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# Association of glucose levels in pregnancy with use of health care services ⋆,⋆⋆

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## Abstract

**Aims:** To determine whether women with abnormal gestational diabetes (GDM) screening test results short of frank GDM have increased health-services utilization compared to women with normal results.

**Methods:** We conducted a retrospective-cohort study among 29,999 women enrolled in Kaiser Permanente Northwest who completed GDM screening (two-step method: 1-h, 50-g glucose-challenge test (GCT); 3-h, 100-g oral-glucose-tolerance test (OGTT)). Test results were categorized as normal GCT (referent, n = 25,535), normal OGTT (n = 2246), abnormal OGTT but not GDM (n = 1477), and GDM (n = 741). Rate ratios (RRs) were calculated for utilization measures and analyses were age- and BMI-adjusted.

**Results:** Compared to women with normal GCT, rates for obstetrical ultrasound, noninvasive and invasive antenatal testing, and ambulatory visits to the obstetrics department were significantly greater among women with abnormal OGTT (RRs 1.2 [95%CI 1.1, 1.4], 1.3 [1.1, 1.4], 1.7 [1.3, 2.3], and 1.1 [1.1, 1.1], respectively) and GDM (RRs 1.8, 1.8, 2.0, and 1.3, respectively). Women with abnormal OGTT results were more likely to visit a dietician than women with normal GCT; RRs ranged from 4.0 [3.3, 4.9] for women with abnormal GCT but normal OGTT to 72.1 [64, 81] for women with GDM.

**Conclusions:** Health-services utilization increased with severity of glucose result, even among women without GDM.

### Keywords

Gestational diabetes; Screening; Health care utilization

⋆Source of the study: The obstetrics department in a large prepaid health maintenance organization.

⋆⋆Condensation: Health-care service utilization is greater among women with a GDM diagnosis or screening test abnormalities falling short of GDM, than among women with normal screening.

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Conflict of interest

The Authors report no conflict of interest.

## 1. Introduction

Gestational diabetes mellitus is one of the most frequently diagnosed complications of pregnancy. The prevalence of the condition is extremely sensitive to the diagnostic criteria used (Table 1), ranging from 1.1 to 25.5% depending on the diagnostic criteria and population screened [1]. Changing from the National Diabetes Data Group (NDDG) diagnostic criteria to the lower cut-points employed by Carpenter and Coustan criteria can increase the percentage of affected pregnancies by as much as 50% [2-5]. In 2009, new International Association of Diabetes and Pregnancy Study Groups (IADPSG) criteria with even lower cut-points and reliance upon one, rather than two, abnormal values were adopted by the American Diabetes Association. Under the new criteria, GDM diagnoses could increase two- to threefold, to a prevalence of approximately 15–20% [6]. Treatment of GDM includes a number of components, including referral for medical nutrition therapy, maternal blood glucose monitoring, and often more frequent obstetrical visits and ultrasounds.

A 2013 Consensus Development Conference by the National Institute of Health (NIH) convened to address controversial questions surrounding GDM screening concluded that there was not enough evidence to recommend universal adoption of a one-step approach to GDM screening [6]. Further, the panel recommended future research was needed to more fully understand resource implications of changing the thresholds for GDM diagnosis and to determine the “real world” impact of GDM treatment on health care utilization and practice patterns. Although health service utilization is expected to increase with increasing severity of glucose status, there currently is little documentation describing how much health service utilization differs among women with a GDM diagnosis and those with lower levels of GDM screening glucose test results that did not meet the threshold for diagnosing GDM. To better understand the potential health care utilization impact of switching to a GDM diagnostic test that would identify more women as having GDM, we sought to evaluate ambulatory health care utilization among women with different levels of glucose on screening and diagnostic test results who were receiving care in an integrated delivery system. Our hypothesis was that there would be an incremental increase in ambulatory health service utilization with increasing glucose levels.

## 2. Materials & methods

We conducted a retrospective cohort study using data from electronic medical records from Kaiser Permanente Northwest (KPNW), a large nonprofit prepaid, federally certified, Joint Commission-accredited, integrated delivery system with approximately 505,000 members in western Oregon and Washington State. Members include individuals and families covered by commercial group and individual self-pay health plans, Washington State Basic Health Plan (subsidized, Washington State only), Medicare Advantage, and Medicaid (Oregon and Washington State). Data used for analyses were extracted from the KPNW electronic medical record system and birth certificates. The linkage of medical records to birth certificates has been described elsewhere [7]. This study was approved by the Centers for Disease Control and Prevention (Protocol #3661, “Extent of Maternal Morbidity in a

Managed Care Setting") and the KPNW Institutional Review Boards (Protocol: NW-02MHorn-02, approved 7/08/2002).

Our study population was comprised of women aged 18–55 years enrolled in KPNW at delivery with singleton births that occurred between January 1, 1999 and December 31, 2008. To be included in the cohort, the pregnancy had to have reached at least 28.0 weeks gestation and GDM screening must have been completed between 24 weeks 0 days and 34 weeks 6 days gestation. Pregnancies were not eligible for inclusion if the patient had an ICD-9 code for diabetes mellitus (DM) type 1 or 2 or listing on the KPNW diabetes registry as type 1 or 2 DM during or prior to pregnancy episode; a multifetal gestation; evidence of dispensing for insulin, metformin, or sulfonylurea prior to the date of the GDM screening test result; or a one hour test result of 140–199mg/dL with no 3 h test completed by 34 weeks 6 days gestation.

