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# Prediction of Gestational Diabetes Mellitus using First-Trimester Parameters during Pregnancy: A Prospective Study in Southern Thailand

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## Abstract:

**Objective:** To assess the incidence of gestational diabetes mellitus (GDM) in pregnant women who have tested negative for gestational diabetes during first-trimester screening. Additionally, to identify first-trimester factors that can predict GDM at 24–28 weeks or later in Southern Thailand.

**Material and Methods:** A prospective study was conducted from March 2018 and March 2020 in two tertiary hospitals. A two-step approach for GDM screening was performed at the first trimester (≤14 weeks) and at 24–28 weeks or later. First-trimester factors associated with the development of GDM at 24 weeks or later were analyzed using multivariable logistic regression.

**Results:** Of 408 pregnant women who had no GDM from screening at the first trimester, 43 women (10.5%) were diagnosed with GDM at 24 weeks of gestation or later. One-hour plasma glucose after 50 grams (g) GCT and HbA1c at the first trimester were found to be significantly higher in GDM women than in non-GDM women. Women with a history of hypertensive disorders of pregnancy (HDP) or GDM in a prior pregnancy, subscapular fat thickness >18.8 millimeter, 1-hour plasma glucose after 50g GCT >165 milligrams per deciliter (mg/dL), and HbA1c >5.3% at first trimester had 2- to 4-fold higher odds of developing GDM.

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**Conclusion:** Approximately, one of 10 pregnant women having had no GDM at first trimester was diagnosed GDM at 24 weeks or later. Close monitoring for the diagnosis of GDM and early treatment should be systematically planned in women with history of HDP or GDM in a prior pregnancy, high subscapular fat thickness, and 1-hour plasma glucose after 50g GCT or HbA1c at first trimester.

**Keywords:** early pregnancy, fat thickness, gestational diabetes mellitus, HbA1c

## Introduction

Gestational diabetes mellitus (GDM) is a global issue, affecting pregnant women from low- to high-income countries. Reported pooled prevalences, mostly diagnosed at 24-28 weeks of gestation, have varied from 7.6% to 12.0%[1-5]. GDM in early pregnancies before 12 weeks of gestation in a systematic review was also found to range from 1.9% to 14.2%, due to different study characteristics, study designs, screening or diagnostic procedures, and approaches[6]. Our previous systematic review on screening tests for GDM in Southeast Asia showed that a two-step approach using a plasma glucose threshold of 140 milligrams per deciliter (mg/dL) in the 50 grams (g) glucose challenge test (GCT), followed by the 100g oral glucose tolerance test (OGTT), is a good test for screening for GDM at 24-28 weeks; additionally, the glycated hemoglobin A1c (HbA1c) test is an alternative choice[7].

It is recommended that pregnant women should be screened at 24–28 weeks of gestation for GDM, while screening at earlier gestational ages for high-risk women is also suggested[7]. However, there is no clear evidence regarding the probability of GDM being diagnosed in negative GDM screening during early pregnancy. Furthermore, there are no simple clinical parameters in early pregnancy that can be used for the prediction of a future diagnosis in late pregnancy within resource-limited settings. Hence, the objective of this study was to assess the incidence of GDM in pregnant women who had undergone a negative screening in early pregnancy, and to identify the first-trimester factors that can predict GDM at 24-28 weeks or later.

## Material and Methods

A prospective study was carried out in two hospitals in the South of Thailand: Songklanagarind Hospital and Naradhiwas Rajanagarindra Hospital, from March 14, 2018, till March 11, 2020. In Thailand, GDM screening for all pregnant women typically follows a two-step method at 24–28 weeks of gestation. This involves the use of a 50g glucose challenge test, followed by a 100g glucose tolerance test, if the 1-hour glucose level after the 50g GCT is greater than or equal to 140 mg/dL. Screening for GDM before 14 weeks of gestation is typically not conducted unless risk factors for hyperglycemia are present; furthermore, HbA1c testing is not routinely recommended. Height is measured only at the first antenatal care (ANC) visit; whereas, weight is measured at each visit. Body circumferences and body composition are not measured.

