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Original Research

Self-Monitoring of Blood Glucose: A Complementary Method Beyond the Oral Glucose Tolerance Test to Identify Hyperglycemia During Pregnancy

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Key Messages

- Diabetes Canada's preferred approach to the diagnosis of gestational diabetes mellitus combines a 50 g glucose load test and a 75 g oral glucose tolerance test.
- We compared this 2-step method with 7-day self-monitoring of blood glucose.
- We found that 53.8% of women with gestational diabetes mellitus were normoglycemic according to self-monitoring of blood glucose and, conversely, that 11.7% of women with normal oral glucose tolerance tests were hyperglycemic.
- Abnormal oral glucose tolerance tests and self-monitored blood glucose levels were equally associated with greater neonatal complications, suggesting that the 2 must be considered equally.

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ABSTRACT

Objectives: To compare: 1) 75 g oral glucose tolerance test (OGTT) and self-monitoring of blood glucose (SMBG) in identifying gestational diabetes mellitus (GDM) and other hyperglycemic statuses in pregnant women; 2) pregnancy outcomes according to glycemic status; and 3) participants' opinions regarding both methods.
Methods: A prospective study in women with a 50 g glucose load test ≥7.2 mmol/L at 24 to 28 weeks' gestation and singleton pregnancy. Women underwent OGTT (blinded) at day 1, followed by 7 days of SMBG (4 daily measurements: fasting and 2 h postprandially) without modifying diet or lifestyle. GDM (OGTT+) was diagnosed using the criteria of the International Association of the Diabetes and Pregnancy Study Groups, while pregnancy hyperglycemia (SMBG+) was defined as ≥4/7 glucose values ≥5.3 after fasting or ≥6.7 mmol/L 2 h postprandially for any meal of the day. Equivalent management was provided to women with GDM and/or pregnancy-related hyperglycemia.
Results: We divided 103 participants (age: 29.5±5.0 years; prepregnancy body mass index: 25.3±5.4 kg/m^2) into 4 groups according to test results: OGTT+/SMBG+ (n=12, 11.7%); OGTT+/SMBG− (n=14, 13.6%); OGTT−/SMBG+ (n=9, 8.7%); and OGTT−/SMBG− (n=68, 66.0%). Clinical characteristics and maternal outcomes were statistically similar between groups. Neonatal complication rates were greater in groups

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with hyperglycemia than in the OGTT−/SMBG− group, notably neonatal hypoglycemia (9/12, 7/14, 5/9 vs. 6/68; p<0.001). Participants reported no convenience difference between methods but would prefer OGTT for a future pregnancy.
Conclusions: More than half of the women with OGTT+ were normoglycemic in daily life. Conversely, 11.7% of women with OGTT− had pregnancy hyperglycemia. OGTT+ and/or SMBG+ were equally associated with greater neonatal complications. This study suggests that alongside OGTT, SMBG could improve the care of pregnant women.

Mots Clés:
diagnostic
diabète gestationnel
hyperglycémie
hyperglycémie provoquée par voie orale
grossesse
autosurveillance de la glycémie

RÉSUMÉ

Objectifs : Comparer: 1) le test d'hyperglycémie provoquée par voie orale (HGPO) avec 75 g de glucose et une autosurveillance de la glycémie (ASG) dans l'identification du diabète gestationnel (DG) et d'autres états hyperglycémiques chez la femme enceinte; 2) les issues de grossesse en fonction de l'état glycémique; et 3) l'opinion des participantes concernant les deux méthodes.
Méthodes : Une étude prospective chez des femmes présentant une épreuve de charge en glucose de 50 g ≥ 7,2 mmol/L entre 24 et 28 semaines de gestation et une grossesse unique. Les femmes ont subi une HGPO (résultats en aveugle) au jour 1, suivie de 7 jours d'ASG (4 mesures quotidiennes: à jeun et 2 h après les repas) sans modifier leur régime alimentaire ni leur mode de vie. Le DG (HGPO+) a été diagnostiqué selon les critères de l'Association Internationale des Groupes d'Etude sur le Diabète et la Grossesse, tandis que l'hyperglycémie de grossesse (ASG+) était définie par ≥4/7 valeurs de glucose ≥5,3 à jeun ou ≥ 6,7 mmol/L 2 h après les repas pour tout repas de la journée. Une prise en charge équivalente a été fournie aux femmes atteintes de DG et/ou d'hyperglycémie liée à la grossesse.
Résultats : Nous avons réparti 103 participantes (âge: 29,5±5,0 ans; indice de masse corporelle avant la grossesse: 25,3±5,4 kg/m^2) en 4 groupes selon les résultats des tests: HGPO+/ASG+ (n=12, 11,7%); HGPO+/ASG− (n=14, 13,6%); HGPO−/ASG+ (n=9, 8,7%); et HGPO−/ASG− (n=68, 66,0%). Les caractéristiques cliniques et les issues maternelles étaient statistiquement similaires entre les groupes. Les taux de complications néonatales étaient plus élevés dans les groupes avec hyperglycémie que dans le groupe HGPO−/ASG−, notamment l'hypoglycémie néonatale (9/12, 7/14, 5/9 contre 6/68, p<0,001). Les participantes n'ont signalé aucune différence de commodité entre les méthodes, mais préféreraient l'HGPO pour une future grossesse.
Conclusions : Plus de la moitié des femmes avec HGPO+ étaient normoglycémiques dans la vie quotidienne. À l'inverse, 11,7% des femmes avec HGPO− présentaient une hyperglycémie de grossesse. L'HGPO+ et/ou l'ASG+ étaient également associées à de plus grandes complications néonatales. Cette étude suggère que, parallèlement à l'HGPO, l'ASG pourrait améliorer les soins prodigués aux femmes enceintes.

Introduction

Gestational diabetes mellitus (GDM) is a state of glucose intolerance of variable severity, with onset or first recognition during pregnancy. GDM affects 2% to 20% of pregnancies, depending on the ethnicity, age and body mass index (BMI) of the mother and on screening and diagnostic methods (1,2). GDM carries many risks for both mother and neonate, although most complications (hypertension, macrosomia, small or large for gestational age, hypoglycemia) (1,2) can be reduced by treatment during pregnancy (3–6). GDM is also associated with increased lifetime risk for type 2 diabetes and cardiovascular diseases for the mothers (7,8) and of obesity, metabolic syndrome and diabetes for the offspring (9,10).

In North America, GDM is diagnosed using either a 1- or a 2-step procedure. In the 1-step method, GDM is directly screened and diagnosed using a 75 g oral glucose tolerance test (OGTT). The 2-step method consists of screening with a 50 g glucose load test (50 g GLT), followed by diagnosis by an OGTT. Diabetes Canada recommends a 75 g OGTT, whereas the American Diabetes Association recommends a 100 g OGTT (1,2).

