Risk factor screening for gestational diabetes mellitus based on the 2013 WHO criteria

Katrien Benhalima¹, Paul Van Crombrugge², Carolien Moyson¹, Johan Verhaeghe³, Sofie Vandeginste⁴, Hilde Verlaenen⁴, Chris Vercammen⁵, Toon Maes⁵, Els Dufrainmont⁶, Christophe De Block⁷, Yves Jacquemyn⁸, Farah Mekahli⁹, Katrien De Clippel¹⁰, Annick Van Den Bruel¹¹, Anne Loccufier¹², Annouschka Laenen¹³, Caro Minschart¹, Roland Devlieger³ and Chantal Mathieu¹

¹Department of Endocrinology, University Hospital Gasthuisberg, KU Leuven, Leuven, Belgium, ²Department of Endocrinology, OLV Ziekenhuis Aalst-Asse-Ninove, Aalst, Belgium, ³Department of Obstetrics & Gynecology, University Hospital Gasthuisberg, KU Leuven, Leuven, Belgium, ⁴Department of Obstetrics & Gynecology, OLV Ziekenhuis Aalst-Asse-Ninove, Aalst, Belgium, ⁵Department of Endocrinology, Imelda Ziekenhuis, Bonheiden, Belgium, ⁶Department of Obstetrics & Gynecology, Imelda Ziekenhuis, Bonheiden, Belgium, ⁷Department of Endocrinology-Diabetology-Metabolism, ⁸Department of Obstetrics & Gynecology, Antwerp University Hospital, Edegem, Belgium, ⁹Department of Endocrinology, ¹⁰Department of Obstetrics & Gynecology, Kliniek St-Jan Brussel, Brussel, Belgium, ¹¹Department of Endocrinology, ¹²Department of Obstetrics & Gynecology, AZ St Jan Brugge, Brugge, Belgium, and ¹³Center of Biostatistics and Statistical Bioinformatics, KU Leuven, Leuven, Belgium

Correspondence should be addressed to K Benhalima
Email
katrien.benhalima@uzleuven.be

Abstract

Objective: Since many European countries use risk factor screening for gestational diabetes mellitus (GDM), we aimed to determine the performance of selective screening for GDM based on the 2013 WHO criteria.

Design and methods: Overall, 1811 women received universal screening with a 75 g oral glucose tolerance test (OGTT) with GDM in 12.5% ($n = 231$) women based on the 2013 WHO criteria. We retrospectively applied different European selective screening guidelines to this cohort and evaluated the performance of different clinical risk factors to screen for GDM.

Results: By retrospectively applying the English, Irish, French and Dutch guidelines for selective screening, respectively 28.5% ($n = 526$), 49.7% ($n = 916$), 48.5% ($n = 894$) and 50.7% ($n = 935$) had at least one risk factor, with GDM prevalence of respectively 6.5% ($n = 120$), 7.9% ($n = 146$), 8.0% ($n = 147$) and 8.4% ($n = 154$). Using maternal age ≥ 30 and/or BMI ≥ 25 for screening, positive rate was 69.9% ($n = 1288$), GDM prevalence 10.2% ($n = 188$), sensitivity 81.4% (CI: 75.8–86.2%) and specificity 31.8% (CI: 29.5–34.1%). Adding other clinical risk factors did not improve detection. GDM women without risk factors had more neonatal hypoglycemia (14.4 vs 4.0%, $P = 0.001$) and labor inductions (39.7 vs 25.9%, $P = 0.020$) than normal-glucose tolerant women, and less cesarean sections than GDM women with risk factors (13.8 vs 31.0%, $P = 0.010$).

Conclusions: By applying selective screening by European guidelines, about 50% of women would need an OGTT with the lowest number of missed cases (33%) by the Dutch guidelines. Screening with age ≥ 30 years and/or BMI ≥ 25 , reduced the number of missed cases to 18.6% but 70% would need an OGTT.

European Journal of
Endocrinology
(2019) **180**, 353–363

Introduction

Gestational diabetes mellitus (GDM) is defined as diabetes diagnosed in the second or third trimester of pregnancy provided that overt diabetes early in pregnancy has been excluded (1). Screening and treatment of GDM reduces

the risk for pregnancy complications such as large-for-gestational age infants (LGAs) and preeclampsia (2, 3). Women with a history of GDM are at increased risk to develop type 2 diabetes (T2DM) later in life (4).

Clinical Study	K Benhalima and others	Selective screening for GDM	180:6	354
----------------	------------------------	-----------------------------	-------	-----

Offspring of women with GDM have also a higher risk to become obese and develop T2DM later in life (5). The 'International Association of Diabetes and Pregnancy Study Groups' (IADPSG) and World Health Organization (WHO) recommend a universal one-step approach with the 75 g oral glucose tolerance test (OGTT) for screening of GDM (6, 7). The IADPSG recommendation remains controversial due to the important increase in GDM prevalence, increased workload, the need for a fasting test and the risk for increased medicalization of care (8, 9, 10). As a consequence, there is still a large variation in screening strategies for GDM used across Europe. A survey in 2015 demonstrated that the majority of European societies still recommended screening based on risk factors. Only a minority (37%) recommended a universal one-step approach with a 75 g OGTT (11). Moreover, the risk factors used in European selective screening guidelines for GDM vary. More data are therefore needed on which clinical risk factors have the best detection rate for GDM when using selective screening. Data are also needed on whether pregnancy outcomes differ between GDM women with and without risk factors compared to normal glucose-tolerant (NGT) women. We aimed therefore to determine the performance of selective screening based on different European guidelines compared to universal screening for GDM based on the 2013 WHO/IADPSG criteria from a large prospective cohort study. In addition, we evaluated the performance of different clinical risk factors to screen for GDM and evaluated pregnancy outcomes in GDM women stratified by risk factors compared to NGT women.

Subjects and methods

The cohort study was registered in ClinicalTrials.gov (NCT02036619). The study protocol was approved by the institutional review boards of all participating centers (B322201420693). Participants provided informed consent before inclusion in the study.

Study design

The Belgian Diabetes in Pregnancy study (BEDIP-N) was a multi-centric prospective cohort with 2006 women included before 14 weeks of pregnancy (12, 13, 14). The overall objective of the BEDIP-N study was to evaluate the diagnostic accuracy of different screening strategies (universal one-step diagnostic approach with 75 g OGTT compared to a universal two-step screening strategy with a 50 g glucose challenge test (GCT) and selective

screening based on risk factors) for GDM based on the 2013 WHO criteria. Participants were included between 6 and 14 weeks of pregnancy and were universally screened with a fasting plasma glucose to exclude prediabetes and diabetes (defined by the American Diabetes Association (ADA) criteria) (15). Participants without prediabetes or diabetes in early pregnancy, received both a non-fasting GCT and 75 g 2-h OGTT between 24 and 28 weeks of pregnancy (12). Of all participants, 5.3% (106) stopped with the study before 24 weeks of pregnancy, half of them due to a medical reason (14). During the study, participants and health care providers were blinded for result of the GCT. We have recently published the results on the accuracy of the GCT to screen for GDM based on the 2013 WHO criteria (13, 14). Women diagnosed with GDM were treated according to a standardized protocol in line with normal routine. (12) The ADA-recommended glycemic targets were used for the treatment of GDM (15). If targets were not achieved with lifestyle measures alone, treatment with insulin was initiated.