We excluded pregnancies that were missing a documented delivery date, which was required for some outcome measures. We also excluded pregnancies missing data for covariates, including body mass index (BMI), parity, tobacco use, education, and Medicaid enrollment (Fig. 1). Medicaid enrollment, a proxy indicator of low socioeconomic status, is missing in records missing health plan enrollment data. Pregravid BMI ($kg/m^2$) was calculated from adult height and weight (measured 180 days before to 91 days after pregnancy onset) documented in the electronic medical record. Covariate information was obtained from the medical record (age, BMI, Medicaid status) and from birth certificate (race/ethnicity, education, parity, tobacco use).

Within KNPW, universal GDM screening is performed at 24–28 weeks gestation for women without diabetes and also in early pregnancy for women at high risk for diabetes (e.g. women with obesity and/or prior history of GDM) [8-11]. Our prior studies have shown that completion of GDM screening occurs in over 95% of eligible women [9]. KPNW uses the 2-step GDM screening method which involves a 1-h, 50-g oral glucose challenge test (GCT) followed by a 3-h, 100-g oral glucose tolerance test (OGTT) if the 1-h test is abnormal (>140 mg/dL). During the study period, GDM was diagnosed based on the NDDG criteria (Appendix A). Clinicians may have clinically managed women with a single abnormal value by NDDG criteria as GDM, but would not have diagnosed women as GDM by the lower Carpentar & Coustan cutpoints.

We categorized pregnancies based on glucose test results from the 1-hour GCT or 3-hour OGTT, by increasing severity of glycemia. Table 1 lists the criteria used to define the 5 exposure categories which consisted of a normal GCT category, 3 categories of abnormal OGTT, and a GDM category. The outcomes of interest were 9 types of service utilization occurring >22 weeks gestation, as follows:

1. Any dispensing of capillary blood glucose test supplies (glucometer, test strips, lancets, control solution)
2. Any dispensing of a medication used to treat GDM (insulin, glyburide, metformin)
3. Number of obstetric ultrasounds

4. Number of noninvasive antenatal tests [non-stress tests (NST), contraction stress tests (CST), and biophysical profiles performed by nurses at the time of a NST
5. Number of invasive antenatal tests (amniocentesis, cordocentesis)
6. Number of lab visits (counted as days, excluding the day of the initial GCT)
7. Number of ambulatory visits (counted as days) with:
    a. obstetrics department (obstetrics and gynecology, perinatology, genetics)
    b. nutrition department
    c. urgent care, emergency department, or other departments (e.g. primary care, ophthalmology, etc)
8. Number of telephone encounters with any department listed above (counted as days)
9. Maternal length of stay (counted as days) for the delivery admission stratified by delivery type (cesarean or vaginal)

We assessed utilization of the above outcomes from 22 weeks gestation through delivery as this ensured lab tests related to GDM testing were included but avoided counting routine first prenatal visit lab tests, routine dating and anatomy ultrasounds, and other noninvasive and invasive screening tests that would typically occur early in pregnancy for reasons unrelated to glucose status. Other than maternal length of stay, we did not assess neonatal length of stay or any health outcomes for the mother or her infant. We stratified length of stay by cesarean and vaginal delivery due to the influence of mode of delivery on this measure [10]. We considered including antepartum lengths of stay that did not result in delivery, but exploration of these data showed many overlapping admissions and inter-hospital transfers that precluded accurate electronic identification of this outcome.

We compared the glucose test result category and demographic characteristics of mothers included in the analysis with those who were excluded using chi square statistics for proportions. We then determined whether there was a difference in service utilization by glucose test result category and assigned women with a normal 1-hour GCT as the referent group. We analyzed the number of ultrasounds, noninvasive and invasive tests, lab visits, ambulatory visits and telephone encounters as rates (number of encounters/total person-weeks from 22.0 weeks' gestation to delivery because gestational age at delivery can vary). For these outcomes, we estimated rate ratios (RR) using generalized linear Poisson regression models, with a negative binomial distribution and person-weeks from 22 weeks gestation to delivery as the offset variable. Logistic regression models were used for dichotomous outcomes (dispensing of glucose testing supplies or GDM medications). Linear regression was used to assess differences in delivery length of stay by delivery type (cesarean versus vaginal). All models accounted for repeated measures (women with more than 1 pregnancy in the study) using generalized estimating equations. The logistic models were adjusted for age and BMI only as the addition of multiple covariates caused model instability due to small cell sizes, and the linear and Poisson models were adjusted for

covariates (age, BMI, race/ethnicity, education, parity, tobacco use, and Medicaid status). As a sensitivity analysis to determine whether another common antepartum condition aside from abnormal glucose levels may be influencing the results, we reran the logistic and linear regression models after excluding women with hypertensive disorders. Tests for linear trends across glucose test result categories were performed using linear contrasts. Statistical significance was set at $p < 0.05$. Statistical analyses were run in Statistical Analysis Software (SAS) version 9.3 (SAS Institute, Cary, NC).