The accuracy and reproducibility of OGTTs have been the subjects of lengthy debates (11–14). Threshold values for GDM diagnosis have been reassessed numerous times since the Princeps study by O'Sullivan in 1964 (15). In 2010, the International Association of Diabetes and Pregnancy Study Groups released their recommendations for GDM diagnosis, and they are now widely recognized (16).

In current practice, when women are diagnosed with GDM (also referred to as OGTT+ in this article), a diet-and-exercise program is initiated immediately, along with self-monitoring of blood glucose (SMBG) to track daily glucose profiles. Therefore, current guidelines do not call for daily glucose profiles to be routinely recorded under normal conditions, before lifestyle modifications, and SMBG comparison is not used to assess the efficacy of these modifications. Pharmacologic therapy is initiated when recommended SMBG targets are not met (1,2).

It has been established that more than 60% of women diagnosed with GDM are successful in controlling their glucose levels using diet and exercise alone (17,18). However, under routine clinical care, we have noticed a paradox: many OGTT+ pregnant women report normal SMBG values despite not having changed their lifestyle habits. This could suggest an intermediate stage in which women are normoglycemic in daily life but respond pathologically to acute oral glucose challenges after overnight fasts (OGTT+) (19). The frequency of this particular glycemic status and its impact on pregnancy outcomes have yet to be explored. Conversely, the occurrence of unexpected neonatal complications in women without GDM (OGTT−) observed in clinical practice and in

population studies (20–23) may suggest that a proportion of these women could be dysglycemic but that it is overlooked by OGTTs.

These pieces of evidence bring into question the reliability of the OGTT as a diagnostic test when performed alone. Our objectives in this exploratory study were to compare: 1) 75 g OGTT and SMBG in defining hyperglycemic statuses in pregnant women; 2) pregnancy outcomes according to glycemic status; and 3) women's opinions with respect to the relative convenience of OGTT and SMBG.

Methods

Study design

We conducted a prospective study of pregnant women receiving pre- and perinatal care and delivering at the Centre Hospitalier Universitaire de Sherbrooke (CHUS), Quebec, Canada, between November 11, 2014, and September 30, 2015. The experiment's protocol was reviewed and approved by the CHUS research ethics committee. All participants were duly informed and gave written consent prior to participation, in accordance with applicable laws and regulations.

Participants

Women were approached to participate during the 50 g GLT screening test at the CHUS Blood Sampling in Pregnancy Clinic (24). Inclusion criteria were age ≥18 years, singleton pregnancy, 24 to 28 weeks' gestation, 50 g GLT ≥7.2 mmol/L (GLT+) and being able to read and understand French. We choose the American Diabetes Association 7.2 mmol/L threshold rather than 7.5 or 7.8 mmol/L to increase sensitivity (25). Exclusion criteria were prepregnancy diabetes, disease or treatment interfering with glucose metabolism and any disorder susceptible to creating a bias in results and/or hindering the study data analyses and interpretation.

Course of the study

On day 1, women performed the 75 g OGTT at the CHUS Research Centre after fasting for at least 8 h. They ingested a 300 mL drink (Jamp-Glucose 75, Jamp-Pharma, Boucherville, Quebec, Canada). Venous blood samples were taken before ingestion, and 1-h and 2-h postingestion. During the waiting time, a nurse educator instructed women on how to perform SMBG with a calibrated glucometer (variations <10% between blood glucose values measured at the CHUS Biochemistry Laboratory and the glucometer were accepted. This calibration was done once; glucometers with more than a 10% variation were set aside and not retested later). SMBG material was provided to participants free of charge. Participants were asked to self-monitor glycemia 4 times a day (after fasting and 2 h after the beginning of each of breakfast, lunch and dinner, according to routine practice in our area), over 7 consecutive days (days 2 through 8) without modifying their eating or exercise habits. SMBG levels were registered by participants on a preprinted data sheet, which they were asked to transmit to the study nurse (via e-mail or fax) on day 9. Upon receipt, the questionnaire was sent out to participants. Completed questionnaires were returned the same day, i.e. before diagnoses were announced to participants.

Results of the 75 g OGTT were blinded to both participants and the research team until reception of the SMBG data and questionnaire. International Association of Diabetes and Pregnancy Study Groups criteria (fasting ≥5.1 mmol/L, 1-h postprandial ≥10.0 mmol/L and 2-h postprandial ≥8.5 mmol/L) were used for diagnosis of GDM (OGTT+) (1,2,16). We defined pregnancy hyperglycemia (also referred to as SMBG+ in this article) as a state in which at least 4 of the 7 SMBG glucose values for any time point of the day (fasting or 2 h postprandially) exceeded the target values used for women with GDM (<5.3 mmol/L and <6.7 mmol/L, respectively, as recommended by Diabetes Canada and the American Diabetes Association) (1,2). For instance, a woman with glucose values ≥6.7 mmol/L after 4 of 7 dinners qualifies as having pregnancy hyperglycemia. A woman with 3 high values after breakfast and 1 high value after dinner would not be considered hyperglycemic because the 4 values are not recorded at the same moment of the day. These SMBG values were not blinded to participants in order to assess conditions close to daily practice. Participants with OGTT+ and/or SMBG+ received the recommended care delivered to women with GDM at our dedicated Diabetes in Pregnancy Clinic (24): a 3-h educational group session and diet and exercise intervention under SMBG surveillance. Insulin therapy was initiated when SMBG values remained above recommended targets at the first follow up (1 or 2 weeks) or later in pregnancy if deterioration in glucose profiles was detected.

Study variables

Demographic and clinical data were recorded at enrolment. Gestational age was calculated from the last menstrual period. Women self-reported their prepregnancy weights, which were used to calculate prepregnancy BMI (kg/m^2).

Plasma glucose was measured in the Biochemistry Laboratory of the CHUS with the hexokinase enzyme technique (Roche Diagnostics, Indianapolis, Indiana, United States). Two types of glucometers of comparable precision (26,27) were used to measure SMBG (Accu-Chek Aviva, Roche Diagnostics, Laval, Quebec, Canada, and Freestyle Lite, Abbott Diabetes Care Canada, Mississauga, Ontario, Canada) by 59% and 41% of the women, respectively. SMBG values were classified as being either below or above recommended targets and, per protocol, were used to define pregnancy hyperglycemia.

Based on the Metformin in Gestational Diabetes study (3) and on the Diabetes Treatment Satisfaction Questionnaire (28), a 5-item suitability questionnaire was developed using standard back-translation, English/French, as we had done in another study (29).