Study assessments

At first visit, baseline characteristics and risk factors for GDM such as maternal age, pre-pregnancy weight, ethnic background, history of smoking, family history of diabetes (a first- or second-degree relative with diabetes or a mother or sister with GDM), parity, history of polycystic ovarian syndrome (PCOS), GDM or impaired glucose intolerance and the obstetrical history were collected (12). Hypertension was defined as a systolic blood pressure (BP) ≥ 140 mmHg and/or diastolic BP ≥ 90 mmHg, overweight as a BMI ≥ 25 – 29.9 kg/m² and obesity as a BMI ≥ 30 kg/m². At first visit and at the time of the OGTT, anthropometric measurements were obtained (12). A 75 g OGTT (with measurement of glycaemia at 0, 30, 60 and 120 min) was performed between 26 and 28 weeks of pregnancy. For the 75 g OGTT participants had to be fasting for at least 10 h.

The following pregnancy outcome data were collected: gestational age, preeclampsia (*de novo* BP $\geq 140/90$ mmHg >20 weeks with proteinuria or signs of end-organ dysfunction), gestational hypertension (*de novo* BP $\geq 140/90$ mmHg >20 weeks), type of labor and type of delivery with the indications, birth weight, macrosomia (>4 kg), birth weight ≥ 4.5 kg, LGA defined as birth weight >90 percentile according to standardized Flemish birth charts adjusted for sex of the baby and parity (16), small for gestational age (SGA) defined as birth weight <10 percentile according to standardized Flemish birth charts adjusted for sex of the baby and parity (16), preterm

delivery (<37 completed weeks), 10min Apgar score, shoulder dystocia, neonatal respiratory distress syndrome, neonatal jaundice, congenital anomalies, neonatal hypoglycemia (defined as glycemia <2.2 mmol/L) and admission on the neonatal intensive care unit (NICU) (12). To compare pregnancy outcomes in GDM women stratified by risk factors compared to NGT women, GDM women without risk factors were defined as BMI <25 kg/m², maternal age <35 years, no history of a macrosomic baby (>4 kg), no history of a first-degree relative with diabetes, a Caucasian origin, no previous history of GDM, PCOS or impaired glucose tolerance.

Analyses of the performance of selective screening for GDM

We analyzed the prevalence of GDM and the number of missed cases with selective screening compared to

universal screening with 75g OGTT by retrospectively applying selective screening to our cohort according to the following European guidelines: the National Institute for Health and Clinical Excellence (NICE) guidelines from 2015, the Irish guidelines from 2010, the French guidelines from 2010 and the Dutch guidelines from 2010 (17, 18, 19, 20) (Table 1). The positive rate was defined as the number of pregnant women (% and *n*) with at least one risk factor who would receive an OGTT to screen for GDM according to the different guidelines. The lowest number of missed cases with GDM was defined as the number of theoretically missed cases with GDM when using selective screening according to the different guidelines compared to universal screening with a 75g OGTT (GDM by universal screening but no risk factors according to each guideline respectively). We also evaluated the performance of selective screening according to the former ADA guidelines (before the endorsement of universal screening

Table 1 Overview of the different guidelines for selective screening for GDM.

NICE	Irish	French	Dutch	ADA
BMI ≥30	BMI ≥30	BMI ≥25	BMI ≥30	BMI ≥25 + 1 risk factor
Family history of diabetes (first-degree relative with diabetes)	Family history of diabetes in a first-degree relative	A first-degree relative with diabetes	A first-degree relative with diabetes	A first-degree relative with diabetes
Previous macrosomic baby ≥4.5 kg	Previous macrosomic baby ≥4.5 kg	Previous macrosomic baby >4 kg	Previous macrosomic baby >4.5 kg	Previous macrosomic baby >4.5 kg
	Maternal age ≥40 years	Maternal age ≥35 years		
Previous GDM			Previous GDM	
Minority ethnic family origin with a high prevalence of diabetes (non-Caucasian)	Non-Caucasian (ethnicity associated with a high prevalence of diabetes)		Non-Caucasian (ethnicity associated with a high prevalence of diabetes)	Non-Caucasian (ethnicity associated with a high prevalence of diabetes)
	PCOS		PCOS	PCOS
	History of unexplained miscarriage		History of unexplained miscarriage	
				Low HDL cholesterol (<1.0 mmol/L) and high Triglycerides (>1.7 mmol/L)
				History of impaired glucose tolerance
				*History of cardiovascular disease
				Hypertension (BP systolic ≥140 and/or diastolic ≥90)
	Polyhydramnios and/or macrosomia in existing pregnancy			
	*Current glucosuria			
	**Women on long-term steroids			

*Variables not available in the BEDIP-N database; **this was an exclusion criterion in the BEDIP-N study.

ADA, American Diabetes Association; BMI, body mass index (kg/m²); BP, blood pressure; GDM, gestational diabetes mellitus; NICE, the National Institute for Health and Clinical Excellence guidelines; PCOS, polycystic ovarian syndrome.

in 2010) (21). In addition, we analyzed the detection rate of GDM across different thresholds for maternal age and BMI with and without the addition of other clinical risk factors (first-degree family history of diabetes, history of GDM, non-Caucasian origin and a history of a macrosomic baby ≥ 4.5 kg).

Statistical analysis

Logistic regression models were used for data analysis with GDM as a binary response variable and maternal age or BMI as continuous predictors. The discriminative power of the predictors for GDM is presented by receiver-operating (ROC) curves and estimated as the area under the curve (AUC) with 95% CI. The AUC ranges between 0.5 (discrimination no better than chance) and 1 (perfect discrimination). As a potential measure to evaluate the optimal cut-off value of both predictors the maximum Youden index was determined, giving equal importance to sensitivity and specificity. In addition, we evaluated the diagnostic accuracy (the sensitivity, specificity, positive and negative likelihood ratio, with 95% CIs) across a wide range of different cut-offs for maternal age and BMI with and without the addition of other clinical risk factors (binary or dichotomized variables).

Comparisons of pregnancy outcomes between women with GDM, with and without risk factors and with the NGT group, were performed using Mann–Whitney *U* test for continuous variables, and chi-square test for categorical variables or Fisher exact test for binary variables with small (<5) cell frequencies. A *P* value <0.05 (two-tailed) was considered significant. Analyses were performed by statistician A. Laenen using SAS software (version 9.4).

Results

Study participants

Of all participants, 1841 (91.8%) received a 75 g OGTT between 24 and 28 weeks of pregnancy. Based on a

universal screening strategy with the 75 g OGTT and 2013 WHO criteria of the whole cohort, the prevalence of GDM was 12.5% (231).