All pregnant women with a gestational age of 14 weeks or less who had attended ANC and planned to give birth at the study hospitals were included in the study. However, women with thalassemia, chronic renal or autoimmune diseases, pre-existing diabetes mellitus (DM), GDM detected at ≤14 weeks, communication difficulties, or an unwillingness to provide urine samples and undergo blood collection were excluded. Eligible participants were informed and invited to join the study. After giving consent, they were interviewed about their personal characteristics. History of hypertensive disorders during pregnancy (HDP) or GDM in prior pregnancy and hypertension, DM or cardiovascular disease in family, and any anthropometric measurements were then taken by trained research assistants.

The anthropometric indices measured were: body mass index (BMI), body composition, and circumferences as well as skinfold thickness at the triceps, biceps, suprailiac, subscapular, and abdominal areas. Body composition included: body fat and skeletal muscle percentage. Body circumferences were measured at the waist, hip, thigh, neck, mid-arm, and wrist. Self-reported pre-pregnancy weight and height at the first visit were used for calculating pre-pregnancy BMI. Pregnant body weight was measured along with a calculation of body fat and skeletal muscle percentages by Omron electronic equipment, body composition monitor HBF-224 (OMRON HEALTHCARE Co., Ltd, Kyoto, Japan) through bioelectrical impedance analysis. Body circumferences were measured with a plastic tape and recorded in centimeters (cm). Skinfold thickness was assessed using a TOOGOO® digital LCD body fat caliper (Shenzhen IMC Digital Technology Co., Ltd., Shenzhen, China); as described in our previous study[8]. In addition, blood pressure, physical activity and total food intake calories were also measured.

Blood glucose and HbA1c tests were performed one hour after administering the 50g GCT. Women that had glucose levels greater than or equal to 140 mg/dL were then tested via a 100g OGTT test. GDM was diagnosed based on abnormal results, according to the Carpenter and Coustan criteria. Appropriate management was provided during prenatal care. HbA1c levels were analyzed using the certified Capillarys 3 Tera instrument (Sebia, France) with the capillary electrophoresis method. HbA1c values are recorded as percentage (%) or millimoles per mole (mmol/mol), using the National Glycohemoglobin Standardization Program (NGSP) HbA1c converter, available at http://www.ngsp.org/convert1.asp. Plasma glucose was analyzed using the Hexokinase method, with a Cobas 8000 modular analyzer series (Roche Diagnostics GmbH, Mannheim, Germany), and reported in mg/dL.

All women included in the study not diagnosed with GDM in the first trimester were screened for GDM again at 24-28 weeks, using the same methods as at the first trimester; anthropometric indices were also measured. Women diagnosed with GDM received treatment from endocrinologists and obstetricians, based on hospital guidelines. All women were followed up until delivery.

**Data management and analysis**

Data were analyzed using R version 4.4.0 (R Foundation for Statistical Computing, Vienna, Austria, 2024). Pre-pregnancy and pregnancy BMIs in kilograms per square meter ($kg/m^2$) were classified based on the Asian classification: with underweight defined as less than 18.5 $kg/m^2$, normal weight as 18.5 to 22.9 $kg/m^2$, overweight as 23.0 to 24.9 $kg/m^2$ and obesity as 25.0 $kg/m^2$ or higher[9,10]. Body composition, body circumference, and skinfold thickness were categorized using cut-off values determined by the Youden method. The parameters with a p-value below 0.2 in the univariate analyses were incorporated into the initial model of the multivariable logistic regression, which employed a stepwise backward selection method. A p-value below 0.05 was considered statistically significant for first-trimester parameters in the final GDM prediction model. The model's predictive performance was assessed using the area under the curve (AUC) of receiver operating characteristic (ROC) curves.

