable risk factors for future glucose intolerance: race/ethnicity, insulin use and glucose levels during the index pregnancy and autoantibody status

Aside from body mass, the most consistent risk factor for future glucose intolerance after a gestational diabetes delivery is non-white race/ethnicity. In southern California, Getahun *et al.* noted that the risk of gestational diabetes

recurrence varied by race/ethnicity, with the highest risk reported among Asian-Pacific Islanders, who had a 45% risk with a second pregnancy [19]. Similar risk estimates have been reported for Koreans living in Asia [58]. It is not known whether gestational diabetes risk might be higher in Asians because of racial/ethnic differences in maternal insulin secretion relative to demand prior to pregnancy or in response to pregnancy metabolic stresses.

As with recurrent gestational diabetes, non-white race/ethnicity may predict future diabetes risk among women with histories of gestational diabetes [59]. This could reflect racial/ethnic differences in underlying maternal insulin sensitivity and secretion or diabetogenic effects of pregnancy. Interestingly, within different racial/ethnic groups, gestational diabetes may confer different risks of Type 2 diabetes, suggesting that there are racial/ethnic differences in β-cell decline after an index gestational diabetes diagnosis. One report examined the risk of diabetes associated with gestational diabetes within each racial/ethnic group in a cohort of approximately 13 000 women with gestational diabetes and 65 000 women without gestational diabetes [60]. Non-Hispanic white women and Asian/Pacific Islanders had the lowest risk for diabetes after their gestational diabetes delivery (hazard ratio 6.5, 95% CI 5.2–8.0 and hazard ratio 6.3, 95% CI 5.0–7.9, respectively), followed by Latinas (hazard ratio 7.7, 95% CI 6.89–8.7) and African-Americans (hazard ratio 9.9, 95% CI 7.5–13.1). Similarly, in another report from Louisiana, African-American women with histories of gestational diabetes had a significantly increased risk of diabetes (hazard ratio 7.43, 95% CI 6.34–8.72) compared with non-Hispanic white women with histories of gestational diabetes (hazard ratio 4.63, 95% CI 3.61–5.94) [59]. The finding that African-Americans have a higher risk of diabetes after a gestational diabetes diagnosis than non-Hispanic white women occurs with the finding that African-Americans have generally lower or similar risk of gestational diabetes compared with non-Hispanic white women [61]. In other words, African-Americans decline more rapidly after a diagnosis of gestational diabetes than non-Hispanic white women, and this is unlikely to be due to misclassification of GDM vs. Type 2 diabetes.

Other risk factors that have been associated with risk of future diabetes include use of insulin as opposed to dietary therapy during the gestational diabetes pregnancy [39]. In a German report [52], use of insulin during pregnancy was associated with increased risk of diabetes post-partum regardless of maternal weight, with 90% of women who required insulin therapy during pregnancy developing diabetes by 15 years post-partum, with a median diabetes-free survival of less than 2.5 years. These findings suggest that the required use insulin during pregnancy reflects greater impairments in β-cell function during pregnancy. Such findings are concordant with the fact that glucose elevations on the index glucose tolerance test during pregnancy are associated with post-partum diabetes risk. In a 2009 review of 11 articles [62], elevations in fasting glucose, 2-h glucose and oral glucose tolerance test area under the curve were all associated with increased diabetes risk, although attrition exceeded one fifth of the study population in six studies and followed women over a relatively short period of time. Elevations in any of the glucose values from the antenatal oral glucose tolerance test are associated with greater post-partum diabetes risk, but fasting glucose and 1-h glucose may be more strongly associated with post-partum diabetes than 2- and 3-h values [22,63–72]. Women with a greater number of abnormal tests, i.e. elevated fasting or post-challenge values, are at greater risk for diabetes [28].