The performance of the European selective screening guidelines for GDM

When we applied the NICE, Irish, French, Dutch and ADA guidelines, respectively 28.5% ($n=526$), 49.7% ($n=916$), 48.5% ($n=894$), 50.7% ($n=935$) and 49.5% ($n=913$) of all women had at least one risk factor and would have received an OGTT, leading to a GDM prevalence of respectively 6.5% ($n=120$), 7.9% ($n=146$), 8.0% ($n=147$), 8.4% ($n=154$) and 8.4% ($n=155$) (Tables 1 and 2). Of all women with GDM (231), the diagnosis would be missed when NICE, Irish, French, Dutch and ADA guidelines were applied in respectively 48% ($n=111$), 36.8% ($n=85$), 36.4% ($n=84$), 33.3% ($n=77$) and 32.9% ($n=76$) of all women with GDM (Table 2).

The performance of screening based on clinical risk factors

The maximum Youden index (0.134) was seen at a maternal age ≥ 30 years, with a sensitivity of 72.7% and specificity of 40.7%. The maximum Youden index (0.159) for maternal BMI in early pregnancy was seen at a BMI ≥ 25 kg/m², with a sensitivity of 48.4% and specificity of 67.5%. The AUC on the ROC curve for maternal age to predict GDM was 0.58 (95% CI: 0.54–0.63) and the AUC for maternal BMI in early pregnancy was 0.61 (95% CI: 0.57–0.65) (Fig. 1). Using these cut-offs for screening, the positive rate was 69.9% ($n=1288$), GDM prevalence 10.2% ($n=188$), 18.6% ($n=43$) of women with GDM would be missed, sensitivity was 81.4% (CI: 75.8–86.2%) and specificity 31.8% (CI: 29.5–34.1%) (Table 3). By adding other clinical risk factors such as a first-degree family history of diabetes, a previous history of GDM, non-Caucasian origin and a history of a macrosomic baby, the positive rate was 70.5% ($n=1300$), GDM prevalence was 10.5% ($n=193$), 16.4% ($n=38$) of women with GDM

Table 2 The numbers diagnosed with GDM based on the different screening guidelines.

	Universal	NICE	Irish	French	Dutch	ADA
% (n) OGTT needed	100 (1843)	28.5 (526)	49.7 (916)	48.5 (894)	50.7 (935)	49.5 (913)
% (n) GDM	12.5 (231)	6.5 (120)	7.9 (146)	8.0 (147)	8.4 (154)	8.4 (155)
% (n) with GDM, theoretically missed (GDM by universal screening but no risk factors according to each guideline)	0	48.0 (111)	36.8 (85)	36.4 (84)	33.3 (77)	32.9 (76)

ADA, American Diabetes Association; NICE, the National Institute for Health and Clinical Excellence guidelines; OGTT, oral glucose tolerance test.

Figure 1

(A and B) ROC curves for maternal age and BMI in early pregnancy as a predictor for GDM. AUC, area under the curve; ROC, receiver-operating curve. (A) ROC curve for maternal age; (B) ROC curve for BMI.

would be missed, sensitivity was 83.5% (CI: 78.1–88.1%) and specificity 31.4% (CI: 29.1–33.7%) (Table 3).

Pregnancy outcomes in GDM stratified by risk factors compared to NGT women

Of all women with GDM, 25.6% ($n=59$) had no risk factors (Table 4). Compared to NGT women, GDM women without risk factors had significantly more often labor inductions (39.7.1 vs 25.9%, $P=0.020$) and significantly more often neonatal hypoglycemia (14.4 vs 4.0%, $P=0.001$) (Table 4). Compared to GDM women with risk factors, GDM women without risk factors had similar pregnancy outcomes except for less cesarean sections (14.3 vs 30.6%, $P=0.016$). Compared to NGT women, GDM women with risk factors had more labor inductions (34.5 vs 25.9%, $P=0.016$), more cesarean sections (planned and emergency cesarean sections combined: 31.0 vs 20.2%, $P=0.001$; emergency cesarean sections: 16.4 vs 10.0%, $P=0.013$), more often neonatal hypoglycemia (14.6 vs 4.0%, $P<0.001$) and more NICU admissions (14.6 vs 9.6%, $P=0.037$) (Table 4). The most common indication for labor inductions was maternal pathology, but without large differences in preexisting pathologies or complications between GDM and NGT women, suggesting a diagnosis of GDM as main indication for the labor inductions (Table 4).

Discussion

Screening practices for GDM vary substantially across Europe (11). The IADPSG/2013 WHO universal one-step screening strategy for GDM has not yet been implemented in many European countries due to the

increased workload and the limited data on the cost-effectiveness of the IADPSG one-step diagnostic approach (8). Selective screening based on risk factors is therefore still recommended in many European countries as an alternative to limit health care expenses and limit the number of OGTTs (11, 22). However, the risk factors used in European selective screening guidelines for GDM vary. Our study aimed therefore to evaluate which clinical risk factors have the best detection rate for GDM when using selective screening. We show that by applying selective screening by most European guidelines, about 50% of women would need an OGTT with the lowest number of missed cases (33%) by the Dutch guidelines. Our study is in line with previous studies showing that selective screening would lead to missing one-third of women with GDM (23, 24, 25). Applying selective screening guidelines for GDM to a large pregnant cohort from Ireland showed that the former ADA guidelines would result in the lowest number (5%) of missed cases compared to the Irish (16%) and the NICE guidelines (20%) (26). This is less than in our study, showing that by applying the NICE guidelines, nearly half of all women with GDM would be missed. However, the Irish study did not evaluate the performance of selective screening according to the French and Dutch guidelines.

By using easy available clinical risk factors such as maternal age and BMI, selective screening guidelines for GDM could be simplified. We demonstrate that the most sensitive and specific cut-offs for maternal age and BMI in our population to screen for GDM, are maternal age ≥ 30 years and BMI in early pregnancy ≥ 25 kg/m². Screening by these risk factors, 70% of all women would need an OGTT and the number of missed cases would be reduced to 18.6%. Adding other clinical risk factors did not significantly improve the detection rate, indicating that a simple approach of offering an OGTT to women ≥ 30 years and/or with a BMI ≥ 25 kg/m² might be as good as more complex risk prediction models. This is supported by a meta-analysis showing that more complex selective screening models (by combinations of risk factors or prediction models or scores) did not improve the detection rate compared to strategies that simply use maternal age and BMI to screen for GDM (27). We have previously demonstrated that a modified two-step screening strategy with a GCT and several clinical risk factors (BMI ≥ 30 kg/m², non-Caucasian origin and previous history of GDM) reduced the number of women missed with GDM to 17% while avoiding an OGTT in about 50% of women (14). We show now that the most appropriate clinical risk factors to determine which

Table 3 The sensitivity and specificity of maternal age and BMI, with and without other clinical risk factors to screen for GDM.