The sample size calculation for the clinical prediction model of a binary outcome[11] was used. Based on the prevalence of GDM in the third trimester among those with normal screenings in the first trimester at 11.8%[12], 10 parameters were expected to be included in the model, with explained variances of at least 20%: at least 398 women were required.

### Ethical statement

The study was approved by the "Human Research Ethics Committee of the Faculty of Medicine, Prince of Songkla University (REC no: 60-413-18-1)". All women that participated in the study were informed and signed consent forms before data collection.

## Results

There were 587 eligible women at the first trimester, with a gestational age of 14 weeks or less; 54 of them, who have been diagnosed with early GDM (9.2%), were excluded. Therefore, a total of 533 pregnant women were enrolled; however, only 408 were investigated for GDM at 24-28 weeks of gestation or later, of which 43 women (10.5%) were diagnosed with GDM. The flow diagram of participants is presented in Figure 1. From the 408 included women, their characteristics at the first trimester were either GDM or non-GDM as shown in Table 1. The mean age of the GDM women was slightly higher than in non-GDM women (33.1 vs 30.7 years, p-value=0.007). History of HDP or GDM in prior pregnancy was reported more in GDM women than in non-GDM women (11.6% vs 3.0%, p-value=0.019). Other characteristics of GDM women were not significantly different from non-GDM women. BMI, body composition, blood pressure, physical activity, and total food intake calories at the first trimester are presented in Table 2. BMI, body composition, blood pressure, physical activity and total food intake calories were not significantly different between both groups; except subscapular thickness (21.2 millimeter (mm) vs 16.8 mm, p-value=0.003) and the mean sum of skinfold thickness (84.6 mm vs 74.8 mm, p-value=0.015), which were significantly higher in GDM women than non-GDM women.

Best cut-off values for subscapular fat thickness, 1-hour plasma glucose after 50g GCT, and HbA1c using the Youden method were: 18.8 mm, 165 mg/dL, and 5.3% (34 mmol/mol), respectively. At the first trimester, 1-hour plasma glucose after 50g GCT, HbA1c and the plasma glucose in 100g OGTT between GDM and non-GDM diagnosed at 24 weeks or later are presented in Table 3. Levels of 1-hour plasma glucose after 50g GCT and HbA1c were found to be significantly higher in GDM women than in non-GDM women. GDM women had a significantly higher rate of having subscapular fat thickness >18.8 mm (68.3% vs 39.3%, p-value<0.001), 1-hour plasma glucose after 50g GCT >165 mg/dL (37.2% vs 17.5%, p-value=0.004), and HbA1c >5.3% (41.9% vs 19.0%, p-value=0.001) than non-GDM women.

The final model of multivariable logistic regression identifying the parameters at the first trimester associated with the development of GDM at 24-28 weeks or later are shown in Table 4. Women with a history of HDP or GDM in prior pregnancy, subscapular fat thickness >18.8 mm 1-hour plasma glucose after 50g GCT >165 mg/dL, and HbA1c >5.3% (34 mmol/mol) at the first trimester had 2- to 4-fold higher odds of developing GDM (AUC 0.73). Among the 408 included women, 405 of them delivered at the study hospital (99.3%), of which the cesarean section rates in GDM and non-GDM women were 58.1% and 44.8%, respectively (p-value=0.107). Maternal and neonatal outcomes measured in this study were not significantly different between women with GDM and non-GDM; except for the fetal weight of the women with GDM (median 3232, IQR 2920 to 3610 gm), which was significantly greater than in women without GDM (median 3098, IQR 2830 to 3355 g), p-value=0.044.