Among populations with a high-risk of Type 1 diabetes, gestational diabetes indicates elevated risk for future Type 1 diabetes as well as Type 2 diabetes [73]. In a cohort of Finnish women with gestational diabetes, 5% developed Type 1 diabetes and 5% developed Type 2 diabetes within 6 years post-partum [74]. In populations with gestational diabetes, as in non-pregnant populations, islet-cell autoantibody presence is a strong predictor of diabetes [74] and also highlights the point that gestational diabetes can reflect defects in maternal insulin secretion caused by autoimmunity, as well as β-cell exhaustion secondary to insulin resistance. Among German women with islet-cell autoantibodies and gestational diabetes, 31 of 32 women developed diabetes, with a median diabetes-free duration post-partum of 4.5 months (95% CI 2.5–6.5) [52]. Risk increased with the number of antibodies present at delivery, with the risk of Type 1 diabetes at 17% for one antibody, 61% for two antibodies and 84% for three antibodies [13]. Similarly, in a cohort of Swedish women with gestational diabetes [75], autoantibodies (to glutamic acid decarboxylase 65 and insulinoma antigen-2) were associated with greater diabetes risk post-partum, although not with impaired glucose tolerance, underlining the fact that insulin resistance leading to pre-diabetes was not a key pathway in disease progression among these women with probable Type 1 diabetes.

Current recommendations for post-partum screening

Recommendations for post-partum screening by medical organizations are shown in Table 1. Data comparing the sensitivity and specificity of these screening strategies do not exist. In particular, it is unclear if the greater sensitivity of the 2-h glucose is outweighed by its greater intra-individual variation [76] and inconvenience, and the optimal frequency of screening is also not clear. While 40% of women with histories of gestational diabetes with glucose dysregulation had normal fasting glucose levels [77], it is unclear if these women would eventually be detected with a fasting glucose or HbA_{1c} and if they would suffer poorer perinatal outcomes in the interim. (As the onset of other types of maternal complications including micro- and macrovascular disease have prolonged onset, particularly in women with

Table 1 Post-partum diabetes screening guidelines for women with histories of gestational diabetes mellitus from the National Institute for Health and Clinical Excellence, the World Health Organization, the American Diabetes Association and the Canadian Diabetes Association (CDA)

	National Institute for Health and Clinical Excellence (NICE) [83]	World Health Organization (WHO) [84]	American Diabetes Association (ADA) [85]	Canadian Diabetes Association (CDA) [86]
When	6 weeks post-partum If normal, annually	6 weeks post-partum	6–12 weeks post-partum If normal, every 3 years If impaired fasting glucose or elevated 2-h glucose, annually	6 weeks post-partum If normal, 6 months post-partum
Which test	Fasting blood glucose	Fasting blood glucose or 75-g 2-h oral glucose tolerance test	75-g 2-h oral glucose tolerance test (HbA_{1c} not recommended)	75-g 2-h oral glucose tolerance test

Type 2 diabetes, it is less likely that these types of outcomes would be averted through earlier detection of isolated post-challenge hyperglycaemia [78].) The conservative, albeit unvalidated, approach would be to perform a 75-g 2-h oral glucose tolerance test at the post-partum visit, in that the 2-h value would detect additional women with glucose intolerance; these women might have more aggressive management of their diabetes at an earlier point in time; and future pregnancy outcomes would be improved. The women most likely to benefit would be those who had post-challenge hyperglycaemia on their index oral glucose tolerance test used to diagnose gestational diabetes. HbA_{1c} at 6 weeks post-partum may be affected by perinatal haemoglobin shifts and, at 1-year post-partum, HbA_{1c} did not improve sensitivity and specificity of fasting plasma glucose compared with a 75-g 2-h oral glucose tolerance test at 1-year post-partum [79]. Longer-term follow-up data are not yet available. It is also important to note that postpartum screening is not universally performed and may require simple reminders for both women and their providers [80].