Data concerning pregnancy, delivery and neonatal outcomes were extracted from medical files. Maternal variables included GDM treatment, weight at delivery, weight gain, hypertension and mode of delivery. Neonatal variables included sex, sex-, race- and gestational age-specific birth weights, gestational age, malformations and admission to the intensive care unit. We defined a metabolic composite outcome score per group as the total number of neonatal metabolic complications in that group, including large for gestational age, macrosomia (≥4000 g), small for gestational age, 5-min Apgar score <7, hypoglycemia (<2.6 mmol/L), hyperbilirubinemia, birth trauma and respiratory distress syndrome. We looked at additional delivery/neonatal outcomes separately: caesarian sections, admissions to the intensive care unit and lengths of stay.

Women's compliance with SMBG was defined as the percentage of tests completed relative to the total maximum of 28 (4 tests per day during 7 days).

Statistical analyses

Because of the relatively small number of women in each category, nonparametric tests were used for the main statistical analyses. Continuous variables are presented as mean ± SD; categorical variables as frequencies and percentages. Comparisons of continuous variables between subgroups of OGTT and SMBG statuses were performed using the Kruskal-Wallis and Mann-Whitney tests for independent groups. Categorical variables were compared using Fisher exact tests. For the composite score, a 1-sample chi-

squared test was used to compare the distribution of adverse events among groups with the expected distributions of these events. Generalized estimating equations for binomial outcome with logit link, considering repeated measures on a same subject, were used to assess the glucose values exceeding target variables. A Spearman rank correlation was used to test the associations among variables in the different groups, and a Pearson correlation was used for the whole cohort. Statistical significance was set at $p < 0.05$, and p values were adjusted by Holm-Bonferroni correction for multiple paired post hoc comparisons. Statistical analyses were performed using SPSS v. 20 software (IBM, Armonk, New York, United States).

Results

We approached 993 pregnant women (Figure 1) and recruited 103 (10.4%) eligible participants (age 29.5±5.0 years, prepregnancy BMI 25.3±5.4 kg/m^2, 55% multiparous, 50 g GLT 8.2±0.8 mmol/L at 27.1±1.0 weeks' gestation).

Women were classified into 4 diagnostic groups according to OGTT and SMBG status (Table 1). Age and weight across groups were not statistically significant in difference. Of the entire cohort, 84 (81.6%) were ≥25 years of age, and 46 (44.7%) had prepregnancy BMIs ≥25 kg/m^2. Other risk factors are listed in Table 1.

Of the 26 (25%) women diagnosed with GDM (OGTT+), SMBG revealed pregnancy hyperglycemia in 12 (group A, 46.2%) and normal levels in 14 (group B, 53.8%). Of the 77 (75%) participants with normal OGTTs, 9 had positive SMBG levels (group C, 11.7%), and 68 had normal SMBG levels (group D, 88.3%). Overall, test discordance was revealed for 23 (22.3%) women in the cohort.

OGTT glucose values (Table 1) differed in all groups at fasting, 1-h and 2-h, with higher values in groups A and B compared to group D at all 3 test times, as expected based on the groups' definitions. Group B's 1-h value was greater than group C's, and group C's 1-h value was greater than group D's.

SMBG data (Table 1) also showed significant differences among groups for mean glucose values at fasting, each 2-h, and the mean of all 2-h values, as expected based on the groups' definitions. There were no differences in SMBG levels between groups A and C (both SMBG+) or between groups B and D (both SMBG−). Individual postprandial values were higher in group A than in groups B and D. Group C had higher overall postprandial values than groups B and D. Over the 28 measurements, the mean number of glucose values exceeding recommended targets, per participant, was higher (10 and 9.8) in groups A and C, respectively, than in groups B and D (3.5 and 2.4, respectively). Among the 21 women classified as SMBG+ (20.4%; groups A and C), 16 (76.2%) exceeded targets at only 1 of the 4 daily testing times, 3 (14.3%) at 2 and 2 (9.5%) at all 4 (total: 30).

Comparing OGTT and SMBG glucose values in the whole cohort showed a correlation between fasting glucose on OGTT and on SMBG ($r=0.626$; $p<0.001$) and between 2-h OGTT and SMBG values after breakfast ($r=0.211$; $p=0.033$). In each of the 4 groups, there were correlations only for fasting values (OGTT vs. SMBG) in groups 1 ($r=0.856$; $p<0.001$), 3 ($r=0.905$; $p=0.001$) and 4 ($r=0.474$; $p<0.001$).

There was no difference between the glucose values of the first 3 and the last 3 days of the 7-day SMBG period (fasting, 4.52±0.41 vs. 4.56±0.44; $p = 0.523$; after breakfast, 5.68±0.80 vs. 5.74±0.75;