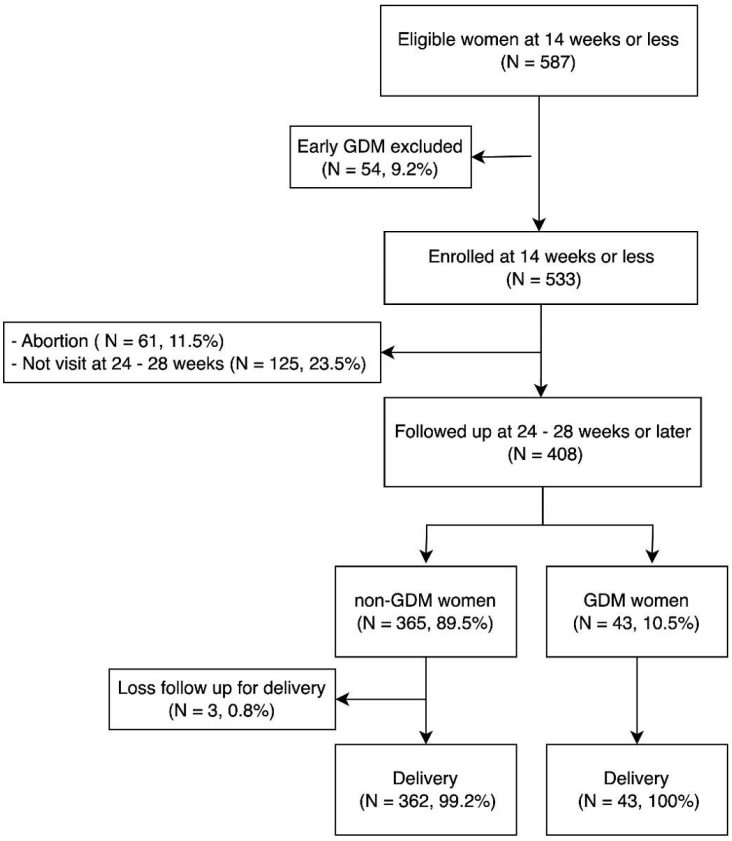


**Figure 1** Diagram flow of participants

**Table 1** Characteristics of included women at the first trimester who were GDM and non-GDM at 24-28 weeks of gestation (n=408)

| Characteristic | non-GDM (N=365) n (%) | GDM (N=43) n (%) | p-value |
|---|---|---|---|
| Gestational age | | | 0.373 |
| Median (IQR) | 8.0 (7.0,10.0) | 8.0 (6.0,9.0) | |
| Maternal age | | | 0.007 |
| Mean (S.D.) | 30.7 (5.4) | 33.1 (5.7) | |
| Education | | | 0.224 |
| Secondary school or less | 99 (27.1) | 9 (20.9) | |
| Vocational school | 40 (11.0) | 2 (4.7) | |
| Bachelor or more | 226 (61.9) | 32 (74.4) | |
| Occupation | | | 0.697 |
| Unemployed | 27 (7.4) | 3 (7.0) | |
| Farmer/fisherman/merchant | 55 (15.1) | 10 (23.3) | |
| Housewife | 59 (16.2) | 5 (11.6) | |
| Laborer | 65 (17.8) | 7 (16.3) | |
| Employee | 159 (43.6) | 18 (41.9) | |

**Table 1** (continued)

| Characteristic | non-GDM (N=365) n (%) | GDM (N=43) n (%) | p-value |
|---|---|---|---|
| Religion | | | 0.134 |
| Buddhism | 147 (40.3) | 23 (53.5) | |
| Other | 218 (59.7) | 20 (46.5) | |
| HDP or GDM in prior pregnancy | | | 0.019 |
| No | 354 (97) | 38 (88.4) | |
| Yes | 11 (3) | 5 (11.6) | |
| History of hypertension in family | | | 0.822 |
| No | 184 (62.2) | 12 (57.1) | |
| Yes | 112 (37.8) | 9 (42.9) | |
| History of diabetes mellitus in family | | | 0.472 |
| No | 217 (73.3) | 18 (85.7) | |
| Yes | 75 (25.3) | 3 (14.3) | |
| Unknown | 4 (1.4) | 0 (0) | |
| History of cardiovascular disease in family | | | 0.296 |
| No | 262 (88.5) | 17 (81.0) | |
| Yes | 34 (11.5) | 4 (19.0) | |

HDP=hypertensive disorders of pregnancy, GDM=gestational diabetes mellitus, IQR=interquartile range, S.D.=standard deviation