The International Association of Diabetes and Pregnancy Study Groups recommendations on the diagnosis and classification of hyperglycaemia in pregnancy [2] will result in a greater proportion of women diagnosed with gestational diabetes compared with previous criteria that employed higher glucose cut-offs. Conversely, more specific, but less sensitive, gestational diabetes criteria lead to fewer women being identified with gestational diabetes. Ferrara *et al.* demonstrated this in their study, in which two sets of diagnostic criteria for gestational diabetes were applied to women who underwent glucose tolerance testing during pregnancy [81]. Of these women, 3.2% had gestational diabetes by National Diabetes Data Group criteria. Of the same women, 4.8% had gestational diabetes by Carpenter and Coustan criteria, which uses lower glucose cut-offs. With the lower cut-offs, the prevalence of gestational diabetes increased by approximately 50%. However, the additional populations identified tended to be low risk; relative increments were greatest in low-risk age and ethnic groups, specifically women aged < 25 years (70%) and in white women (58%). Thus, although the denominator, women with gestational diabetes, increased, the additional women identified were at similar or lower risk when compared with the original National Diabetes Data Group cohort. In general, the lower the glucose cut-offs for the original diagnosis of gestational diabetes, the broader the range of risk in the population subsequently diagnosed with gestational diabetes.

Identification of a greater proportion of pregnant women with gestational diabetes necessarily leads to a greater denominator, and a decreased proportion subsequently identified with post-partum glucose intolerance. Presumably, this will lead to a lower proportion of women with gestational diabetes at risk for post-partum diabetes or glucose intolerance [82]. While it seems likely that post-partum diabetes risk would still be elevated in this lower risk pool, the estimates of diabetes risk could decrease. As these new diagnostic criteria for gestational diabetes are implemented, recommendations for frequency of testing and the optimal glucose testing may be affected.

Conclusions

The gestational diabetes pregnancy provides a snapshot of carbohydrate metabolism that reflects underlying maternal insulin sensitivity and secretion. While we do not completely understand to what extent this snapshot will predict post-partum alterations, we do know that women with gestational diabetes are at significant risk for future glucose intolerance, and the degree of this risk is associated with both fixed and modifiable risk factors. Further investigation into the contributions of temporary exposures from the placenta and fetus might improve our understanding of why not all women with gestational diabetes develop gestational diabetes in subsequent pregnancies, and why not all women with gestational diabetes develop future diabetes, despite lack of improvement in body mass and lifestyle habits. The primary therapeutic question is how to alter the natural disease trajectory of gestational diabetes so that women

avoid recurrent gestational diabetes and post-partum diabetes. While lifestyle changes post-partum can be effective, they have proven difficult to implement in the critical years after delivery, when women are still of childbearing age, and when women may rapidly progress to overt diabetes at young ages. The long-term use of medications in this reproductive-age population is a less attractive option, but such therapies should be tested as an adjunct approach. In the meantime, translational research needs to be conducted to find ways to best facilitate healthy behaviours in this high-risk population.

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Competing interests

None declared.