Risk factors (≥ 1)	Positive rate, % (n)	Abnormal OGTT (prevalence GDM), % (n)	Number of GDM without risk factors (missing rate), % (n)	Sensitivity, % (95% CI)	Specificity, % (95% CI)	LR+ (95% CI)	LR- (95% CI)
BMI ≥ 25	31.4% (578)	4.5% (101)	56.3% (130)	43.7 (37.2–50.4) 101/231	70.4 (68.1–72.6) 1135/1612	1.48 (1.25–1.74)	0.80 (0.71–0.90)
BMI ≥ 30	10.2% (188)	2.5% (47)	79.6% (184)	20.3 (15.3–26.1) 47/231	91.2 (89.8–92.6) 1471/1612	2.33 (1.72–3.14)	0.87 (0.82–0.93)
Age ≥ 25 ; BMI ≥ 25	95.5 (1761)	12.0 (221)	4.3 (10)	95.7 (92.2–97.9) 221/231	4.5 (3.5–5.6) 72/1612	1.00 (0.97–1.03)	0.97 (0.51–1.85)
Age ≥ 25 ; BMI ≥ 30	93.9 (1730)	11.8 (217)	6.1 (14)	93.9 (90.0–96.6) 217/231	6.1 (5.0–7.4) 99/1612	1.00 (0.97–1.04)	0.99 (0.57–1.70)
Age ≥ 30 ; BMI ≥ 25	69.9 (1288)	10.2 (188)	18.6 (43)	81.4 (75.8–86.2) 188/231	31.8 (29.5–34.1) 512/1612	1.19 (1.11–1.28)	0.59 (0.44–0.77)
Age ≥ 30 ; BMI ≥ 30	60.2 (1110)	9.3 (172)	25.5 (59)	74.5 (68.3–79.9) 172/231	51.8 (39.4–44.3) 674/1612	1.28 (1.17–1.39)	0.61 (0.49–0.77)
Age ≥ 35 ; BMI ≥ 25	41.4% (764)	6.9% (128)	44.6% (103)	55.4 (48.7–61.9) 128/231	60.5 (58.1–62.9) 976/1612	1.40 (1.23–1.60)	0.74 (0.63–0.85)
Age ≥ 35 ; BMI ≥ 30	24.0% (442)	5.1% (94)	59.3% (137)	40.7 (34.3–47.3) 94/231	78.4 (76.3–80.4) 1264/1612	1.88 (1.57–2.26)	0.76 (0.68–0.84)
Age ≥ 40 ; BMI ≥ 25	32.4% (596)	5.7% (106)	54.1% (125)	45.9 (39.3–52.5) 106/231	69.6 (67.3–71.8) 1122/1612	1.51 (1.29–1.77)	0.78 (0.69–0.88)
Age ≥ 40 ; BMI ≥ 30	11.8% (217)	3.2% (59)	74.5% (172)	25.5 (20.0–31.7) 59/231	90.2 (88.6–91.6) 1454/1612	2.61 (2.00–3.40)	0.83 (0.76–0.89)
Age ≥ 25 ; BMI ≥ 25 ; first degree with DM	95.5 (1761)	12.0 (221)	4.3 (10)	95.7 (92.2–97.9) 221/231	4.5 (3.5–5.6) 72/1612	1.00 (0.97–1.03)	0.97 (0.51–1.85)
Age ≥ 25 ; BMI ≥ 25 ; prior GDM	95.6 (1762)	12.0 (222)	3.9 (9)	96.1 (92.7–98.2) 222/231	4.5 (3.5–5.6) 72/1612	1.01 (0.98–1.03)	0.87 (0.44–1.72)
Age ≥ 25 ; BMI ≥ 25 ; first degree with DM; prior GDM	95.6 (1762)	12.0 (222)	3.9 (9)	96.1 (92.7–98.2) 222/231	4.5 (3.5–5.6) 72/1612	1.01 (0.98–1.03)	0.87 (0.44–1.72)
Age ≥ 25 ; BMI ≥ 25 ; first degree with DM; prior GDM, non-Caucasian	95.6 (1762)	12.0 (222)	3.9 (9)	96.1 (92.7–98.2) 222/231	4.5 (3.5–5.6) 72/1612	1.01 (0.98–1.03)	0.87 (0.44–1.72)
Age ≥ 25 ; BMI ≥ 25 ; first degree with DM; prior GDM, non-Caucasian, macroscopic baby ≥ 4.5 kg	93.9 (1730)	11.8 (217)	6.1 (14)	93.9 (90.0–96.6) 217/231	6.1 (5.0–7.4) 99/1612	1.00 (0.97–1.04)	0.99 (0.57–1.70)
Age ≥ 25 ; BMI ≥ 30 ; first degree with DM	93.9 (1731)	11.8 (218)	5.6 (13)	94.4 (90.6–97.0) 218/231	6.1 (5.0–7.4) 99/1612	1.01 (0.97–1.04)	0.92 (0.52–1.61)
Age ≥ 25 ; BMI ≥ 30 ; prior GDM	93.9 (1731)	11.8 (218)	5.6 (13)	94.4 (90.6–97.0) 218/231	6.1 (5.0–7.4) 99/1612	1.01 (0.97–1.04)	0.92 (0.52–1.61)
Age ≥ 25 ; BMI ≥ 30 ; first degree with DM; prior GDM							