## 3. Results

Our study sample included 29,999 pregnancies to 24,615 women; 2.5% of pregnancies met the NDDG diagnostic criteria for GDM used during the study period. Compared to pregnancies included in the analyses, those that were excluded were among women who were younger, more likely to use tobacco and to be insured by Medicaid, and less likely to be married or to have more than a high school education (data not shown, $p < .0001$). There were also some differences in race/ethnicity, such that the excluded pregnancies had a higher proportion of racial ethnic minorities (Black, Hispanic, and Asian/Pacific Islander) and Other/Multiple/Unknown race categories ($p < .0001$). The pregnancies excluded from the analysis were also less likely to have abnormal glucose test results and less likely to meet threshold for GDM diagnosis ($p= .0012$).

Among pregnancies included in the analyses, severity of the glucose test result increased with age and BMI. The proportion of women with abnormal glucose test results was lower among those insured by Medicaid and higher among those with less than a high school education (Table 2). Diagnosis of GDM was highest among women of Asian/Pacific Islander and Hispanic backgrounds (6.1 and 3.3%, respectively), compared to those of non-Hispanic Black (2.0%) and non-Hispanic White (1.9%) backgrounds.

As expected, over 90% of pregnancies with GDM had a dispensing for GDM testing supplies (Table 3). Among women with one abnormality by NDDG criteria, 16.6% were treated as if they had GDM (i.e, dispensed glucose testing supplies). The majority of women with 1–2 abnormalities by Carpenter & Coustan criteria were not treated as if they had GDM (only 3% dispensed glucose testing supplies. The proportion of pregnancies with medication dispensing to treat GDM was 8.5% among pregnancies with GDM and 3.7% among women with 1 abnormal value by NDDG criteria. Only 5 women, among the nearly 28,500 women with lesser to no glucose abnormalities were dispensed a medication used to treat GDM.

The rate of obstetric ultrasounds and noninvasive and invasive antenatal tests after 22 weeks' gestation increased with severity of glucose test result such that the rate ratios for pregnancies with GDM were nearly twice as high compared to pregnancies with a normal GCT. There was little variation in laboratory visits by severity of glucose test result other than the additional OGTT test required of those who failed the GCT.

The increase in the rate of ambulatory visits by severity of glucose test result was most notable for Ob/Gyn and nutrition visits (Table 3). Compared to pregnancies with a normal GCT, the rate ratio (RR) for Ob/Gyn visits was 1.1 (95% CI 1.1, 1.1) and 1.3 (95% CI

1.3,1.4) among pregnancies with 1 abnormality by NDDG or GDM, respectively. For nutrition visits, the RR was higher for pregnancies with any glucose abnormality ranging from 4.0 (95% CI 3.3, 4.9) among pregnancies with an abnormal GCT but normal OGTT to 72 (95% CI 64, 81) among pregnancies with GDM. Women with GDM had a 3-fold greater rate of phone encounters than women with normal testing.

Cesarean delivery occurred in 25.0% of pregnancies but was most common among women with 1–2 abnormal values by the Carpenter & Coustan criteria (36.1%). Cesarean delivery occurred in 24.0% of deliveries among women with normal testing, 34.0% of deliveries among women with one abnormal value by NDDG criteria, and 32% of deliveries among women with GDM (chi square $p < .0001$; data not shown). Maternal lengths of stay for vaginal and cesarean delivery did not differ substantially by glucose category.

The results of our analyses did not change when women with hypertensive disorders (n = 2,290; 7.6%) were excluded (Supplemental Table).

## 4. Discussion

The results of our study show that, compared to women with normal GDM test results, there was a greater use of several health care services among women with GDM as well as among women with glucose test results that were abnormal but did not meet the threshold for GDM diagnosis. About 10% of women with glucose test results below the diagnostic thresholds of GDM were dispensed supplies related to glucose testing and management. We suspect they were treated as having GDM based on either maternal or clinical risk factors that are associated with GDM, such as obesity, polyhydramnios or large-for-gestational age fetus, or based on the presence of GDM risk factors in combination with an abnormal but nondiagnostic test result. However, the number of women with subdiagnostic test results treated as GDM (just over 150 women) is small compared to the additional number of women that would be diagnosed and treated with GDM if our health care system switched to lower diagnostic thresholds. In our population, we approximate that as many as 1500 more women would have met criteria for GDM during our study period if lower diagnostic thresholds were utilized (such as those based on IADPSG and/or C&C criteria), which would be a 3-fold increase in prevalence from 2.5% to 7.4% of those screened.