**Table 2** Anthropometric indices, blood pressure, physical activity, total food intake calories, one-hour plasma glucose after 50g GCT, and HbA1c at first trimester that were GDM and non-GDM at 24-28 weeks of gestation (n=408)

| Factors | non-GDM (N=365) n (%) | GDM (N=43) n (%) | p-value |
|---|---|---|---|
| Pre-pregnancy BMI | | | 0.177 |
| Median (IQR) | 22.5 (19.9,25.9) | 23.1 (21.6,26.3) | |
| Pre-pregnancy BMI group (kg/m$^2$) | | | 0.734 |
| Underweight/normal | 193 (52.9) | 21 (48.8) | |
| Overweight/obese | 172 (47.1) | 22 (51.2) | |
| Pregnancy BMI at 14 weeks or less (kg/m$^2$) | | | 0.139 |
| Median (IQR) | 23.1 (20.3,26.8) | 24.2 (22.1,27.1) | |
| Pregnancy BMI group (kg/m$^2$) | | | 0.277 |
| Underweight/normal | 181 (49.6) | 17 (39.5) | |
| Overweight/obese | 184 (50.4) | 26 (60.5) | |
| Body fat percentage | | | |
| Mean (S.D.) | 31.2 (5.5) | 32.7 (5.1) | 0.091 |
| Cut-off value >29.1% | 238 (65.4) | 34 (79.1) | 0.103 |
| Skeletal muscle percentage | | | |
| Mean (S.D.) | 26.5 (2.7) | 25.9 (2.6) | 0.146 |
| Cut-off value >22.8% | 327 (89.8) | 39 (90.7) | 1 |
| Hip circumference (cm) | | | |
| Median (IQR) | 96.5 (91.0,104.5) | 98.9 (93.8,103.9) | 0.480 |
| Cut-off value >97.6 cm | 167 (45.8) | 25 (58.1) | 0.168 |

**Table 2** (continued)

| Factors | non-GDM (N=365) n (%) | GDM (N=43) n (%) | p-value |
|---|---|---|---|
| Subscapular fat thickness (mm) | | | |
| median (IQR) | 16.8 (12.2,22) | 21.2 (17.3,25) | 0.003 |
| cut-off value >18.8 mm | 143 (39.3) | 28 (68.3) | <0.001 |
| Sum of skinfold thickness (mm) | | | |
| mean (SD) | 74.8 (24.4) | 84.6 (24.7) | 0.015 |
| cut-off value >78.6 mm | 157 (43.1) | 26 (63.4) | 0.021 |
| Systolic blood pressure (mmHg) | | | |
| median (IQR) | 105 (99.0,112.3) | 107.7 (101.8,114.5) | 0.117 |
| cut-off value >113 mmHg | 93 (25.5) | 17 (39.5) | 0.075 |
| Diastolic blood pressure (mmHg) | | | |
| median (IQR) | 64.7 (59.7,70.0) | 68 (61.0,74.2) | 0.238 |
| cut-off value >68 mmHg | 125 (34.2) | 19 (44.2) | 0.262 |
| Physical activity | | | 0.642 |
| Active | 57 (15.6) | 5 (11.6) | |
| Inactive | 308 (84.4) | 38 (88.4) | |
| Total calories of food intake (calories/day) | | | |
| median (IQR) | 1161.1 (929.4,1423.1) | 1067.3 (894.0,1198.0) | 0.174 |
| cut-off value >712.5 | 331 (90.7) | 41 (95.3) | 0.405 |

GCT=glucose challenge test, HbA1c=glycated hemoglobin, GDM=gestational diabetes mellitus, BMI=Body Mass index, IQR=interquartile range, kg/m$^2$=kilogram per square meter, S.D.=standard deviation, mm=millimeter, mmHg=millimeter of mercury