Clinical Study		K Benhalima and others		Selective screening for GDM		180:6	359
Age ≥ 25 ; BMI ≥ 30 ; first degree with DM; prior GDM, non-Caucasian	93.9 (1731)	11.8 (218)	5.6 (13)	94.4 (90.6–97.0) 218/231	6.1 (5.0–7.4) 99/1612	1.01 (0.97–1.04)	0.92 (0.52–1.61)
Age ≥ 25 ; BMI ≥ 30 ; first degree with DM; prior GDM, non-Caucasian, prior macrosomic baby ≥ 4.5 kg	93.9 (1731)	11.8 (218)	5.6 (13)	94.4 (90.6–97.0) 218/231	6.1 (5.0–7.4) 99/1612	1.01 (0.97–1.04)	0.92 (0.52–1.61)
Age ≥ 30 ; BMI ≥ 25 ; first degree with DM	69.9 (1288)	10.2 (188)	18.6 (43)	81.4 (75.8–86.2) 188/231	31.8 (29.5–34.1) 512/1612	1.19 (1.11–1.28)	0.59 (0.44–0.77)
Age ≥ 30 ; BMI ≥ 25 ; prior GDM	70.5 (1299)	10.5 (193)	16.4 (38)	83.5 (78.1–88.1) 193/231	31.4 (29.1–33.7) 506/1612	1.22 (1.14–1.30)	0.52 (0.39–0.71)
Age ≥ 30 ; BMI ≥ 25 ; first degree with DM; prior GDM	70.5 (1299)	10.5 (193)	16.4 (38)	83.5 (78.1–88.1) 193/231	31.4 (29.1–33.7) 506/1612	1.22 (1.14–1.30)	0.52 (0.39–0.71)
Age ≥ 30 ; BMI ≥ 25 ; first degree with DM; prior GDM, non-Caucasian	70.5 (1299)	10.5 (193)	16.4 (38)	83.5 (78.1–88.1) 193/231	31.4 (29.1–33.7) 506/1612	1.22 (1.14–1.30)	0.52 (0.39–0.71)
Age ≥ 30 ; BMI ≥ 25 ; first degree with DM; prior GDM; non-Caucasian; macrosomic baby ≥ 4.5 kg	70.5% (1300)	10.5% (193)	16.4% (38)	83.5 (78.1–88.1) 193/231	31.4 (29.1–33.7) 506/1612	1.22 (1.14–1.30)	0.52 (0.39–0.71)
Age ≥ 30 ; BMI ≥ 30 ; first degree with DM	60.2 (1110)	9.3 (172)	25.5 (59)	74.5 (68.3–79.9) 172/231	41.8 (39.4–44.3) 674/1612	1.28 (1.17–1.39)	0.61 (0.49–0.77)
Age ≥ 30 ; BMI ≥ 30 ; prior GDM,	61.0 (1125)	9.7 (179)	22.5 (52)	77.5 (71.5–82.7) 179/231	41.3 (38.9–423.8) 666/1612	1.32 (1.22–1.43)	0.54 (0.43–0.70)
Age ≥ 30 ; BMI ≥ 30 ; first degree with DM; prior GDM	61.0 (1125)	9.7 (179)	22.5 (52)	77.5 (71.5–82.7) 179/231	41.3 (38.9–423.8) 666/1612	1.32 (1.22–1.43)	0.54 (0.43–0.70)
Age ≥ 30 ; BMI ≥ 30 ; first degree with DM; prior GDM, non-Caucasian	61.0 (1125)	9.7 (179)	22.5 (52)	77.5 (71.5–82.7) 179/231	41.3 (38.9–423.8) 666/1612	1.32 (1.22–1.43)	0.54 (0.43–0.70)
Age ≥ 30 ; BMI ≥ 30 ; first degree with DM; prior GDM; nonCaucasian; macrosomic baby ≥ 4.5 kg	61.1 (1127)	9.8 (180)	22.1 (51)	77.9 (72.0–83.1) 180/231	41.2 (38.8–43.7) 665/1612	1.33 (1.22–1.44)	0.54 (0.42–0.69)

Risk factors (≥ 1): to receive screening with an OGTT, at least one risk factor is needed; gestational diabetes mellitus, age, in years; BMI, body mass index (kg/m²); DM, diabetes; LR⁺, positive likelihood ratio; LR⁻, negative likelihood ratio; OGTT, oral glucose tolerance test; positive rate, the number of OGTTs that would need to be performed based on the presence of at least 1 risk factor; sensitivity: n , number with risk factor; Specificity: n , number without risk factors;

Table 4 Pregnancy outcomes in GDM women stratified by risk factors compared to normal glucose tolerant women.

	Group 1: GDM RF+	Group 2: GDM RF–	Group 3: NGT	P value		
				1 vs 2	1 vs 3	2 vs 3
n (%)	172 (74.4)	59 (25.6)	1612			
Preeclampsia	1.2% (2/171)	1.7% (1/58)	1.8% (29/1608)	1.000	0.762	1.000
Gestational hypertension	5.3% (9/171)	0% (0/58)	4.2% (68/1608)	0.116	0.551	0.169
Chronic preexisting hypertension	2.9% (5/171)	0% (0/58)	0.7% (11/1605)	0.333	0.014	1.000
Preterm delivery	8.2% (14/171)	5.2% (3/58)	5.4% (86/1601)	0.571	0.160	1.000
Gestational age	38.8 ± 1.5	39.2 ± 1.3	39.3 ± 1.6	0.116	<0.001	0.236
Breech presentation	2.9% (5/171)	5.2% (3/58)	5.7% (92/1605)	0.424	0.155	1.000
Induction labor	34.5% (59/171)	39.7% (23/58)	25.9% (416/1605)	0.479	0.016	0.020
Reason for induction				0.853	<0.001	0.001
Fetal pathology	3.6% (2/56)	4.3% (1/23)	13.5% (56/416)			
Maternal pathology	75.0% (42/56)	65.2% (15/23)	25.2% (105/416)			
Planned delivery	7.1% (4/56)	8.7% (2/23)	13.2% (55/416)			
Post-term	8.9% (5/56)	17.4% (4/23)	35.6% (148/416)			
Premature rupture membranes	5.4% (3/56)	4.3% (1/23)	12.5% (52/416)			
Forceps or vacuum	10.5% (18/171)	15.5% (9/58)	12.3% (198/1603)	0.308	0.488	0.473
Cesarean sections (total)	31.0% (53/171)	13.8% (8/58)	20.2% (324/1603)	0.010	0.001	0.230
Planned Cesarean sections	14.6% (25/171)	6.9% (4/58)	10.2% (164/1603)	0.170	0.089	0.511
Emergency Cesarean sections (during labor)	16.4% (28/171)	6.9% (4/58)	10.0% (160/1603)	0.082	0.013	0.652
Reason for planned CS				0.047	0.078	0.350
Fetal pathology	4.0% (1/25)	25.0% (1/4)	6.6% (10/151)			
Feto-pelvic disproportion	0% (0/25)	25.00% (1/4)	4.0% (6/151)			
Malpresentation	20.0% (5/25)	50.0% (2/4)	39.1% (59/151)			
Maternal pathology	8.0% (2/25)	0% (0/4)	9.9% (15/151)			
Maternal request	0% (0/25)	0% (0/4)	2.6% (4/151)			
Placenta praevia	4.0% (1/25)	0% (0/4)	4.6% (7/151)			
Scarred uterus	44.0% (11/25)	0% (0/4)	15.9% (24/151)			
Other	20.0% (5/25)	0% (0/4)	17.2% (26/151)			
Reason for maternal pathology (for CS and induction)				0.165	0.040	0.294
Cardiac disorder	2.1% (1/47)	0% (0/15)	0% (0/122)			
Coagulation abnormalities	0% (0/47)	6.7% (1/15)	3.3% (4/122)			
Liver disease	0% (0/47)	0% (0/15)	3.3% (4/122)			
Preeclampsia, eclampsia or HELPP	10.6% (5/47)	0% (0/15)	25.4% (31/122)			
Renal impairment	0% (0/47)	0% (0/15)	0.8% (1/122)			
Utero-placental reason	0% (0/47)	0% (0/15)	4.1% (5/122)			
Other	87.2% (41/47)	93.3% (14/15)	63.1% (77/122)			
Reason for fetal pathology (for CS and induction)				0.292	0.462	0.339
Fetal malformation	20.0% (1/5)	0% (0/3)	6.8% (5/73)			
IUGR	0% (0/5)	33.3% (1/3)	23.3% (17/73)			
Macrosomia	40.0% (2/5)	66.8% (2/3)	26.0% (19/73)			
Other	40.0% (2/5)	0% (0/0)	43.8% (32/73)			
Reason for emergency CS				0.973	0.696	0.982
Cervix dilatation stagnation	33.3% (9/27)	33.3% (1/3)	25.3% (40/158)			
Fetal heart rate abnormalities	29.6% (8/27)	33.3% (1/3)	31.0% (49/158)			
A mix of both	0% (0/27)	0% (0/3)	3.2% (5/158)			
Feto-pelvic disproportion	11.1% (3/27)	0% (0/3)	13.9% (22/158)			
Hemorrhage	3.7% (1/27)	0% (0/3)	0.6% (1/158)			
Planned CS performed during labor	3.7% (1/27)	0% (0/3)	6.3% (10/158)			
Other	18.5% (5/27)	33.3% (1/3)	19.6% (31/158)			
Postpartum blood loss				0.503	0.809	0.297
≥500 mL	21.6% (37/171)	17.2% (10/58)	20.7% (327/1583)			
≥1000 mL	2.9% (5/171)	5.2% (3/58)	2.5% (39/1583)			
Male sex baby	52.9% (90/170)	48.3% (28/58)	49.7% (797/1602)	0.539	0.429	0.825
Weight baby (g)	3347.7 ± 487.2	3269.1 ± 439.6	3397.9 ± 509.9	0.113	0.233	0.016