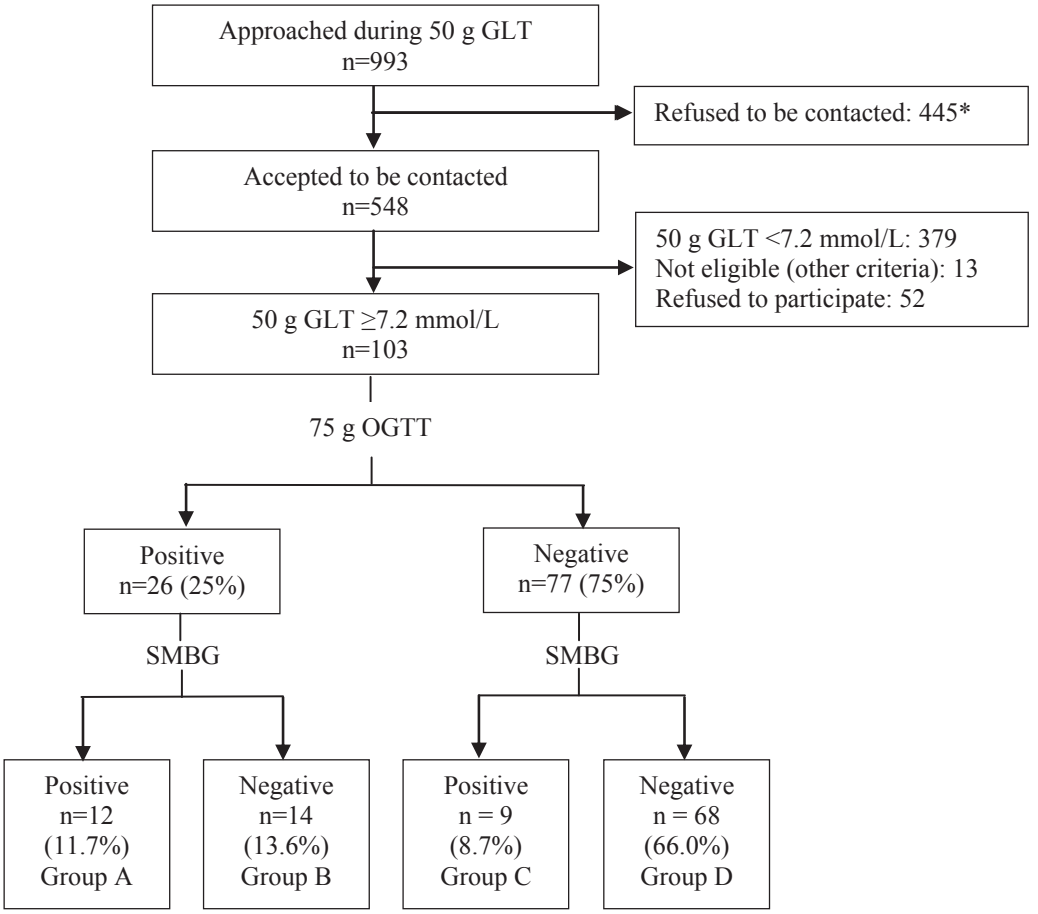

Figure 1. Course of the study. *50 g GLT*, 50 g glucose load test; *n (%)*, numbers and percentages of the whole cohort of participants; *75 g OGTT*, 75 g oral glucose tolerance test; *SMBG*, self-monitoring of blood glucose. *Including 159 women with 50 g-GLT ≥7.2 mmol/L (35.7%).

Table 1
Maternal characteristics

	Participants (N=103)	Group A: OGTT+ and SMBG+ (n=12)	Group B: OGTT+ and SMBG− (n=14)	Group C: OGTT− and SMBG+ (n=9)	Group D: OGTT− and SMBG− (n=68)	p value
Age (years)	29.5±5.0	32.0±6.5	26.9±5.0	28.7±4.0	29.8±4.7	0.188
Prepregnancy weight (kg)	66.7±17.0	67.6±12.4[¶]	66.3±13.5	79.0±18.8	66.4±13.2	0.266
Prepregnancy BMI (kg/m^2)	25.3±5.4	26.2±5.8	25.2±4.6	30.5±8.8	24.5±4.6	0.116
Weight at OGTT (kg)	76.5±15.0	80.8±22.3[¶]	76.4±14.7	88.3±17.8	74.3±12.7	0.107
Gestational weight gain at OGTT (kg)	8.5±4.2	9.1±3.2	10.1±5.2	9.2±3.9	7.9±4.1	0.435
Weeks of gestation at OGTT	27.7±1.0	28.0±1.3	27.7±1.0	27.6±1.2	27.7±1.0	0.683
50 g GLT	8.2±0.8	8.3±0.6	8.6±1.0	8.3±0.6	8.1±0.6	0.270
Risk factors for GDM	95 (92.2)	12 (100.0)	13 (92.9)	9 (100.0)	61 (89.7)	0.693
Age ≥25 years: n (%)	84 (81.6)	10 (83.3)	10 (71.4)	7 (77.8)	57 (83.8)	0.667
Prepregnancy BMI ≥25 kg/m^2 n (%)	46 (44.7)	5 (41.7)	7 (50.0)	7 (77.8)	27 (39.7)	0.191
Race or ethnic group						
Caucasian: n (%)	101 (98.1)	11 (91.7)	14 (100.0)	9 (100.0)	67 (98.5)	0.385
Other: n (%)[*]	2 (1.9)	1 (8.3)	0 (0.0)	0 (0.0)	1 (1.5)	
Previous GDM: n (%)	7 (6.8)	0 (0.0)	1 (7.1)	0 (0.0)	6 (8.8)	0.912
Family history of diabetes: n (%)	17 (16.7)[§]	5 (45.5)[§]	3 (21.4)	1 (11.1)	8 (11.8)	0.045
OGTT (mmol/L)						
Fasting	4.4±0.4	4.9±0.5[‖]	4.6±0.4[#]	4.4±0.2	4.3±0.3	<0.001
1 h	8.3±1.6	9.2±1.8[‖]	10.5±1.0[‖]	8.6±0.8[#,**]	7.6±1.1	<0.001
2 h	6.6±1.3	7.9±1.6[‖]	7.5±1.3[‖]	6.5±1.2	6.2±1.0	<0.001
SMBG (mmol/L)						
Fasting[†]	4.5±0.4	5.0±0.6[#]	4.5±0.4	4.7±0.4	4.4±0.3	<0.001
2 h after breakfast[†]	5.7±0.7	6.5±1.0[‖,††]	5.6±0.5	5.8±0.8	5.5±0.5	<0.001
2 h after lunch[†]	5.9±0.7	6.6±0.9[‖,**]	5.6±0.5	6.9±0.6[‖,**]	5.7±0.4	<0.001
2 h after dinner[†]	5.9±0.6	6.6±0.7[‖,**]	5.7±0.5	6.2±0.5[‖]	5.7±0.4	<0.001
2 h postprandial[‡]	5.8±0.5	6.6±0.8[‖,**]	5.7±0.4	6.3±0.4[‖,**]	5.6±0.3	<0.001
Glucose values exceeding targets (n, %)	419/2647 (15.8)	120/326 (36.8)[‖,**]	49/387 (12.7)[‡‡]	88/250 (35.2)[‖]	162/1684 (9.6)	0.0002
Gestational hyperglycemia (n)						
Fasting	6	5	-	1	-	0.178
2 h after breakfast	7	5	-	2	-	0.642
2 h after lunch	11	5	-	6	-	0.387
2 h after dinner	6	3	-	3	-	1.000
Gestational hyperglycemia at n (%)						
1 moment of the day	16/21 (76.2)	8 (66.7)	-	8 (88.9)	-	0.355
2 moments of the day	3/21 (14.3)	3 (25.0)	-	0 (0.0)	-	
3 moments of the day	0/21 (0.0)	0 (0.0)	-	0 (0.0)	-	
4 moments of the day	2/21 (9.5)	1 (8.3)	-	1 (11.1)	-	

BMI, Body mass index; *GDM*, gestational diabetes mellitus; *GLT*, glucose load test; *OGTT*, oral glucose tolerance test; *OGTT−*, glucose values below GDM range; *OGTT+*, glucose values in GDM range; *SMBG*, self-monitoring of blood glucose; *SMBG−*, below pregnancy hyperglycemia range; *SMBG+*, pregnancy hyperglycemia.

[*] Hispanic (n=2).
[†] Mean ± SD of 7 values.
[‡] Mean ± SD of the 3 postprandial capillary glucose values.
[§] Information unavailable for one woman (adopted).
[¶] Information unavailable for one woman.
[‖] ≤0.009 and [#]=0.02: compared to group D.
[**] ≤0.009 and [††] = 0.02: compared to group B.
[‡‡] ≤0.009 compared to group C.

p = 0.557; after lunch, 5.89±0.85 vs. 5.89±0.78; p=0.979; after dinner, 5.86±0.67 vs. 5.88±0.72; p=0.821).