For the health care system, the increased staffing needs for management of GDM if conversion to lower diagnostic thresholds was implemented could be substantial, especially for those staff that are required to provide dietary consultation and feedback (e.g. telephone calls), capillary blood glucose surveillance, and antenatal testing. To demonstrate the potential impact of diagnosing more women with GDM, we estimated service utilization for GDM diet teaching, blood sugar management, and antenatal surveillance; and how it could be impacted by a tripling of the volume of women with GDM (Table 4). For the estimates, we assumed all women with GDM have weekly blood sugar reviews for an average of 13 weeks (26–39 weeks); see a dietitian for a single, one-hour teaching visit; and start antenatal testing twice weekly at 32 weeks if they are on medication. Given these estimates, the number of case management contacts per year could increase from 6500 for 500 women with GDM to 19,500 for 1500 women with GDM, dietitian visits could increase from 500 h

to 1500 h per year, and antenatal testing visits could range from 280 to 840 per year. The ACOG practice bulletin for GDM indicates there is some leeway for local practices to determine the frequency of antenatal and capillary blood sugar surveillance as well as the timing of delivery [11], so the full impact of GDM diagnosis on staffing could be variable depending on local practices for these services. In our practice model, for a single woman diagnosed with GDM at 26 weeks who requires medication prior to, or by 32 weeks, and delivers at 39 weeks, the minimum amount of additional time above and beyond routine prenatal care that is required by the case management telephone calls, antenatal surveillance (twice weekly NST and AFI), and dietitian visit is 11.5 contact hours. This does not include the time the patient spends traveling to and from the office to attend her prenatal and antenatal testing visits, or the time she spends testing her blood sugars.

While it was tempting to attach a cost analysis with these data, we intentionally did not do so because other health care systems may differ from ours in their cost structures. Further, another important aspect of a cost analysis is consideration of cost to the patient. The cost of GDM diagnosis to the patient is not only financial due to copays, cost of supplies and medications, and lost time at work, but also includes the social-emotional impact of the diagnosis. In a past study examining medical costs associated with gestational diabetes, researchers generated estimates of an excess cost due to GDM of $3305 per pregnancy, plus an excess cost of $209 in the first year of life for each newborn. Total estimated medical costs attributable to GDM were $636 million for 2007, $230 million of which was covered by government programs [12]. If the prevalence of GDM abruptly increases by wide spread adoption of lower diagnostic thresholds, health system and patient costs related to diagnosis and treatment of GDM could substantially increase. Whether this increased expenditure for GDM-related care would be balanced out by reduction in adverse pregnancy outcomes and long-term maternal and child health requires further study. Preliminary studies in U.S. and Canadian populations have not shown improved outcomes among women with GDM diagnosed at lower thresholds [13,14], A recent study comparing the use of Carpentar & Coustan with the IADPSG criteria for GDM diagnosis found an increase in the rate of cesarean delivery for women diagnosed by the IADPSG criteria, without a reduction in the rate of LGA, macrosomia, NICU admissions, preterm birth, preeclampsia, shoulder dystocia, or hyperbilirubinemia [14].

Strengths of our analyses include that we had access to multiple years of data within a large health care system with universal screening and standardized protocols of care and diagnostic cut points, which limits bias due to failure to screen and limits variability in provider practice allowing for better observation of utilization by GDM test result. Although our data come from an insured population, this may be the most useful scenario to estimate the upper limits of health care service burden related to GDM; whereas, data from uninsured or underinsured population may underestimate this burden. Most women included in our study cohort would have had access to recommended supplies, medications, and services. The GDM prevalence in this study cohort (2.5%) is lower than would be expected if women screened for GDM at all gestational ages were included. Women diagnosed with GDM early in pregnancy may better represent those with pregestational glucose abnormalities and, as such, would potentially have an even greater utilization of health care services than those diagnosed at the time of routine screening (24–28 weeks gestation). Limitations of our

analyses include our inability to directly evaluate the utilization of care among women diagnosed with GDM by diagnostic criteria with thresholds lower than those of the NDDG cut-points utilized in this study. While we examined categories of glucose abnormalities that would approximate the milder abnormalities detected with the lower C&C and IADPSG thresholds, these abnormalities were not clinically recognized in our population and, thus, the impact on health care utilization of a GDM diagnosis at these lower thresholds could not be ascertained. One potential bias to this analysis is that we excluded pregnancies for which data regarding our prespecified covariates were not available. In our analysis of included versus excluded pregnancies, we found the excluded population to be younger with less likelihood for abnormal glucose test results. Unless the excluded women were high utilizers of health care, it is unlikely that the dose response relationship observed in the study would have been impacted by the exclusion of these women. Our sensitivity analysis, which additionally excluded women with hypertensive disorders during pregnancy, provides additional strength for the observed relationship. The characteristics of our study population limit the generalizability of our results; however, it seems likely that patient populations from other backgrounds or health care systems would also have increased levels of utilization with a GDM diagnosis given recommendations from ACOG and the ADA for management of women with diabetes in pregnancy [11,15].