(Continued)

Clinical Study	K Benhalima and others	Selective screening for GDM	180:6	361
----------------	------------------------	-----------------------------	-------	-----

Table 4 Continued.

	Group 1: GDM RF+	Group 2: GDM RF–	Group 3: NGT	P value		
				1 vs 2	1 vs 3	2 vs 3
Length baby (cm)	50.2 ± 2.1	49.8 ± 2.1	50.5 ± 2.6	0.145	0.075	0.009
Head circumference baby (cm)	34.4 ± 1.6	34.1 ± 1.5	34.4 ± 1.8	0.198	0.585	0.231
Macrosomia (>4 kg)	6.5% (11/170)	8.6% (5/58)	9.4% (151/1600)	0.580	0.202	0.834
Weight baby ≥4.5 kg	0.6% (1/171)	0% (0/58)	1.3% (21/1602)	1.000	0.716	1.000
LGA	12.3% (21/171)	12.1% (7/58)	12.9% (206/1601)	0.966	0.827	0.858
SGA	5.3% (9/171)	3.4% (2/58)	5.1% (81/1598)	0.734	0.855	1.000
Apgar 10 min <7	0.6% (1/170)	0% (0/58)	0.9% (15/1597)	1.000	1.000	1.000
Shoulder dystocia	1.2% (2/171)	0% (0/58)	1.1% (18/1598)	1.000	1.000	1.000
Birth trauma (total)				0.557	0.303	0.982
Brain hematoma	0% (0/169)	0% (0/58)	0.2% (3/1603)			
Clavicular or humerus fracture	0.6% (1/169)	0% (0/58)	0.1% (1/1603)			
Perinatal asphyxia	0% (0/169)	0% (0/58)	0.4% (6/1603)			
Plexus brachialis palsy	0% (0/169)	0% (0/58)	0.1% (1/1603)			
Congenital anomaly (total)	5.3% (9/171)	3.5% (2/57)	4.3% (68/1593)	0.735	0.553	1.000
Respiratory distress syndrome	0.6% (1/171)	1.7% (1/58)	0.9% (15/1594)	0.443	1.000	0.437
Neonatal hypoglycemia (≤2.2 mmol/l)	14.4% (22/153)	13.7% (7/51)	4.0% (41/1023)	0.908	<0.001	0.001
Neonatal jaundice	16.4% (19/116)	13.5% (5/37)	18.9% (216/1141)	0.676	0.502	0.406
NICU admission	14.6% (25/171)	12.1% (7/58)	9.6% (153/1597)	0.628	0.037	0.529
Days on NICU	7.9 ± 8.5	3.8 ± 3.7	8.4 ± 14.0	0.369	0.945	0.382

CS, cesarean section; GDM, gestational diabetes mellitus; NGT, normal glucose tolerant women; NICU, neonatal intensive care unit; RF+, with risk factors; RF–, without risk factors (BMI <25 kg/m², maternal age <35 years, no history of a macrosomic baby (>4 kg), no history of a first-degree relative with diabetes, a Caucasian origin, no history of polycystic ovarian syndrome, GDM or impaired glucose tolerance).

women should receive an OGTT when using selective screening differ from the most appropriate clinical risk factors when using a modified two-step screening strategy with GCT. This difference is related to the characteristics of women with GDM that would be missed when using a GCT with a threshold ≥7.2 mmol/L (14).

Using an efficient screening strategy with clinical risk factors, might identify a GDM group at high risk for adverse pregnancy outcomes while universal screening might identify more women with GDM at low risk with less clinical significance (28). However, other studies have shown similar adverse pregnancy outcomes among young, lean women with GDM (29, 30). We demonstrate that despite treatment, GDM women without risk factors had still higher rates of labor inductions and neonatal hypoglycemia than NGT women. In addition, women with GDM without risk factors had a non-significantly higher rate of instrumental delivery than NGT women but a significantly lower rate of cesarean sections. The pregnancy outcomes in GDM women without risk factors were better than in GDM women with risk factors. GDM women with risk factors had higher rates of cesarean sections, labor inductions, neonatal hypoglycemia and NICU admissions than NGT women. The differences in pregnancy outcomes between both GDM groups is probably mainly driven by the presence of risk factors such as an increased BMI which is an established independent

risk factor for adverse pregnancy outcomes (9). However, the increased rates of labor inductions seem to be largely driven by the label of 'GDM' rather than a clear clinical indication while the increased rate of cesarean sections was driven by an increase in emergency cesarean sections. This highlights the need for appropriate education on the management of GDM, especially in the face of the increased prevalence of GDM when using a universal one-step screening strategy identifying many women with mild forms of GDM.

By diagnosing GDM, a group of women at high risk to develop T2DM and cardiovascular disease later in life is identified (4, 31). GDM women diagnosed by a universal one-step screening strategy with 2013 WHO criteria might have a lower risk for glucose intolerance in early postpartum than women diagnosed by a two-step screening strategy (32, 33, 34). A universal one-step screening strategy might identify milder forms of GDM with less underlying β-cell dysfunction and therefore less risk to develop T2DM over time. An Irish study showed that of the women who progressed to glucose intolerance postpartum, 90% had risk factors for GDM (32, 35). If health care resources are limited, identifying GDM by using easy-to-use clinical risk factors, might be a good alternative to universal screening to identify the highest risk women for adverse pregnancy outcomes and for glucose intolerance on the long term.

Strengths of our study are the large multi-ethnic cohort and the fact that clinical risk factors were prospectively collected in early pregnancy. In addition, we evaluated the performance of selective screening across many different guidelines and risk factors. However, some bias in recruitment cannot be excluded since we had less women from a non-Caucasian origin compared to the background population. On the other hand, the rates of overweight and obese women in our cohort were representative of our background population (14). In addition, caution is required to interpret the different analyses in pregnancy outcomes between the different GDM groups and NGT women. Due to the small sample size, the power is limited to evaluate less frequent pregnancy complications such as preeclampsia and preterm delivery.