Mean compliance with SMBG was 97.6% (fasting, 99%; after breakfast, 97.1%; after lunch, 97.6%; after dinner, 96.9%). Overall, 69 women (67% of the cohort) complied with 28 of 28 tests, and 101 (98.1%) completed at least 24 of 28 measurements.

Maternal and neonatal outcomes are presented in Table 2. Weight at study entry, weight gain (Table 1), birth weight, gestational age at delivery and mode of delivery were not statistically different in any of the groups. Treatment was similar for the 3 groups with hyperglycemia and significantly different from that for group D. Neonatal complications were found in 44 (42.7%) infants: 22 (21.4%) had 1, 18 (17.5%) had 2 and 4 (3.9%) had at least 3. Neonatal hypoglycemia rates were significantly greater in groups A (n=9, 75.0%), B (n=7, 50.0%) and C (n=5, 55.6%) compared to group D (n=6, 8.8%; p ≤0.001). Additionally, there was no difference in the ratio of composite score values per neonate among groups A, B and C, but the ratios in each of these 3 groups were significantly greater than those in group D.

The suitability questionnaire (Table 3) was completed by all participants. Women seem to prefer performing the OGTT (n=52, 50.5%) to the SMBG (n=36, 35%), with 15 (14.5%) uncertain. The easiest task reported was drinking the sugary beverage, according to 35 (34.0%) respondents, and the multiple finger-prick tests were easiest for 32 (31.1%). Remembering to test after meals was the most difficult task for 58 (56.3%) participants. They did not report any difference in subjective convenience for both tests.

Discussion

Our team's overall goal was to find an optimal method of identifying hyperglycemia during pregnancy because its treatment reduces complications (3–6). To our knowledge, this study is the first to propose a 7-day SMBG practice without lifestyle changes as a complementary measure to 75 g OGTTs in pregnant women screened and having positive 50 g GLT. Participants were sorted into 4 groups. It is not surprising that OGTT glucose values in groups A and B (both OGTT+) were higher than those in group D (OGTT−/SMBG−). Similarly, the total number of glucose values exceeding SMBG targets in groups A and C (both SMBG+) were significantly greater than those in groups B and D (both SMBG−), and there was no difference between groups A and C. It is of interest that even in

Table 2
Maternal and neonatal outcomes

	Participating women (N=103)	Group A: OGTT+ and SMBG+ (n=12)	Group B: OGTT+ and SMBG− (n=14)	Group C: OGTT− and SMBG+ (n=9)	Group D: OGTT− and SMBG− (n=68)	p value
Maternal outcomes						
Weight gain during pregnancy (kg)	14.9±5.3	14.8±6.5	15.6±5.8	15.4±4.5	14.7±5.2	0.856
Treatment: n (%)						
Diet only	23 (20.4)	8 (66.6)†	10 (71.4)†	5 (55.6)†	0 (0.0)	<0.001
Insulin	11 (12.6)	4 (33.3)†	3 (21.4)†	4 (44.4)†	0 (0.0)	
None	69 (67.0)	0 (0.0)†	1 (7.1)†	0 (0.0)†	68 (100)	
Mode of delivery: n (%)						
Vaginal	74 (71.8)	9 (75.0)	8 (57.1)	7 (77.8)	50 (73.5)	0.724
Assisted	10 (9.7)	0 (0.0)	3 (21.4)	0 (0.0)	7 (10.3)	
Elective C-section	8 (7.8)	1 (8.3)	1 (7.1)	1 (11.1)	5 (7.4)	
Emergency C-section	11 (10.7)	2 (16.7)	2 (14.3)	1 (11.1)	6 (8.8)	
Neonatal outcomes						
Sex male: n (%)	53 (51.5)	4 (33.3)	11 (78.6)	4 (44.4)	34 (50.0)	0.118
Birth weight (g)	3361±399	3349±480	3243±408	3296±537	3396±366	0.481
Birth weight z-score	0.092±0.742	0.143±0.976	-0.044±0.806	0.128±0.743	0.107±0.697	0.600
Gestational age (weeks)	39.1±1.1	39.0±1.2	38.9±1.3	38.5±1.6	39.2±0.9	0.308
Complications: n (%)						
Macrosomia (≥4,000 g)	5 (4.9)	2 (16.7)	0 (0.0)	0 (0.0)	3 (4.4)	0.234
LGA (>90th percentile)	3 (2.9)	1 (8.3)	0 (0.0)	0 (0.0)	2 (2.9)	0.536
SGA (<10th percentile)	6 (5.8)	1 (8.3)	1 (7.1)	1 (11.1)	3 (4.4)	0.439
Apgar score, 5 min <7	2 (2.0)	0 (0.0)	2 (14.3)	0 (0.0)	0 (0.0)	0.036‡
Hypoglycemia (<2.6 mmol/L)	27 (26.2)	9 (75.0)†	7 (50.0)†	5 (55.6)†	6 (8.8)	<0.001
Hyperbilirubinemia	8 (7.8)	3 (25.0)	1 (7.1)	1 (11.1)	3 (4.4)	0.068
Birth trauma	1 (1.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.5)	1.000
Respiratory distress syndrome	4 (3.9)	2 (16.7)	1 (7.1)	0 (0.0)	1 (1.5)	0.072
Composite of complications: n (ratio per neonate)	56 (0.54)	18 (1.50)†	12 (0.86)†	7 (0.78)	19 (0.28)	<0.001
Other neonatal outcomes: n (%)						
Malformations*	3 (2.9)	0 (0.0)	0 (0.0)	0 (0.0)	3 (4.4)	1.000
Admission to ICU	11 (10.7)	2 (16.7)	2 (14.3)	1 (11.1)	6 (8.8)	0.678

Apgar, American pediatric gross assesment record at 5 minutes of life: Appearance, Pulse, Grimace, Activity and Respiration (scores range from 0 to 10); *GDM*, gestational diabetes mellitus; *ICU*, intensive care unit; *LGA*, large for gestational age; *OGTT*, 75 g oral glucose tolerance test; *OGTT−*, glucose values below GDM range; *OGTT+*, glucose values in GDM range; *SGA*, small for gestationl age; *SMBG*, self-monitoring of blood glucose; *SMBG−*, below pregnancy hyperglycemia range; *SMBG+*, pregnancy hyperglycemia.

Notes: Composite includes macrosomia, LGA, SGA, Apgar score, neonatal hypoglycemia, hyperbilirubinemia, birth trauma and respiratory distress syndrome (transient tachypnea of the newborn). Given the small size of our study, we aggregated SGA and LGA in the composite score although they have different etiologies

* Three malformations (hypospadias, paralysis of the left vocal cord and cryptorchidism) not related to glycemia.