In summary, health care utilization increased with severity of glucose test result, even among women not meeting criteria for GDM by NDDG criteria. Further study is needed to determine whether lowering diagnostic thresholds, resulting in a substantially larger proportion of women with GDM, improves maternal and child health outcomes and whether the additional patient and health care system related costs of increased detection are offset by a reduction in adverse outcomes.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

## Acknowledgements

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## Appendix A

Criteria for abnormal result on an oral glucose tolerance test (OGTT) for the diagnosis of gestational diabetes mellitus (GDM)

| Timing of sample | National Diabetes Data Group (NDDG) | Carpentar & Coustan (C&C) | International Association of Diabetes and Pregnancy Study Groups (IADPSG) |
|---|---|---|---|
| | 100 g, 3-h | 100 g, 3-h | 75 g, 2 h |
| Fasting | ≥105 mg/dL | ≥95 mg/dL | ≥ 92 mg/dL |
| 1-h | ≥190 mg/dL | ≥ 180 mg/dL | ≥180 mg/dL |
| 2-h | ≥165 mg/dL | ≥155 mg/dL | ≥153 mg/dL |
| 3-h | ≥145 mg/dL | ≥ 140 mg/dL | not applicable |

*Note:* NDDG and C&C thresholds criteria include the 50 g, 1-h glucose challenge test (GCT). Women with a glucose ≥140 mg/dL or ≥130 mg/dL, respectively, go on to the OGTT which are typically applied to a 100 g, 3-h oral glucose tolerance test and requires at least 2 abnormal values for diagnosis of GDM.; The IADPSG criteria does not include a GCT and requires only 1 abnormal value during the 75 g, 2-h OGTT for GDM diagnosis.

## Appendix B. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.diabres.2019.04.025.

## REFERENCES

[1]. Hartling L, Dryden DM, Guthrie A, Muise M, Vandermeer B, Aktary WM, et al. Screening and diagnosing gestational diabetes mellitus. Evidence Report/Technol Assess 2012;210:1–327.

[2]. Berggren EK, Boggess KA, Stuebe AM, Jonsson Funk M. National Diabetes Data Group vs Carpenter-Coustan criteria to diagnose gestational diabetes. Am J Obstet Gynecol 2011;205(3). 10.1016/j.ajog.2011.06.026.

[3]. Cheng YW, Block-Kurbisch I, Caughey AB. Carpenter-Coustan criteria compared with the national diabetes data group thresholds for gestational diabetes mellitus. Obstet Gynecol 2009;114(2 Pt 1):326–32. 10.1097/AOG.0b013e3181ae8d85. [PubMed: 19622994]

[4]. Ferrara A, Hedderson MM, Quesenberry CP, Selby JV. Prevalence of gestational diabetes mellitus detected by the national diabetes data group or the carpenter and coustan plasma glucose thresholds. Diabetes Care 2002;25(9):1625–30. [PubMed: 12196438]

[5]. Schwartz ML, Ray WN, Lubarsky SL. The diagnosis and classification of gestational diabetes mellitus: is it time to change our tune? Am J Obstet Gynecol 1999;180(6 Pt 1):1560–71. [PubMed: 10368504]

[6]. NIH Diagnosing Gestational Diabetes Mellitus. In: NIH Development Conference, Bethesda, Maryland; 3 4–6, 2013.

[7]. Dietz PM, Rizzo JH, England LJ, Callaghan WM, Vesco KK, Bruce FC, et al. Early term delivery and health care utilization in the first year of life. J Pediatr 2012; 161 (2): 234–239.e231. S0022-3476(12)00136-9 [pii];10.1016/j.jpeds.2012.02.005 [doi] [PubMed: 22421263]

[8]. American Diabetes Association. Classification and Diagnosis of Diabetes. Sec. 2. In Standards of Medical Care in Diabetes-2017. Diabetes Care 2017; 40 (Suppl 1): S11–S24. 10.2337/dc17-S005. [PubMed: 27979889]

[9]. Hillier TA, Pedula KL, Vesco KK, Schmidt MM, Mullen JA, LeBlanc ES, et al. Excess gestational weight gain: Modifying fetal macrosomia risk associated with maternal glucose. Obstet Gynecol 2008;112(5):1007–14. [PubMed: 18978099]

[10]. Chu SY, Bachman DJ, Callaghan WM, Whitlock EP, Dietz PM, Berg CJ, et al. Association between obesity during pregnancy and increased use of health care. N Engl J Med 2008;358 (14): 1444–53. 10.1056/NEJMoa0706786. [PubMed: 18385496]

[11]. Gestational diabetes mellitus. ACOG Practice Bulletin No. 190. American College of Obstetricians and Gynecologists. Obstet Gynecol 2018; 131 (2): e49–e64. 10.1097/AOG.0000000000002501. [PubMed: 29370047]

[12]. Chen Y, Quick WW, Yang W, Zhang Y, Baldwin A, Moran J, et al. Cost of gestational diabetes mellitus in the United States in 2007. Popul Health Manag 2009;12(3):165–74. 10.1089/pop.2009.12303. [PubMed: 19534581]

[13]. Bodmer-Roy S, Morin L, Cousineau J, Rey E. Pregnancy outcomes in women with and without gestational diabetes mellitus according to the International Association of the Diabetes and Pregnancy Study Groups criteria. Obstet Gynecol 2012;120(4):746–52. [PubMed: 22996090]

[14]. Feldman RK, Tieu RS, Yasumura L. Gestational diabetes screening: the international association of the diabetes and pregnancy study groups compared with Carpenter-Coustan screening. Obstet Gynecol 2016;127(1):10–7. 10.1097/aog.0000000000001132. [PubMed: 26646142]