In conclusion, we show that by applying selective screening by most European guidelines, about 50% of women would need an OGTT with the lowest number of missed cases (33%) by the Dutch guidelines. In addition, we demonstrate that a simple approach of offering an OGTT to women ≥ 30 years and/or with a BMI ≥ 25 kg/m² might be a good alternative to more complex risk prediction models and guidelines to screen for GDM. We also demonstrate that despite treatment, GDM women without risk factors had higher rates of neonatal hypoglycemia than NGT women. However, GDM women with risk factors have worse pregnancy outcomes.

Declaration of interest

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of this study.

Funding

This investigator-initiated study was funded by the Belgian National Lottery, the Fund of Academic studies of UZ Leuven and the Fund Yvonne and Jacques François – de Meurs of the King Boudewijn Foundation. The sponsors of the study had no role in the design of the study; or in the collection, handling, analysis; or interpretation of the data or in the decision to write and submit the manuscript for publication.

Author contribution statement

K B, P V C and C M conceived the project. Carolien Moyson prepared the data and A Laenen did the statistical analysis. K B did the literature review. K B and C M wrote the first draft of the manuscript. All authors contributed to the study design, including data collection, data interpretation and manuscript revision. The corresponding author K B had full access to all the data in the study and had final responsibility for the contents of the article and the decision to submit for publication.

Acknowledgements

R D is the recipient of a 'Fundamenteel Klinisch Navorserschap FWO Vlaanderen'. The authors thank Dr Inge Beckstedde from the UZA site and

Dr Sylva Van Imschoot from the AZ St Jan Brugge site for their help with the recruitment and study assessments. They thank the research assistants, paramedics and physicians of all participating centers for their support and they thank all women who participated in the study.

References

- 1 American Diabetes Association. 14. Management of diabetes in pregnancy: standards of medical care in Diabetes-2019. *Diabetes Care* 2019 **42** (Supplement 1) S165–S172. (<https://doi.org/10.2337/dc19-S014>)
- 2 Crowther CA, Hiller JE, Moss JR, McPhee AJ, Jeffries WS, Robinson JS & Australian Carbohydrate Intolerance Study in Pregnant Women (ACHOIS) Trial Group. Effect of treatment of gestational diabetes mellitus on pregnancy outcomes. *New England Journal of Medicine* 2005 **352** 2477–2486. (<https://doi.org/10.1056/NEJMoa042973>)
- 3 Landon MB, Spong CY, Thom E, Carpenter MW, Ramin SM, Casey B, Wapner RJ, Varner MW, Rouse DJ, Thorp JM Jr *et al.* A multicenter, randomized trial of treatment for mild gestational diabetes. *New England Journal of Medicine* 2009 **361** 1339–1348. (<https://doi.org/10.1056/NEJMoa0902430>)
- 4 Bellamy L, Casas JP, Hingorani AD & Williams D. Type 2 diabetes mellitus after gestational diabetes: a systematic review and meta-analysis. *Lancet* 2009 **373** 1773–1779. ([https://doi.org/10.1016/S0140-6736\(09\)60731-5](https://doi.org/10.1016/S0140-6736(09)60731-5))
- 5 Grunnet LG, Hansen S, Hjort L, Madsen CM, Kampmann FB, Thuesen ACB, Granstrømi C, Strøm M, Maslova E, Frikke-Schmidt R *et al.* Adiposity, dysmetabolic traits, and earlier onset of female puberty in adolescent offspring of women with gestational diabetes mellitus: a clinical study within the Danish national birth cohort. *Diabetes Care* 2017 **40** 1746–1755. (<https://doi.org/10.2337/dc17-0514>)
- 6 Consensus P, Metzger BE, Gabbe SG, Persson B, Buchanan TA, Catalano PA, Damm P, Dyer AR, Leiva Ad HM, Kitzmiller JL *et al.* International association of diabetes and pregnancy study groups recommendations on the diagnosis and classification of hyperglycemia in pregnancy. *Diabetes Care* 2010 **33** 676–682. (<https://doi.org/10.2337/dc09-1848>)
- 7 Diagnostic criteria and classification of hyperglycaemia first detected in pregnancy: a World Health Organization Guideline. *Diabetes Research and Clinical Practice* 2014 **103** 341–363. (<https://doi.org/10.1016/j.diabres.2013.10.012>)
- 8 Benhalima K, Mathieu C, Damm P, Van Assche A, Devlieger R, Desoye G, Corcoy R, Mahmood T, Nizard J, Savona-Ventura C *et al.* A proposal for the use of uniform diagnostic criteria for gestational diabetes in Europe: an opinion paper by the European Board & College of Obstetrics and Gynaecology (EBCOG). *Diabetologia* 2015 **58** 1422–1429. (<https://doi.org/10.1007/s00125-015-3615-7>)
- 9 Ryan EA. Diagnosing gestational diabetes. *Diabetologia* 2011 **54** 480–486. (<https://doi.org/10.1007/s00125-010-2005-4>)
- 10 Cundy T, Ackermann E & Ryan EA. Gestational diabetes: new criteria may triple the prevalence but effect on outcomes is unclear. *BMJ* 2014 **348** g1567. (<https://doi.org/10.1136/bmj.g1567>)
- 11 Benhalima K, Mathieu C, Van Assche A, Damm P, Devlieger R, Mahmood T & Dunne F. Survey by the European Board and College of Obstetrics and Gynaecology on screening for gestational diabetes in Europe. *European Journal of Obstetrics, Gynecology, and Reproductive Biology* 2016 **201** 197–202. (<https://doi.org/10.1016/j.ejogrb.2016.04.003>)
- 12 Benhalima K, Van Crombrugge P, Verhaeghe J, Vandeginste S, Verlaenen H, Vercammen C, Dufraimont E, De Block C, Jacquemyn Y, Mekahli F *et al.* The Belgian Diabetes in Pregnancy Study (BEDIP-N), a multi-centric prospective cohort study on screening for diabetes in pregnancy and gestational diabetes: methodology and design. *BMC Pregnancy and Childbirth* 2014 **14** 226. (<https://doi.org/10.1186/1471-2393-14-226>)