References

1 Metzger B, Buchanan T, Coustan D, De Leiva A, Dunger D, Hadden D *et al.* Summary and recommendations of the Fifth International Workshop—Conference on Gestational Diabetes Mellitus. *Diabetes Care* 2007; **30**: S251–S260.
2 IADSPG Consensus Panel. International Association of Diabetes and Pregnancy Study Groups recommendations on the diagnosis and classification of hyperglycemia in pregnancy. *Diabetes Care* 2010; **33**: 676–682.
3 Xiang A, Kjos S, Takayanagi M, Trigo E, Buchanan T. Detailed physiological characterization of the development of type 2 diabetes in Hispanic women with prior gestational diabetes mellitus. *Diabetes* 2010; **59**: 2625–2630.
4 Handwerger S, Freemark M. The roles of placental growth hormone and placental lactogen in the regulation of human fetal growth and development. *J Pediatr Endocrinol Metab* 2000; **13**: 343–356.
5 McIntyre H, Chang A, Callway L, Cowley D, Dyer A, Radaelli T *et al.* Hormonal and metabolic factors associated with variations in insulin sensitivity in normal pregnancy. *Diabetes Care* 2010; **33**: 356–360.
6 Ernst S, Demirci C, Valle S, Velazquez-Garcia S, Garcia-Ocana A. Mechanisms in the adaptation of maternal beta-cells during pregnancy. *Diabetes Manag (Lond)* 2011; **1**: 239–248.
7 Butler A, Cao-Minh L, Galasso R, Rizza R, Corradin A, Cobelli C *et al.* Adaptive changes in pancreatic beta-cell fractional area and beta-cell turnover in human pregnancy. *Diabetologia* 2010; **53**: 2167–2176.
8 Catalano P, Drago N, Amini S. Longitudinal changes in pancreatic beta-cell function and metabolic clearance rate of insulin in pregnant women with normal and abnormal glucose tolerance. *Diabetes Care* 1998; **21**: 403–408.
9 Buchanan T, Xiang A, Peters R, Kjos S, Berkowitz K, Marroquin A *et al.* Response of pancreatic beta-cells to improved insulin sensitivity in women at high risk for type 2 diabetes. *Diabetes* 2000; **49**: 782–788.
10 Peters R, Kjos S, Xiang A, Buchanan T. Long-term diabetogenic effect of a single pregnancy in women with prior gestational diabetes mellitus. *Lancet* 1996; **347**: 227–230.
11 Manson J, Rimm E, Colditz G, Stampfer M, Willett W, Arky R *et al.* Parity and incidence of non-insulin dependent diabetes mellitus. *Am J Med* 1992; **93**: 13–18.
12 Gunderson E, Lewis C, Tsai A, Chiang V, Carnethon M, Quesenberry C Jr *et al.* A 20-year prospective study of childbearing and incidence of diabetes in young women, controlling for glycemia before conception: the Coronary Artery Risk Development in Young Adults (CARDIA) Study. *Diabetes* 2007; **56**: 2990–2996.
13 Fuchtenbusch M, Ferber K, Standl E, Ziegler A. Prediction of type 1 diabetes postpartum in patients with gestational diabetes mellitus by combined islet cell autoantibody screening: a prospective multicenter study. *Diabetes* 1997; **46**: 1459–1467.