**Table 3** One-hour plasma glucose after 50g GCT, HbA1c and plasma glucose in 100g OGTT at the first trimester in GDM and non-GDM diagnosed at 24-28 weeks of gestation (N=408)

| Factors | non-GDM n (%) | GDM n (%) | p-value |
|---|---|---|---|
| Having HDP or GDM in prior pregnancy; n=365 vs n=43 | 11 (3.0) | 5 (11.6) | 0.019 |
| Subscapular fat thickness[1]; n=364 vs n=41 | | | |
| Median (IQR) | 16.8 (12.2, 22.0) | 21.2 (17.3, 25.0) | 0.003 |
| 1-hour plasma glucose after 50g GCT (mg/dl); n=365 vs n=43 | | | |
| Median (IQR) | 128.0 (107.0, 156.0) | 139.0 (118.5, 180.5) | 0.004 |
| HbA1c; n=365 vs n=43 | | | |
| Median (IQR)-% | 5.1 (4.9, 5.3) | 5.3 (4.9, 5.4) | 0.004 |
| Median (IQR)-mmol/mol | 32.0 (30.0, 34.0) | 34.0 (30.0, 36.0) | |
| Plasma glucose in 100g OGTT[2]; n=131 vs n=20 | | | |
| Fasting blood level: mean (S.D.) | 79.5 (7.0) | 78.8 (6.3) | 0.648 |
| 1-hour level: mean (S.D.) | 141.5 (27.2) | 156.1 (21.5) | 0.023 |
| 2-hour level: mean (S.D.) | 121.7 (23.8) | 136.6 (26.5) | 0.012 |
| 3-hour level: mean (S.D.) | 102.0 (20.2) | 102.7 (22.2) | 0.892 |

[1]Missing data=one in non-GDM and two in GDM, [2]100g OGTT performed only when abnormal 50g GCT and for some high-risk women, 50g replaced by 100g, GCT=glucose challenge test, HbA1c=glycated hemoglobin, OGTT=oral glucose tolerance test, GDM=gestational diabetes mellitus, HDP=hypertensive disorders of pregnancy, IQR=interquartile range, S.D.=standard deviation

**Table 4** Factors at the first trimester associated with the development of GDM at 24–28 weeks or later (n=408)

| Factors | crude OR (95%CI) | adj. OR (95%CI) | p-value (Wald's test) | p-value (LR-test) |
|---|---|---|---|---|
| Model 1 with HbA1c | | | | |
| HDP or GDM in prior pregnancy: yes vs no | 4.43 (1.34–12.93) | 3.80 (1.06–12.28) | 0.030 | 0.041 |
| Subscapular fat thickness: >18.8 mm vs ≤18.8 mm | 3.30 (1.68–6.78) | 2.86 (1.42–6.01) | 0.004 | 0.003 |
| 1-hour plasma glucose after 50g GCT: >165 mg/dL vs ≤165 mg/dL | 2.98 (1.48–5.86) | 2.39 (1.15–4.84) | 0.017 | 0.021 |
| HbA1c: >5.3% (34 mmol/mol) vs ≤5.3% (34 mmol/mol) | 3.01 (1.51–5.88) | 2.23 (1.08–4.51) | 0.026 | 0.030 |
| | | AUC 0.73 | | |
| Model 2 without HbA1c | | | | |
| HDP or GDM in prior pregnancy: yes vs no | 4.11 (1.42–11.85) | 4.1 (1.33–12.64) | 0.019 | 0.030 |
| Subscapular fat thickness: >18.8 mm vs ≤18.8 mm | 3.45 (1.74–6.82) | 3.33 (1.66–6.68) | 0.001 | <0.001 |
| 1-hour plasma glucose after 50g GCT: >165 mg/dL vs ≤165 mg/dL | 2.59 (1.33–5.03) | 2.2 (1.10–4.37) | 0.009 | 0.012 |
| | | AUC 0.71 | | |

GDM=gestational diabetes mellitus, HDP=hypertensive disorders of pregnancy, IQR=interquartile range, S.D.=standard deviation, GCT=glucose challenge test, HbA1c=glycated hemoglobin, mm=millimeter, mg/dL=milligram per deciliter, hr=hour, AUC=area under the curve

## Discussion

Almost one-fifth of the pregnant women in our study were diagnosed with GDM in the first, second and up to the third trimester of pregnancy. First-trimester factors can be used for predicting GDM at 24–28 weeks of gestation; namely a history of HDP or GDM in prior pregnancies, high subscapular fat thickness, 1-hour plasma glucose after 50g GCT, and HbA1c levels.