[15]. American Diabetes Association. 13. Management of Diabetes in Pregnancy: Standards of Medical Care in Diabetes - 2018. Diabetes Care 2018; 41: S137–S143. [PubMed: 29222384]

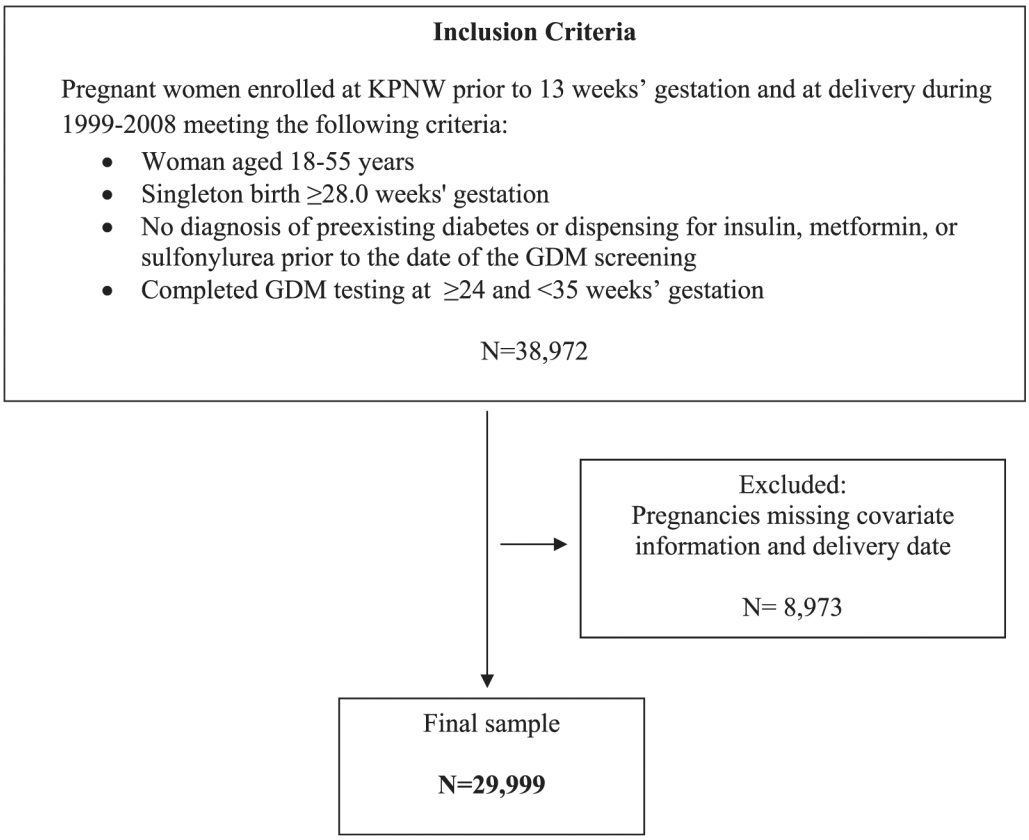


**Fig. 1 -**
Description of study sample selection.

**Table 1 -**

Criteria used to categorize women based on glucose test result.

| Women categorized as: | Criteria used: |
|---|---|
| Normal GCT | 1-h, 50 g GCT: <140 mg/dL |
| Normal OGTT by NDDG and CC | 3-h, 100 g OGTT (all criteria met):<br>fasting <95 mg/dL, 1-h < 180 mg/dL, 2-h < 155 mg/dL, 3 h <140 mg/dL |
| 1–2 Abnormal by CC, but not by NDDG | 3-h, 100 g OGTT (1–2 criteria met):<br>fasting 95–105 mg/dL, 1-h 180–190 mg/dL, 2-h 155–165 mg/dL, 3 h 140–145 mg/dL |
| 1 Abnormal by NDDG | 3-h, 100 g OGTT (only 1 criteria met):<br>fasting >105 mg/dL, 1-h > 190 mg/dL, 2-h > 165 mg/dL, 3 h > 145 mg/dL |
| GDM | 1-h, 50 g GCT: >200 mg/dL<br>OR<br>3-h, 100 g OGTT (≥2 criteria met):<br>fasting > 105 mg/dL, 1-h > 190 mg/dL, 2-h > 165 mg/dL, 3 h > 145 mg/dL |

*Abbreviations*: GCT, glucose challenge test; OGTT, oral glucose tolerance test; GDM, gestational diabetes mellitus.

**Table 2 -**

Maternal characteristics by glucose test result.