14 Xiang A, Takayanagi M, Black M, Trigo E, Lawrence J, Watanabe R *et al.* Longitudinal changes in insulin sensitivity and beta-cell function between women with and without a history of gestational diabetes mellitus. *Diabetologia* 2013; **56**: 2753–2760.
15 Lim S, Choi S, Park Y, Park K, Lee H, Jang H *et al.* Visceral fatness and insulin sensitivity in women with a previous history of gestational diabetes mellitus. *Diabetes Care* 2007; **30**: 348–353.
16 Smith D, Lewis C, Caveny J, Perkins L, Burke G, Bild D. Longitudinal changes in adiposity associated with pregnancy: the CARDIA Study. *J Am Med Assoc* 1994; **271**: 1747–1751.
17 Rasmussen K, Yaktine A, Committee to Re-Examine Institute of Medicine Weight Guidelines. *Weight Gain During Pregnancy: Re-Examining the Guidelines*. Washington DC: National Academies Press, 2009.
18 Nehring I, Schmoll S, Beverlein A, Hauner H, von Kries R. Gestational weight gain and long-term postpartum weight retention: a meta-analysis. *Am J Clin Nutr* 2011; **94**: 1225–1231.
19 Getahun D, Nath C, Ananth C, Chavez M, Smulian J. Gestational diabetes in the United States: temporal trends 1989 through 2004. *Am J Obstet Gynecol* 2008; **198**: 525.
20 Ehrlich S, Hedderson M, Feng J, Davenport E, Gunderson E, Ferrara A. Change in body mass index between pregnancies and the risk of gestational diabetes in a second pregnancy. *Obstet Gynecol* 2011; **117**: 1323–1330.
21 Bellamy L, Casas J, Hingorani A, Williams D. Type 2 diabetes mellitus after gestational diabetes: a systematic review and meta-analysis. *Lancet* 2009; **373**: 1773–1779.
22 Cheung N, Helmink D. Gestational diabetes: the significance of persistent fasting hyperglycemia for the subsequent development of diabetes mellitus. *J Diabetes Complications* 2006; **20**: 21–25.
23 Lawrence J, Contreras R, Sacks D. Trends in the prevalence of pre-existing diabetes and gestational diabetes mellitus among a racially/ethnically diverse population of pregnant women, 1999–2005. *Diabetes Care* 2008; **31**: 899–904.
24 Cho N, Jan J, Park J, Cho Y. Waist circumference is the key risk factor for diabetes in Korean women with history of gestational diabetes. *Diabetes Res Clin Pract* 2006; **71**: 177–183.
25 Pallardo L, Herranz L, Martin-Vaquero P, Garcia-Ingelmo T, Grande C, Janez M. Impaired fasting glucose and impaired glucose tolerance in women with prior gestational diabetes are associated with a different cardiovascular profile. *Diabetes Care* 2003; **26**: 2318–2322.
26 Rivero K, Portal V, Vieria M, Behle I. Prevalence of the impaired glucose metabolism and its association with risk factors for coronary artery disease in women with gestational diabetes. *Diabetes Res Clin Pract* 2008; **79**: 433–437.
27 Kousta E, Efstathiadou Z, Lawrence N, Jeffs JA, Godsland JF, Barrett SC *et al.* The impact of ethnicity on glucose regulation and the metabolic syndrome following gestational diabetes. *Diabetologia* 2006; **49**: 36–40.
28 Pallardo F, Herranz L, Garcia-Ingelmo T, Grande C, Martin-Vaquero P, Janez M *et al.* Early postpartum metabolic