† Difference between groups using Mann-Withney tests with Bonferroni-corrected p values: ≤0.009 compared to group D.

‡ Not significant after post hoc test.

Table 3
Suitability questionnaire

Questions*	N (%)	95% confidence interval
1. In a future pregnancy, if you were told that you had to do a diagnostic test to determine whether you have pregnancy diabetes, which test would you choose?		
Measurement of blood sugar at home	36 (35.0)	25.7–44.2
Test with the sweet juice	52 (50.5)	40.8–60.2
I am uncertain	15 (14.5)	7.7–21.4
2. Which part of the tests was the *easiest*?		
Doing the finger-prick tests	32 (31.1)	22.1–40.0
Remembering to measure blood sugar 2 h after meals	3 (2.9)	−0.4–6.2
Having to fast for the sweet-juice test	17 (16.5)	9.3–23.7
Drinking the sweet juice	35 (34.0)	24.8–43.2
Staying seated for 2 h	16 (15.5)	8.5–22.6
3. Which part of the tests was the most *difficult*?		
Doing the finger-prick tests	5 (4.9)	0.7–9.0
Remembering to measure blood sugar 2 h after meals	58 (56.3)	46.7–65.9
Having to fast for the sweet-juice test	16 (15.5)	8.5–22.6
Drinking the sweet juice	10 (9.7)	4.0–15.5
Staying seated for 2 h	14 (13.6)	6.9–20.1
4. How convenient did you find…†,‡		
…measuring blood sugar at home?	6.6±2.5	6.2–7.1
…performing the test with the sweet juice?	6.9±2.2	6.5–7.3

* For all questions, n=103.

† Rated from 0 to 10 (not at all to very convenient); calculated as the mean ± SD.

‡ Difference between both answers using the paired t test; p=0.442.

the normoglycemic group (group D), 10% of SMBG glucose values were above targets. Interestingly, 1-h glucose values in group C (OGTT−/SMBG+) were significantly greater than those in group D. This could suggest that group C, although characterized by SMBG+, may present some OGTT alterations. The comparison of glucose values on OGTT and SMBG showed that fasting is fasting, as demonstrated by the strong correlation of fasting values and that the OGTT cannot be seen as a meal, according to the poor relationship between 2-h OGTT and SMBG values after breakfast and the divergence of glucose profiles for the OGTT and daily meals.

Women in the 3 hyperglycemic groups (A, B and C) were provided with similar follow up and care to achieve glycemic control. Remarkably, the relative proportions of women treated by diet and exercise or by insulin therapy were comparable in these groups, with no difference in maternal outcomes or modes of delivery, although this is likely to be due to the small sample size of our study. Only 19 women (18.5%) in our sample underwent caesarian sections, presumably due to intense knowledge-transfer activities and audits aiming to decrease the rate of caesarian sections in Quebec (30). Neonatal hypoglycemia and the composite scores were higher in groups A, B and C compared to group D, with no significant differences among these 3 groups. This was probably due to the small size of our study, which was not powered to detect differences in clinical characteristics and obstetric/neonatal outcomes. If confirmed by larger studies, this finding suggests that all forms of dysglycemia pose risks to mother and infant and, thus, should be equally treated.

The rates of hypoglycemia are rather high for this type of population, although that can be explained by our low threshold value (2.6 mmol/L, as in the Metformin in Gestational Diabetes study) (3), by our institutional protocol to utilize a single measure for the initiation of hypoglycemia treatment and by intravenous dextrose fluids given to women during labour (a routine procedure at time of study), which is related to neonatal hypoglycemia (31).

As expected from our clinical observations, we found a preoccupying divergence (22.3%) between OGTT results and SMBG profiles. In groups with OGTT+ (A and B), SMBG values were within recommended glycemic targets in 53.8% of women before any lifestyle modifications. These data are noteworthy because the women in group B represent 13.6% of our cohort, suggesting that this condition may be a common occurrence. Assuming that 4,400,000 pregnancies occur yearly in Canada (32,33) and the United States (34), group B could translate yearly into approximately 120,000 women who are immediately managed as having GDM, according to current guidelines. Although it is possible to deduce that these women could be followed by delaying intervention until deterioration of SMBG profiles, this assumption should be subtly reconsidered. In our view, thorough SMBG follow up and care should be offered because the prevalence of adverse outcomes in group B was comparable to that of group A. Interestingly, 21% of women in group B were taking insulin, which indicates that continued monitoring detected a deterioration of glucose control some time after initial testing.

However, we see 2 unwelcome consequences related to group B. First, quality of life may deteriorate because of the intensity of SMBG monitoring over many weeks, especially while values are still on target, and because of the lifestyle changes that accompany a diagnosis of GDM (35,36). Second, in our experience, most women with GDM on diets are well aware that relatively little effort is needed to keep glucose targets in check (likely belonging to group B), which could be why many pay little attention to or devalue the importance of GDM and do not consider themselves sick or at risk for future diabetes (36,37). Counseling and education are of the utmost importance in women with group B characteristics.

The second case of debate, group C, includes women at risk for GDM, i.e. screened GLT+, who had normal OGTT results but presented with SMBG+ and glucose values exceeding targets, similar to group A. In terms of clinical characteristics or GDM risk factors, data from group C were not statistically different from those of the other groups. Prepregnancy weights and BMIs and weights at entry and the 1-h OGTTs were greater, but the size of our cohort did not enable us to detect any statistical difference. This may suggest that overweight women with GLT+ might benefit from further attention, even if OGTTs are normal. Under current recommendations, they are not offered timely care, putting both mother and child at higher risk for short- and long-term complications (7,9,10,38). This may represent a serious issue, and it invites further consideration and investigation.

The answers to the suitability questionnaire, although based on validated tools (3,28), are subjective and do not allow for firm conclusions. Questions were subject to interpretation, which could have contributed to the high variability in answers. Although both diagnostic measures were rated by respondents as being equally convenient, they reported that they would prefer doing an OGTT in future pregnancies. Remembering to measure blood glucose after each meal was deemed the most difficult task of the study. Most women at 24 to 28 weeks of gestation are still at work, and some may quite understandably experience difficulties in managing SMBG while complying with the demands of their workplaces. Our analysis is that women tend to prefer the single-appointment test (OGTT) to the longer term 7-day testing (SMBG), which can be challenging.