- 13 Benhalima K, Van Crombrugge P, Moyson C, Verhaeghe J, Vandeginste S, Verlaenen H, Vercammen C, Maes T, Dufraimont E, De Block C *et al.* The sensitivity and specificity of the glucose challenge test in a universal two-step screening strategy for gestational diabetes mellitus using the 2013 World Health Organization criteria. *Diabetes Care* 2018 **41** e111–e112. (<https://doi.org/10.2337/dc18-0556>)
- 14 Benhalima K, Van Crombrugge P, Moyson C, Verhaeghe J, Vandeginste S, Verlaenen H, Vercammen C, Maes T, Dufraimont E, De Block C *et al.* A modified two-step screening strategy for gestational diabetes mellitus based on the 2013 WHO criteria by combining the glucose challenge test and clinical risk factors. *Journal of Clinical Medicine* 2018 **7** E351. (<https://doi.org/10.3390/jcm7100351>)
- 15 American Diabetes Association. Standards of medical care in diabetes – 2013. *Diabetes Care* 2013 **36** (Supplement 1) S11–S66. (<https://doi.org/10.2337/dc13-S011>)
- 16 Devlieger H, Martens G, Bekaert A & Eeckels R. Standaarden van geboortegewicht-voor-zwangerschapsduur voor de Vlaamse boreling. *Tijdschrift voor Geneeskunde* 2000 **56** 1–14. (<https://doi.org/10.2143/TVG.56.1.5000625>)
- 17 NICE guideline. Diabetes in pregnancy: management from preconception to the postnatal period, 2015. (available at: <https://www.nice.org.uk/guidance/ng3/resources/diabetes-in-pregnancy-management-from-preconception-to-the-postnatal-period-pdf-51038446021>). Accessed on February 2018.
- 18 Health Service Executive of Ireland. Guidelines for the management of pre-gestational and gestational diabetes mellitus from pre-conception to the postnatal period, 2010. (available at: <http://www.hse.ie/eng/services/Publications/corporate/NursingMidwifery%20Services/onsdguidelinesgestationaldiabetes.pdf>). Accessed on February 2018.
- 19 Le Collège national des gynécologues et obstétriciens français et par la Société francophone du diabète. Recommendations pour la pratique clinique: le diabète gestationnel, 2010. (available at: http://www.cngof.asso.fr/D_TELE/RPC_DIABETE_2010.pdf). Accessed on February 2018.
- 20 Richtlijn van de Nederlands Vereniging voor Obstetrie en Gynaecologie (NVOG) diabetes mellitus en zwangerschap, 2010. (available at: <http://nvogdocumenten.nl/index.php?pagina=/site/pagina.php&id=54321>). Accessed on February 2018.
- 21 American Diabetes Association. Diagnosis and classification of diabetes mellitus. *Diabetes Care* 2009 **32** (Supplement 1) S62–S67. (<https://doi.org/10.2337/dc09-S062>)
- 22 Benhalima K, Damm P, Van Assche A, Mathieu C, Devlieger R, Mahmood T & Dunne F. Screening for gestational diabetes in Europe: where do we stand and how to move forward? A scientific paper commissioned by the European Board and College of Obstetrics and Gynaecology (EBCOG). *European Journal of Obstetrics, Gynecology, and Reproductive Biology* 2016 **201** 192–196. (<https://doi.org/10.1016/j.ejogrb.2016.04.002>)
- 23 Cosson E, Benbara A, Pharisien I, Nguyen MT, Revaux A, Lormeau B, Sandre-Banon D, Assad N, Pillegand C, Valensi P *et al.* Diagnostic and prognostic performances over 9 years of a selective screening strategy for gestational diabetes mellitus in a cohort of 18,775 subjects. *Diabetes Care* 2013 **36** 598–603. (<https://doi.org/10.2337/dc12-1428>)
- 24 Cosson E, Cussac-Pillegand C, Benbara A, Pharisien I, Jaber Y, Banu I, Nguyen MT, Valensi P & Carbillon L. The diagnostic and prognostic performance of a selective screening strategy for gestational diabetes mellitus according to ethnicity in Europe. *Journal of Clinical Endocrinology and Metabolism* 2014 **99** 996–1005. (<https://doi.org/10.1210/jc.2013-3383>)
- 25 Benhalima K, Devlieger R & Van Assche A. Screening and management of gestational diabetes. *Best Practice and Research: Clinical Obstetrics and Gynaecology* 2015 **29** 339–349. (<https://doi.org/10.1016/j.bpobgyn.2014.07.026>)
- 26 Avalos GE, Owens LA, Dunne F & ATLANTIC DIP Collaborators. Applying current screening tools for gestational diabetes mellitus to a European population: is it time for change? *Diabetes Care* 2013 **36** 3040–3044. (<https://doi.org/10.2337/dc12-2669>)
- 27 Farrar D, Simmonds M, Bryant M, Lawlor DA, Dunne F, Tuffnell D & Sheldon TA. Risk factor screening to identify women requiring oral glucose tolerance testing to diagnose gestational diabetes: a systematic review and meta-analysis and analysis of two pregnancy cohorts. *PLoS ONE* 2017 **12** e0175288. (<https://doi.org/10.1371/journal.pone.0175288>)
- 28 Naylor CD, Sermer M, Chen E & Farine D. Selective screening for gestational diabetes mellitus. Toronto Trihospital Gestational Diabetes Project Investigators. *New England Journal of Medicine* 1997 **337** 1591–1596. (<https://doi.org/10.1056/NEJM199711273372204>)
- 29 Moses RG, Moses J & Davis WS. Gestational diabetes: do lean young Caucasian women need to be tested? *Diabetes Care* 1998 **21** 1803–1806. (<https://doi.org/10.2337/diacare.21.11.1803>)
- 30 Weeks JW, Major CA, de Veciana M & Morgan MA. Gestational diabetes: does the presence of risk factors influence perinatal outcome? *American Journal of Obstetrics and Gynecology* 1994 **171** 1003–1007. ([https://doi.org/10.1016/0002-9378\(94\)90023-X](https://doi.org/10.1016/0002-9378(94)90023-X))
- 31 Song C, Lyu Y, Li C, Liu P, Li J, Ma RC & Yang X. Long-term risk of diabetes in women at varying durations after gestational diabetes: a systematic review and meta-analysis with more than 2 million women. *Obesity Reviews* 2018 **19** 421–429. (<https://doi.org/10.1111/obr.12645>)
- 32 Noctor E, Crowe C, Carmody LA, Avalos GM, Kirwan B, Infanti JJ, O'Dea A, Gillespie P, Newell J, McGuire B *et al.* Atlantic DIP: simplifying the follow-up of women with previous gestational diabetes. *European Journal of Endocrinology* 2013 **169** 681–687. (<https://doi.org/10.1530/EJE-13-0491>)
- 33 Noctor E, Crowe C, Carmody LA, Saunders JA, Kirwan B, O'Dea A, Gillespie P, Glynn LG, McGuire BE, O'Neill C *et al.* Abnormal glucose tolerance post-gestational diabetes mellitus as defined by the International Association of Diabetes and Pregnancy Study Groups criteria. *European Journal of Endocrinology* 2016 **175** 287–297. (<https://doi.org/10.1530/EJE-15-1260>)
- 34 Benhalima K, Jegers K, Devlieger R, Verhaeghe J & Mathieu C. Glucose intolerance after a recent history of gestational diabetes based on the 2013 WHO criteria. *PLoS ONE* 2016 **11** e0157272. (<https://doi.org/10.1371/journal.pone.0157272>)
- 35 O'Reilly MW, Avalos G, Dennedy MC, O'Sullivan EP & Dunne F. Atlantic DIP: high prevalence of abnormal glucose tolerance post partum is reduced by breast-feeding in women with prior gestational diabetes mellitus. *European Journal of Endocrinology* 2011 **165** 953–959. (<https://doi.org/10.1530/EJE-11-0663>)

Received 21 February 2019

Revised version received 4 April 2019

Accepted 11 April 2019