assessment in women with prior gestational diabetes. *Diabetes Care* 1999; **22**: 1053–1058.
29 Xiang A, Kawakubo M, Kjos S, Buchanan T. Long-acting injectable progestin contraception and risk of type 2 diabetes in Latino women with prior gestational diabetes mellitus. *Diabetes Care* 2006; **29**: 613–617.
30 Heitritter S, Solomon C, Mitchell G, Skali-Ounis N, Seely E. Subclinical inflammation and vascular dysfunction in women with previous gestational diabetes mellitus. *J Clin Endocrinol Metab* 2005; **90**: 3983–3988.
31 Bo S, Valpreda S, Menato G, Bardelli C, Botto C, Gambino R *et al.* Should we consider gestational diabetes a vascular risk factor? *Atherosclerosis* 2007; **194**: e72–e79.
32 Brewster S, Zinman B, Retnakaran R, Floras J. Cardiometabolic consequences of gestational dysglycemia. *J Am Coll Cardiol* 2013; **62**: 677–684.
33 Carr D, Utzschneider K, Hull R, Tong J, Wallace T, Kodama K *et al.* Gestational diabetes mellitus increases the risk of cardiovascular disease in women with a family history of type 2 diabetes. *Diabetes Care* 2006; **29**: 2078–2083.
34 Kessous R, Shoham-Vardi I, Pariente G, Sherf M, Sheiner E. An association between gestational diabetes mellitus and long-term maternal cardiovascular morbidity. *Heart* 2013; **99**: 1118–1121.
35 Shah B, Retnakaran R, Booth G. Increased risk of cardiovascular disease in young women following gestational diabetes. *Diabetes Care* 2008; **31**: 1668–1669.
36 Moses R. The recurrence rate of gestational diabetes in subsequent pregnancies. *Diabetes Care* 1996; **19**: 1348–1350.
37 MacNeill S, Dodds L, Hamilton D, Armson B, Van den Hof M. Rates and risk factors for recurrence of gestational diabetes. *Diabetes Care* 2001; **24**: 659–662.
38 Kim C, Berger D, Chamany S. Recurrence of gestational diabetes mellitus: a systematic review. *Diabetes Care* 2007; **30**: 1314–1319.
39 Baptiste-Roberts K, Barone B, Gary T, Golden S, Wilson L, Bass E *et al.* Risk factors for type 2 diabetes among women with gestational diabetes: a systematic review. *Am J Med* 2009; **122**: 207–214.
40 Ratner R, Christophi C, Metzger B, Dabelea D, Bennett P, Pi-Sunyer X *et al.* Prevention of diabetes in women with a history of gestational diabetes; effects of metformin and lifestyle interventions. *J Clin Endocrinol Metab* 2008; **93**: 4774–4779.
41 The Diabetes Prevention Program Research Group. The Diabetes Prevention Program: recruitment methods and results. *Control Clin Trials* 2001; **23**: 157–171.
42 Ferrara A, Ehrlich S. Strategies for diabetes prevention before and after pregnancy in women with GDM. *Curr Diabetes Rev* 2011; **7**: 75–83.
43 Ferrara A, Hedderson M, Albright C, Ehrlich S, Quesenberry C, Peng T *et al.* A pregnancy and postpartum lifestyle intervention in women with gestational diabetes mellitus reduces diabetes risk factors: a feasibility randomized control trial. *Diabetes Care* 2011; **34**: 1519–1525.
44 Shek N, Ngai C, Lee C, Chan J, Lao T. Lifestyle modifications in the development of diabetes mellitus and metabolic syndrome in Chinese women who had gestational diabetes mellitus: a randomized intervention trial. *Arch Gynecol Obstet* 2014; **289**: 319–327.
45 Tobias D, Hu F, Chavarro J, Rosner B, Mozaffarian D, Zhang C. Healthful dietary patterns and type 2 diabetes mellitus risk among women with a history of gestational diabetes mellitus. *Arch Intern Med* 2012; **172**: 1566–1572.
46 Kim S, Kim M, Yang J, Park S, Yim C, Han K *et al.* Nutritional risk factors of early development of postpartum prediabetes and diabetes in women with gestational diabetes mellitus. *Nutrition* 2011; **27**: 782–788.