The particular role of SMBG before lifestyle changes in women with GDM and in GLT+/OGTT− women needs to be thoroughly assessed. It should be noted that in many centres in Canada and the United Kingdom, women with histories of GDM are immediately offered self-monitoring, but they do not have a repeat OGTTs (39,40). At this time, it is up for debate whether it is acceptable to ask all at-risk (GLT+) pregnant women to perform SMBG for an entire week following OGTTs if results are normal so as to detect the hyperglycemic status described in this study. A subsidiary issue is that because the 7-day period may be too long, studies are needed to assess whether the SMBG-detected criteria to define pregnancy hyperglycemia can be met with fewer monitoring days. One can also argue that women could have changed their dietary habits over the 7-day SMBG after having some high glucose values, suggesting that we have missed abnormal SMBG cases. However, we found no difference between the first 3 and the last 3 days of the 7-day SMBG assessment. Acceptance of this dual method (OGTT plus SMBG) and its related quality of life also deserve further investigation. However, our experience indicates that the SMBG diagnosis method is feasible. In our area, GDM is universally screened for using a 50 g GLT, and women with GLT+ have been offered OGTTs and/or 7-day SMBG since 2007 (more than 30,000 pregnancies). Most choose SMBG (20). This management route was originally initiated as a 3-year research trial, after which it was implemented in regular practice (24). Of course, if pregnancy hyperglycemia is diagnosed, treatment ensues accordingly (20), as described in this study. We observed an important advantage of the SMBG method: women (and practitioners) can appreciate for themselves the beneficial effects of lifestyle changes when comparing their glucose profiles before and after intervention or when their glucose values deteriorate. However, performing only SMBG should not be recommended because it may overlook cases of GDM that would otherwise be captured by an OGTT (group B).

Our original findings add to the literature that brings into question the relative value of the OGTT as a diagnostic gold standard (11–14). Our results suggest that the OGTT should not be used alone in at-risk pregnant women, and they point to a useful complementary role for SMBG to capture the true complexity of postprandial glycemia during pregnancy. Moreover, practitioners should treat both women with OGTT+ and those who are hyperglycemic in their daily lives (41). GLT+ and OGTT+ could be seen as red flags to employ SMBG over a to-be-determined window of time. Optimal care and timely intervention in these different hyperglycemic statuses need to be investigated further.

Limitations

The small size of our cohort may explain why some differences were not statistically significant (older age and more complications in group A, higher weights and BMIs in group C) in the normoglycemic and hyperglycemic groups. Conversely, differences obtained despite the small sample groups invite pursuance of this area of research. Another limitation is the lack of ethnic diversity, although it increases the internal validity of our study. Moreover, we cannot infer whether treatment improved outcomes in hyperglycemic groups because there were no control groups, for ethical reasons.

Our study is impaired by the procedures used in this work. First, we used the 2-step method, which hampers extrapolation to the 1-step strategy. This method has also been shown to miss as much as 16% of women with abnormal glucose tolerance (42), suggesting that groups A and B may represent larger populations in clinical practice. Second, glucose was monitored 2 h postprandially, as is the standard practice in our area. However, the postprandial glucose peak occurs at approximately 55 to 80 min (43), so even more women may have been detected by testing at 60 min. This

could imply that group C may be under-represented in our study. Moreover, participants with normal 2-h values may have scored high at 1 h. Testing at both time points, using new devices not on the market at the time of study, will improve the relevance of future studies.

It may have also been preferable to use identical glucometers throughout the study, although previous reports (26,27) showed that the 2 models used in this work are of comparable precision. Additionally, using multiple glucometers better reflects real-life conditions and increases the external validity of our study. Another drawback is that capillary glucose data were not downloaded directly from glucometers but transcribed by participants, leaving potentially erroneous values unchecked. This concern is debated (44) and difficult to verify. Nevertheless, the transcription method is used with most patients in routine medical practice, so it is a better representation of real-life care. The reliability of our results is not expected to be substantially affected because the rate of transcription errors should be similar in all groups. Moreover, this possibility is mitigated by the high compliance rate, the initial rehearsal, the thorough education of participants and the short period of SMBG in our study.

Conclusions

This study highlights the limitations of the OGTT, which measures only the response to a fast-acting carbohydrate load, unlike SMBG, which measures glucose profiles in day-to-day life. It points to the possible benefits of combining OGTT and SMBG in characterizing hyperglycemic statuses in pregnant women. Complementary SMBG allows differentiation between women with GDM who are hyperglycemic daily vs. normoglycemic and allows for the identification of women who are hyperglycemic daily but do not exceed International Association of Diabetes and Pregnancy Study Groups thresholds during OGTTs. The fact that, under current guidelines, women who are hyperglycemic daily remain untreated, despite their risk for adverse neonatal outcomes, is cause for worry.

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Author Contributions

JLA, JPB and MFH contributed substantially to the conception and design of the work. AA, PB, CS and JM conducted the data acquisition. AA, PB, CA, MPG, JM, MFH, JPB and JLA analyzed and interpreted the data. All authors drafted the article or revised it critically for important intellectual content and gave final approval of the version to be published.