Our study detected early GDM before 14 weeks of gestation in 9.2% of participants, which falls within the global prevalence range reported in a systematic review (1.9%–14.2%), based on different screening policies and diagnostic criteria across various cohorts of women[6]. After excluding cases of early GDM, an additional 8.1% of pregnant women were diagnosed at 24–28 weeks or later. This finding aligns with the weighted pooled prevalences reported in previous systematic reviews, accounted for 7.6% (95% [confidence interval] CI: 6.1%–9.4%) in Iran[4], 11.0% (95% CI 8.0%–13.0%) in Nigeria[13] and 10.9% (95% CI: 10.0% to 11.8%) across 24 European countries[1]. This is despite variations in screening methods and diagnostic criteria. A study in Northern Thailand, using universal screening and the Carpenter and Coustan criteria with a two-step approach to diagnose GDM which was the same as in our study, found GDM at 24 weeks of gestation in 9.3% without screening at early pregnancy[14]. Our study found a higher prevalence of late-onset GDM than reported in the other two studies conducted in a hospital in Bangkok with the same screening methods[15,16]. A systematic review involving 45 studies containing 91,260 women reported sensitivities of ≥81% and specificities of ≥73% for the two-step approach to diagnose GDM at 24 to 28 weeks' gestation using the Carpenter and Coustan criteria. One- versus two step screening was not associated with improved health outcomes[17]. Likewise, the reports from a systematic review for GDM in pregnant Asian women ranged from 1.2% to 49.5%, which is related to the differences in diagnostic criteria, sample size, and population source[18].

The mean age of women with GDM was slightly higher than that of women without GDM, which aligns with the findings of a systematic review on GDM in the Middle East and North Africa, wherein GDM was more commonly diagnosed in pregnant women aged 30 years or older[5]. In addition, women with previous history of GDM had a higher likelihood of developing GDM compared to those without such history. This finding is supported by a systematic review in Ethiopia[2] and another systematic review for future T2DM studies in South Asia and Southeast Asia[19]. The GDM women were more likely to be older, have a higher pre-pregnancy BMI, and higher HbA1c values[20]. We found no significance of blood pressure, physical activity, and total food intake calories between GDM and non-GDM women in multivariable regression. However, this was different from the findings of a systematic review in Ethiopia, which reported that the odds of developing GDM were increased in pregnant women with a BMI greater than or equal to 25 kg/m$^2$ and low physical activity[2]. HbA1c in non-pregnant healthy women was higher than in pregnant women without GDM, with an average of 4.8% and 5.0% at 28-36 weeks during the gestational age of 15-24 weeks[21].

There was no consensus on the best cut-off HbA1c for diagnosing GDM. In our study, we found levels of >5.3% were the best cut-off values. A previous systematic review showed that a cut-off HbA1c of 5.2% had a pooled sensitivity of 86% and specificity of 32%, with positive and negative likelihood ratios of 1.28 and 0.43, respectively[22]. A recent evidence report and systematic review for the US Preventive Services Task Force highlighted that using an HbA1c threshold between 4.5% and 5.0% at or beyond 24 weeks of gestation achieved a sensitivity exceeding 90%, and it was associated with treatment and improved outcomes[23]. A previous study assessing pregnancy outcomes with an HbA1c threshold of 5.5% reported a significantly reduced risk of neonatal hypoglycemia in cases where baseline HbA1c ranged from 5.0% to 5.5%[24]. Follow-up levels of HbA1c in healthy pregnant women were 4.7±1.24% in the first trimester, 4.5±1.28% in the second trimester, and 4.8±1.35% in the third trimester[25].