| Characteristic | Normal GCT (n = 25,535, 85.1%) | Normal OGTT by CC & NDDG (n = 2246, 7.5%) | 1–2 Abnormal CC (n = 657, 2.2%) | 1 Abnormal by NDDG (n = 820, 2.7%) | GDM (n = 741, 2.5%) |
|---|---|---|---|---|---|
| | % | % | % | % | % |
| Age (years)[a] | | | | | |
| <25 | 90.8 | 5.6 | 1.2 | 1.2 | 1.2 |
| 25–29 | 85.6 | 7.3 | 2.2 | 2.6 | 2.3 |
| 30–34 | 82.2 | 8.4 | 2.6 | 3.6 | 3.2 |
| ≥35 | 77.9 | 10.1 | 3.4 | 4.4 | 4.2 |
| Race/Ethnicity[a] | | | | | |
| NH-White | 86.9 | 7.0 | 1.9 | 2.3 | 1.9 |
| NH-Black | 90.4 | 4.4 | 1.7 | 1.4 | 2.0 |
| Hispanic | 81.5 | 8.9 | 2.7 | 3.6 | 3.3 |
| Asian/Pacific Islander | 70.0 | 13.9 | 4.3 | 5.8 | 6.1 |
| Multiple/Other/Unknown | 75.8 | 9.5 | 3.8 | 5.1 | 5.8 |
| Education (years)[a] | | | | | |
| <12 | 83.3 | 7.3 | 2.3 | 3.1 | 4.0 |
| 12 | 85.8 | 7.2 | 2.2 | 2.7 | 2.1 |
| >12 | 85.1 | 7.6 | 2.2 | 2.7 | 2.5 |
| Medicaid[a] | | | | | |
| Yes | 89.2 | 5.6 | 1.5 | 1.9 | 1.9 |
| No | 84.9 | 7.6 | 2.2 | 2.8 | 2.5 |
| Parity | | | | | |
| 0 | 85.4 | 7.3 | 2.1 | 2.6 | 2.6 |
| ≥1 | 84.9 | 7.7 | 2.2 | 2.8 | 2.4 |
| Smoker | | | | | |
| Yes | 85.5 | 7.2 | 2.6 | 2.2 | 2.5 |
| No | 85.1 | 7.5 | 2.1 | 2.8 | 2.5 |
| BMI (kg/m$^2$)[a] | | | | | |

| Characteristic | Normal GCT (n = 25,535, 85.1%) | Normal OGTT by CC & NDDG (n = 2246, 7.5%) | 1–2 Abnormal CC (n = 657, 2.2%) | 1 Abnormal by NDDG (n = 820, 2.7%) | GDM (n = 741, 2.5%) |
|---|---|---|---|---|---|
| | % | % | % | % | % |
| <25 | 88.0 | 6.8 | 1.4 | 1.9 | 1.9 |
| 25.0–29.9 | 84.4 | 7.7 | 2.2 | 2.9 | 2.8 |
| 21 ≥ 30.0 | 79.1 | 8.8 | 4.0 | 4.6 | 3.6 |

[a]Chi-square <0.05.

**Table 3 -**

Distribution and regression results for service utilization measures by severity of glucose test result.

| Service utilization measure | GDM screening test result | | | | |
|---|---|---|---|---|---|
| | **Normal GCT (n = 25,535, 85.1%)** | **Normal OGTT by CC & NDDG (n = 2,246, 7.5%)** | **1–2 Abnormal by CC (n = 657, 2.2%)** | **1 Abnormal by NDDG (n = 820, 2.7%)** | **GDM (n = 741, 2.5%)** |
| Dispensed glucose testing supplies[a] | | | | | |
| % yes | 0.2 | 1.9 | 3.0 | 16.6 | 93.2 |
| OR (95%CI)[d] | 1.0 | 6.9 | 10.0 | 65.0 | 5151 |
| | referent | (4.6, 10.3) | (5.9, 16.9) | (47.1, 89.7) | (3516, 7545) |
| Dispensed medications for GDM[a] | | | | | |
| % yes | 0 | 0.1 | 0.1 | 3.7 | 8.5 |
| OR (95%CI) | Model not able to run to due small cell sizes | | | | |
| Obstetrical ultrasound[b] | | | | | |
| Number of encounters | 1.2 | 1.3 | 1.4 | 1.6 | 2.3 |
| RR (95% CI)[d] | 1.0 | 1.0 | 1.1 | 1.2 | 1.8 |
| | referent | (1.0, 1.1) | (0.9, 1.2) | (1.1, 1.4) | (1.6, 2.0) |
| Noninvasive antenatal tests[b] | | | | | |
| Number of encounters | 1.7 | 1.9 | 2.0 | 2.4 | 3.3 |
| RR (95% CI)[d] | 1.0 | 1.1 | 1.1 | 1.3 | 1.8 |
| | referent | (1.0, 1.2) | (1.0, 1.2) | (1.1, 1.4) | (1.7, 2.0) |
| Invasive antenatal tests[b] | | | | | |
| Number of encounters | 0.05 | 0.07 | 0.06 | 0.10 | 0.11 |
| RR (95% CI)[d] | 1.0 | 1.2 | 0.9 | 1.7 | 2.0 |
| | referent | (1.0, 1.6) | (0.6, 1.5) | (1.3, 2.3) | (1.5, 2.7) |
| Laboratory visits[b] | | | | | |
| Number of encounters | 1.6 | 2.8 | 2.8 | 2.9 | 2.8 |
| RR (95% CI)[d] | 1.0 | 1.7 | 1.7 | 1.8 | 1.7 |
| | referent | (1.7, 1.8) | (1.6, 1.8) | (1.7, 1.9) | (1.7, 1.8) |