47 Kieffer E, Sinco B, Kim C. Health behaviors in women with a history of gestational diabetes mellitus in the Behavioral Risk Factor Surveillance System. *Diabetes Care* 2006; **29**: 1788–1793.
48 Bennett W, Liu S, Yeh H, Nicholson W, Gunderson E, Lewis C *et al.* Change in weight and health behaviors after pregnancies complicated by gestational diabetes mellitus: the CARDIA Study. *Obesity (Silver Spring)* 2013; **21**: 1269–1275.
49 Retnakaran R, Qi Y, Sermer M, Connelly P, Zinman B, Hanley A. Gestational diabetes and postpartum physical activity: evidence of lifestyle change 1-year after delivery. *Obesity (Silver Spring)* 2010; **18**: 1323–1329.
50 O'Reilly M, Avalos G, Dennedy M, O'Sullivan E, Dunne F. Atlantic DIP: high prevalence of abnormal glucose tolerance post-partum is reduced by breast-feeding in women with prior gestational diabetes mellitus. *Eur J Endocrinol* 2011; **165**: 953–959.
51 Gunderson E, Hedderson M, Chiang V, Crites Y, Walton D, Azevedo R *et al.* Lactation intensity and postpartum maternal glucose tolerance and insulin resistance in women with recent GDM: the SWIFT cohort. *Diabetes Care* 2012; **35**: 50–56.
52 Ziegler A, Wallner M, Kaiser I, Rossbauer M, Harsunen M, Lachmann L *et al.* Long-term protective effect of lactation on the dvelopment of type 2 diabetes in women with recent gestational diabetes mellitus. *Diabetes* 2012; **61**: 3167–3171.
53 Finkelstein S, Keely E, Feig D, Tu X, Yasseen A 3rd, Walker M. Breastfeeding in women with diabetes: lower rates despite greater rewards. *A population-based study. Diabet Med* 2013; **30**: 1094–1101.
54 Kjos S, Peters R, Xiang A, Thomas D, Schaefer U, Buchanan T. Contraception and the risk of type 2 diabetes mellitus in Latina women with prior gestational diabetes mellitus. *J Am Med Assoc* 1998; **280**: 533–538.
55 Kim C, Seidel K, Begier E, Kwok Y. Diabetes and depot medroxyprogesterone contraception in Navajo women. *Arch Intern Med* 2001; **161**: 1766–1771.
56 Truitt S, Fraser A, Grimes D, Gallo D, Schulz K. Hormonal contraception during lactation: systematic review of randomized controlled trials. *Contraception* 2003; **68**: 233–238.
57 Espey E, Ogburn T, Leeman L, Singh R, Ostrom K, Schrader R. Effect of progestin compared with combined oral contraceptive pills on laactation: a randomized controlled trial. *Obstet Gynecol* 2012; **119**: 5–13.
58 Kwak S, Kim H, Choi S, Lim S, Cho Y, Park K *et al.* Subsequent pregnancy after gestational diabetes mellitus: frequency and risk factors for recurrence in Korean women. *Diabetes Care* 2008; **31**: 1867–1871.
59 Wang Y, Chen L, Horswell R, Xiao K, Besse J, Johnson J *et al.* Racial differences in the association between gestational diabetes mellitus and risk of type 2 diabetes. *J Womens Health (Larchmt)* 2012; **21**: 628–633.
60 Xiang A, Li B, Black M, Sacks D, Buchanan T, Jacobsen S *et al.* Racial and ethnic disparities in diabetes risk after gestational diabetes mellitus. *Diabetologia* 2011; **54**: 3016–3021.
61 Kim C, Kim S, Sappenfield W, Wilson H, Salihu H, Sharma A. Are gestational diabetes mellitus and preconception diabetes mellitus less common in non-Hispanic black women than in non-Hispanic white women? *Matern Child Health J* 2013; doi: 10.1007/s10995-013-1295-9 [Epub ahead of print].
62 Golden S, Bennett W, Baptiste-Roberts K, Wilson L, Barone B, Gary T *et al.* Antepartum glucose tolerance test results as predictors of type 2 diabetes mellitus in women with a history of gestational diabetes mellitus: a systematic review. *Gend Med* 2009; **6**: S109–S122.
63 Catalano P, Vargo K, Bernstein I, Amini S. Incidence and risk factors associated with abnormal postpartum glucose tolerance in