Our study highlights the prediction of GDM women by a subscapular fat thickness >18.8 mm, a 1-hour plasma glucose after 50g GCT >165 mg/dL, and a HbA1c >5.3%. This had a similar discrimination performance to the findings of a previous study using HbA1c of 5.7%-6.4%[12]. A meta-analysis on factors associated with GDM suggested risk factors that included: maternal age ≥25 years, primigravida, history of GDM, pre-pregnancy overweight and/or obesity, stillbirth, macrosomia, preterm delivery, and smoking prior to prgnancy[26]. HbA1c in women with prior GDM in all BMI groups was higher than in those with no prior GDM, indicating metabolic deterioration in prior GDM[27]. We found significantly higher subscapular thickness and sum of skinfold thickness in GDM women than in non-GDM women; however, there was no difference in BMI or body composition. A cross-sectional study demonstrated that visceral adipose tissue measuring 4 cm or more and/or subcutaneous fat thickness of at least 2 cm serves as a strong predictor of elevated C-reactive protein and HbA1c levels, and key inflammatory markers in pregnant women[28].

No significantly different maternal and neonatal outcomes measured in this study were found between women with GDM and non-GDM, except that the mean fetal weight of women with GDM was significantly greater than in women without GDM. A prior study in Japan found that a pregestational BMI of 25 or higher and excessive gestational weight gain in mothers with GDM were significantly linked to increased infant birth weight relative to gestational age[29]. Another study in Thailand suggested that pre-pregnancy BMI was one of the parameters to predict adverse pregnancy outcomes[30]; however, the outcomes measured were different from our study. A systematic review showed high heterogeneity of body circumferences, visceral fat, and subcutaneous fat thickness in association with the prediction of GDM, which suggests a need for further research in order to explore adiposity measures rather than BMI in predicting the risk of adverse pregnancy outcomes[31].

This prospective study enrolled pregnant women from the first trimester; early GDM women were excluded

to ensure the absence of undiagnosed DM. Simple and feasible first-trimester indicators for predicting GDM at 24–28 weeks of gestation, even in resource-limited settings, were identified. However, there were some limitations in this study. First, at 24–28 weeks, few women underwent the 100g OGTT directly without first taking the 50g GCT, as clinicians deemed them high risk. This may have affected diagnostic performance due to the use of a one-step rather than a two-step approach. Second, there was variation in the timing of serum collection for HbA1c testing: either one hour after the 50g GCT or during fasting before the 100g OGTT if the 50g GCT was not performed. However, this variation was unlikely to have had any significant impact, as fasting and fed states do not affect HbA1c levels. Third, following the diagnosis of GDM, pregnant women were managed by endocrinologists for blood sugar control; accordingly, treatment and subsequent blood sugar monitoring data were not included in this study. Finally, the cut-off values of each factor in this study may be suitable for Thai women in Southern Thailand, but not widely generalizable.

## Conclusion

Approximately 1 in 10 pregnant women were diagnosed with GDM in the first trimester, with a slightly higher proportion in the second-to-third trimester. Prior history of HDP or GDM, subscapular fat thickness, 1-hour plasma glucose after 50g GCT, and HbA1c levels at the first trimester can be used for predicting GDM, and applied for close monitoring of women not diagnosed with GDM during early pregnancy. The cut-off values of each factor should be further studied in different populations. Furthermore, the effects of early prediction and counselling for proper management should be evaluated in future studies.

### Author contributions

T.L. developed the research proposal, formulated the concept of the study, data collection, data analysis, wrote and edited the manuscript. W.S. and K.J. contributed to the concept of the study, data collection, and reviewed the manuscript. M.S. contributed to the concept of the study, plan of data collection, and reviewed the manuscript. P.R. contributed to the concept of the study, data collection, and reviewed the manuscript. All authors have approved the final version of the manuscript.

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## Conflict of interest

All authors declare no conflict of interest.

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