| Service utilization measure | GDM screening test result | | | | |
|---|---|---|---|---|---|
| | **Normal GCT (n = 25,535, 85.1%)** | **Normal OGTT by CC & NDDG (n = 2,246, 7.5%)** | **1–2 Abnormal by CC (n = 657, 2.2%)** | **1 Abnormal by NDDG (n = 820, 2.7%)** | **GDM (n = 741, 2.5%)** |
| Ambulatory visits[b] | | | | | |
| OB/Gyn | | | | | |
| Number of encounters | 8.1 | 8.1 | 8.4 | 8.9 | 10.8 |
| RR (95% CI)[d] | 1.0 | 1.0 | 1.0 | 1.1 | 1.3 |
| | referent | (1.0, 1.0) | (1.0, 1.1) | (1.1, 1.1) | (1.3, 1.4) |
| Nutrition | | | | | |
| Number of encounters | 0.0 | 0.1 | 0.1 | 0.5 | 1.1 |
| RR (95% CI)[d] | 1.0 | 4.0 | 5.3 | 30.1 | 72.1 |
| | referent | (3.3, 4.9) | (4.0, 7.1) | (26.1, 34.7) | (64.0, 81.3) |
| Urgent/Emergent/Other | | | | | |
| Number of encounters | 3.2 | 3.3 | 3.2 | 3.4 | 3.2 |
| RR (95% CI)[d] | 1.0 | 1.1 | 1.0 | 1.1 | 1.1 |
| | referent | (1.0, 1.1) | (1.0, 1.1) | (1.0, 1.2) | (1.0, 1.2) |
| Telephone encounters | | | | | |
| Number of encounters | 2.8 | 4.1 | 4.3 | 5.2 | 8.2 |
| RR (95% CI)[d] | 1.0 | 1.5 | 1.5 | 1.9 | 3.1 |
| | referent | (1.4, 1.5) | (1.5, 1.6) | (1.8, 2.0) | (2.9, 3.2) |
| Maternal delivery length of stay[c] | | | | | |
| Overall (days) | 3.5 | 3.6 | 3.8 | 3.8 | 3.8 |
| β (95% CI)[d] | 0.0 | 0.0 | 0.2 | 0.1 | 0.2 |
| | Referent | (0.0, 0.1) | (0.1, 0.3) | (0.1, 0.2) | (0.1, 0.2) |
| Cesarean births (days) | 4.6 | 4.6 | 4.8 | 4.8 | 4.7 |
| β (95% CI) | 0.0 | −0.0 | 0.1 | 0.1 | 0.0 |
| | Referent | (−0.1, 0.1) | (−0.0, 0.3) | (−0.0, 0.2) | (−0.1, 0.2) |
| Vaginal (days) | 3.2 | 3.3 | 3.3 | 3.3 | 3.4 |
| β (95% CI)[d] | 0.0 | 0.1 | 0.1 | 0.1 | 0.2 |
| | Referent | (0.0, 0.1) | (−0.0, 0.2) | (0.0, 0.2) | (0.1, 0.3) |

*Abbreviations*: GCT, glucose challenge test; OGTT, oral glucose tolerance test; CC, Carpenter and Coustan; NDDG, National Diabetes Data Group; CI, confidence interval; OR, odds ratio; RR, rate ratio.

[a]Dichotomous outcomes (yes/no) analyzed with logistic regression models to estimate odds ratios (OR) accounting for repeated measures (women with more than 1 pregnancy in the study) and adjusting for age and BMI. The addition of multiple covariates caused model instability due to small cell sizes and therefore the logistic regression analyses were adjusted only for age and BMI.

[b]Rate outcomes calculated as number of encounters divided by total person-weeks from >22 weeks gestation to delivery and analyzed with generalized linear Poisson regression models, with a negative binomial distribution and person-weeks from 22 weeks gestation to delivery as the offset variable to estimate rate ratios (RR). In situations where there were no zero counts, we modeled the number of "excess" counts. All models accounted for repeated measures (women with more than 1 pregnancy in the study) and were adjusted for age, BMI, race/ethnicity, education, parity, tobacco use, and Medicaid status.

[c]Linear outcomes (days) were analyzed with linear generalized estimating equation models to estimate a β coefficient. All models accounted for repeated measures (women with more than 1 pregnancy in the study) and were adjusted for age, BMI, race/ethnicity, education, parity, tobacco use, and Medicaid status.

[d]Linear trend $p < 0.05$.

**Table 4 -**

One year service volume estimates for women with a GDM diagnosis.

| Women with GDM | Case management calls | Case manager hours | Nutrition visits | Dietitian hours | Antenatal tests | Antenatal nurse hours |
|---|---|---|---|---|---|---|
| 100 | 1300 | 325 | 100 | 100 | 112 | 56 |
| 500 | 6500 | 1625 | 500 | 500 | 560 | 280 |
| 1000 | 13,000 | 3250 | 1000 | 1000 | 1120 | 560 |
| 1500 | 19,500 | 4875 | 1500 | 1500 | 1680 | 840 |

*Assumptions*: Average 13 weeks in case management (26–39 weeks gestation) with minimum of once weekly blood sugar review and 15 min case management calls; 60 min dietitian visits; 8% of GDM patients require medication and undergo twice weekly antenatal testing for an average of 7 weeks (32–39 weeks) with 30 min antenatal testing visits.

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