References

1. American Diabetes Association. Standards of medical care in diabetes 2014. Diabetes Care 2014;37(Suppl. 1):S14–80.
2. 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(Suppl. 1):S1–212.
3. Rowan JA, Hague WM, Gao W, Battin MR, Moore MP. Metformin versus insulin for the treatment of gestational diabetes. N Engl J Med 2008;358:2003–15.
4. Langer O, Conway DL, Berkus MD, Xenakis EM, Gonzales O. A comparison of glyburide and insulin in women with gestational diabetes mellitus. N Engl J Med 2000;343:1134–8.
5. Crowther CA, Hiller JE, Moss JR, McPhee AJ, Jeffries WS, Robinson JS. Effect of treatment of gestational diabetes mellitus on pregnancy outcomes. N Engl J Med 2005;352:2477–86.
6. Landon MB, Spong CY, Thom E, et al. A Multicenter, randomized trial of treatment for mild gestational diabetes. N Engl J Med 2009;361:1339–48.
7. Bellamy L, Casas J-P, Hingorani AD, Williams D. Type 2 diabetes mellitus after gestational diabetes: A systematic review and meta-analysis. Lancet 2009;373:1773–9.
8. Retnakaran R, Shah BR. Role of type 2 diabetes in determining retinal, renal, and cardiovascular outcomes in women with previous gestational diabetes mellitus. Diabetes Care 2017;40:101–8.
9. Damm P. Future risk of diabetes in mother and child after gestational diabetes mellitus. Int J Gynecol Obstet 2009;104(Suppl):S25–6.
10. Dabelea D. The predisposition to obesity and diabetes in offspring of diabetic mothers. Diabetes Care 2007;30(Suppl. 2):S169–74.
11. Bonongwe P, Lindow SW, Coetzee EJ. Reproducibility of a 75 g oral glucose tolerance test in pregnant women. J Perinat Med 2015;43:333–8.
12. Mooy JM, Grootenhuis PA, De Vries H, et al. Intra-individual variation of glucose, specific insulin and proinsulin concentrations measured by two oral glucose tolerance tests in a general Caucasian population: The Hoorn Study. Diabetologia 1996;39:298–305.
13. Eschwège E, Charles MA, Simon D, Thibult N, Balkau B. Reproducibilily of the diagnosis of diabetes over a 30-month follow-up: The Paris prospective study. Diabetes Care 2001;24:1941–4.
14. Wang P, Lu MC, Yu CW, Yan YH. Influence of the time of day and fasting duration on glucose level following a 1-hour, 50-gram glucose challenge test in pregnant women. PLOS ONE 2014;9:e112526.
15. O'Sullivan JB, Mahan CM. Criteria for the oral glucose tolerance test in pregnancy. Diabetes 1964;13:278–85.
16. International Association of Diabetes and Pregnancy Study groups Consensus Panel, Metzger BE, Gabbe SG, Persson B, et al. International Association of Diabetes and pregnancy study groups' recommendations on the diagnosis and classification of hyperglycemia in pregnancy. Diabetes Care 2010;33:676–82.
17. Benhalima K, Robyns K, Van Crombrugge P, et al. Differences in pregnancy outcomes and characteristics between insulin- and diet-treated women with gestational diabetes. BMC Preg Childbirth 2015;15:271.
18. Sapienza AD, Francisco RPV, Trindade TC, Zugaib M. Factors predicting the need for insulin therapy in patients with gestational diabetes mellitus. Diabetes Res Clin Pract 2010;88:81–6.
19. Carr CA. Evidence-based diabetes screening during pregnancy. J Midwif Women Health 2001;46:152–8.
20. Allard C, Sahyouni E, Menard J, et al. Gestational diabetes mellitus identification based on self-monitoring of blood glucose. Can J Diabetes 2015;39:162–8.
21. Billionnet C, Mitanchez D, Weill A, et al. Gestational diabetes and adverse perinatal outcomes from 716,152 births in France in 2012. Diabetologia 2017;60:636–44.
22. Bromiker R, Perry A, Kasirer Y, Einav S, Klinger G, Levy-Khademi F. Early neonatal hypoglycemia: Incidence of and risk factors: A cohort study using universal point of care screening. J Matern Fetal Neonatal Med 2019;32:786–92.
23. Dodd JM, Crowther CA, Antoniou G, Baghurst P, Robinson JS. Screening for gestational diabetes: The effect of varying blood glucose definitions in the prediction of adverse maternal and infant health outcomes. Aust N Z J Obstet Gynaecol 2007;47:307–12.
24. Hivert M-F, Allard C, Menard J, Ouellet A, Ardilouze J-L. Impact of the creation of a specialized clinic for prenatal blood sampling and follow-up care in pregnant women. J Obstet Gynaecol Can 2012;34:236–42.
25. American Diabetes Association. Standards of medical care in diabetes, 2018. Diabetes Care 2018;41(Suppl. 1):1–159.
26. Freckmann G, Schmid C, Baumstark A, Pleus S, Link M, Haug C. System accuracy evaluation of 43 blood glucose monitoring systems for self-monitoring of blood glucose according to DIN EN ISO 15197. J Diabetes Sci Technol 2012;6:1060–75.
27. Freckmann G, Schmid C, Baumstark A, Rutschmann M, Haug C, Heinemann L. Analytical performance requirements for systems for self-monitoring of blood glucose with focus on system accuracy. J Diabetes Sci Technol 2015;9:885–94.
28. Bradley C. The Diabetes Treatment Satisfaction Questionnaire: DTSQ. In: Bradley C, editor. Handbook of psychology and diabetes: A guide to

psychological measurement in diabetes research and practice. Chur, Switzerland: Harwood Academic Publishers; 1994.
29. Ménard J, Payette H, Dubuc N, Baillargeon JP, Maheux P, Ardilouze JL. Quality of life in type 2 diabetes patients under intensive multitherapy. Diabetes Metab 2007;33:54–60.
30. Chaillet N, Dumont A, Abrahamowicz M, et al. A cluster-randomized trial to reduce cesarean delivery rates in Quebec. N Engl J Med 2015;372:1710–21.
31. Singhi S. Effect of maternal intrapartum glucose therapy on neonatal blood glucose levels and neurobehavioral status of hypoglycemic term newborn infants. J Perinat Med 1988;16:217–24.
32. Statistics Canada. Births and stillbirths, 2014. http://www.statcan.gc.ca/daily-quotidien/171019/dq171019c-eng.htm. Accessed December 2, 2017.
33. Sermer M, Naylor CD, Gare DJ, et al. Impact of increasing carbohydrate intolerance on maternal-fetal outcomes in 3637 women without gestational diabetes: The Toronto Tri-Hospital Gestational Diabetes Project. Am J Obstet Gynecol 1995;173:146–56.
34. Martin JA, Hamilton BE, Osterman MJK, Driscoll AK, Mathews TJ. Births: Final data for 2015. Natl Vital Stat Rep 2017;66:1.
35. Lapolla A, Di Cianni G, Di Benedetto A, et al. Quality of life, wishes, and needs in women with gestational diabetes: Italian DAWN pregnancy study. Int J Endocrinol 2012;2012:784726.
36. Morrison MK, Lowe JM, Collins CE. Australian women's experiences of living with gestational diabetes. Women Birth 2014;27:52–7.
37. Kim C, McEwen LN, Piette JD, Goewey J, Ferrara A, Walker EA. Risk perception for diabetes among women with histories of gestational diabetes mellitus. Diabetes Care 2007;30:2281–6.
38. Coustan DR. Gestational diabetes mellitus. Clin Chem 2013;59:1310–21.
39. National Institute for Health and Excellence Care. Diabetes in pregnancy: Management from preconception to the postnatal period. NICE Guide (NG3). https://www.nice.org.uk/guidance/ng3. 2015. Accessed January 23, 2018.
40. BC Women's Hospital + Health Centre. http://www.bcwomens.ca/health-professionals/refer-a-patient/diabetes-clinic. Accessed January 7, 2019.
41. Ardilouze JL, Mahdavian M, Baillargeon JP, Hivert MF. Glucose challenge test for detecting gestational diabetes mellitus: A systematic review. BJOG 2012;119:1283. author reply 1283–4.
42. National Institutes of Health. National Institutes of Health Consensus Development Conference: Diagnosing Gestational Diabetes Mellitus Conference. http://www.prevention.nih.gov/cdp/conferences/2013/gdm/resources.aspx. Accessed March 11, 2013.
43. Hernandez TL, Friedman JE, Van Pelt RE, Barbour LA. Patterns of glycemia in normal pregnancy: Should the current therapeutic targets be challenged? Diabetes Care 2011;34:1660–8.
44. Cosson E, Baz B, Gary F, et al. Poor reliability and poor adherence to self-monitoring of blood glucose are common in women with gestational diabetes mellitus and may be associated with poor pregnancy outcomes. Diabetes Care 2017;40:1181–6.