women with gestational diabetes. *Am J Obstet Gynecol* 1991; **165**: 914–919.
64 Steinhart J, Sugarman J, Connell F. Gestational diabetes is a herald of NIDDM in Navajo women. *Diabetes Care* 1997; **20**: 943–947.
65 Cho N, Lim S, Jang H, Park H, Metzger B. Elevated homocysteine as a risk factor for the development of diabetes in women with a previous history of gestational diabetes mellitus: a 4-year prospective study. *Diabetes Care* 2005; **28**: 2750–2755.
66 Kjos S, Peters R, Xiang A, Henry O, Montoro M, Buchanan T. Predicting future diabetes in Latino women with gestational diabetes. *Diabetes* 1995; **44**: 586–591.
67 Schaefer-Graf U, Buchanan T, Xiang A, Peters R, Kjos S. Clinical predictors for a high risk for the development of diabetes mellitus in the early puerperium in women with recent gestational diabetes mellitus. *Am J Obstet Gynecol* 2002; **186**: 751–756.
68 Retnakaran R, Zinman B, Connelly P, Sermer M, Hanley A. Impaired glucose tolerance of pregnancy is a heterogeneous metabolic disorder as defined by the glycemic response to the oral glucose tolerance test. *Diabetes Care* 2006; **29**: 57–62.
69 Retnakaran R, Qi Y, Sermer M, Connelly P, Zinman B, Hanley A. Isolated hyperglycemia at 1-hour on oral glucose tolerance test in pregnancy resembles gestational diabetes in predicting postpartum metabolic dysfunction. *Diabetes Care* 2008; **31**: 1275–1281.
70 Buchanan T, Xiang A, Kjos S, Trigo E, Lee W, Peters R. Antepartum predictors of the development of type 2 diabetes in Latino women 11–26 months after pregnancies complicated by gestational diabetes. *Diabetes* 1999; **48**: 2430–2436.
71 Jang H, Yim C, Han K, Yoon H, Han I, Kim M *et al.* Gestational diabetes mellitus in Korea: prevalence and prediction of glucose intolerance at early postpartum. *Diabetes Res Clin Pract* 2003; **61**: 117–124.
72 Metzger B, Cho N, Roston S, Radvany R. Prepregnancy weight and antepartum insulin secretion predict glucose tolerance five years after gestational diabetes mellitus. *Diabetes Care* 1993; **16**: 1598–1605.
73 de Leiva A, Mauricio D, Corcoy R. Diabetes-related autoantibodies and gestational diabetes. *Diabetes Care* 2007; **30**: S127–S133.
74 Jarvela I, Juutinen J, Koskela P, Hartikainen A, Kulmala P, Knip M *et al.* Gestational diabetes identifies women at risk for permanent type 1 and type 2 diabetes in fertile age: predictive role of autoantibodies. *Diabetes Care* 2006; **29**: 607–612.
75 Papadopolou A, Lynch K, Anderberg E, Landin-Olsson M, Hansson I, Agardh C *et al.* HLA-DQB1 genotypes and islet cell autoantibodies against GAD65 and IA-2 in relation to development of diabetes postpartum in women with gestational diabetes mellitus. *Diabetes Res Clin Pract* 2012; **95**: 260–264.
76 DECODE Study Group. Will new diagnostic criteria for diabetes mellitus change phenotype of patients with diabetes? *Br Med J* 1998; **317**: 371–375.
77 Ferrara A, Peng T, Kim C. Trends in postpartum diabetes screening and subsequent diabetes and impaired glucose regulation among women with histories of gestational diabetes mellitus: a TRIAD study. *Diabetes Care* 2009; **32**: 269–274.
78 Kahn R, Alperin P, Eddy D, Borch-Johnsen K, Buse J, Feigelman J *et al.* Age at initiation and frequency of screening to detect type 2 diabetes: a cost-effectiveness analysis. *Lancet* 2010; **375**: 1365–1374.
79 Picon M, Murri M, Munoz A, Fernandez-Garcia J, Gomez-Huelgas R, Tinahones F. Hemoglobin A1c versus oral glucose tolerance test in postpartum diabetes screening. *Diabetes Care* 2012; **35**: 1648–1653.
80 Clark H, Graham I, Karovitch A, Keely E. Do postal reminders increase postpartum screening of diabetes mellitus in women with gestational diabetes mellitus? A randomized controlled trial. *Am J Obstet Gynecol* 2009; **200**: 634.e1–7.
81 Ferrara A, Hedderson M, Quesenberry C, Selby J. Prevalence of gestational diabetes mellitus detected by the National Diabetes Data Group or the Carpenter and Coustan plasma glucose thresholds. *Diabetes Care* 2002; **25**: 1625–1630.
82 Sacks D, Hadden D, Maresh M, Derrochanawong C, Dyer A, Metzger B *et al.* Frequency of gestational diabetes mellitus at collaborating centers based on IADPSG consensus panel-recommended criteria: the Hyperglycemia and Adverse Pregnancy Outcome (HAPO) Study. *Diabetes Care* 2012; **35**: 526–528.
83 National Institute for Health and Clinical Excellence (NICE). *Diabetes in Pregnancy: Management of Diabetes and its Complications from Pre-Conception to the Post-Natal Period*. London: National Collaborating Centre for Women's and Children's Health, 2008.
84 World Health Organization. *Definition and Diagnosis of Diabetes Mellitus and Intermediate Hyperglycemia: A Report of a WHO/IDF Consultation*. Geneva: WHO, 2006.
85 American Diabetes Association. Diagnosis and classification of diabetes mellitus. *Diabetes Care* 2010; **33**: S62–S69.
86 Canadian Diabetes Association Clinical Practice Guidelines Expert Committee. Canadian Diabetes Association 2013 Clinical Practice Guidelines for the Prevention and Management of Diabetes in Canada. *Can J Diabetes* 2013; **37**: S1–S212.