Original Article

JHSMR Journal of Health Science and Medical Research

External Validation of the PeRSonal Gestational Diabetes Model for Predicting Adverse Pregnancy Outcomes in Women with Gestational Diabetes: A Retrospective Cohort Study in a Tertiary Hospital in Thailand

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Received 8 July 2024 ● Revised 21 July 2024 ● Accepted 6 August 2024 ● Published online 6 November 2024

Abstract:

Objective: This study aimed to validate the PeRSonal Gestational Diabetes (GDM) model with two-step glucose tolerance diagnostic criteria.

Material and Methods: A retrospective cohort study was conducted on participants having delivered with GDM diagnosis in a tertiary hospital; from October 1, 2020, until September 30, 2022. The main outcome was a composite of maternal and perinatal adverse pregnancy complications. Model validation evaluated the predictors and calculated risk by using a two-step glucose tolerance test in the PeRSonal model formula. Model performance was analyzed for discrimination, calibration, and overall performance.

Results: This study analyzed 685 from the initial 764 participants with GDM, with 218 (31.8%) developing adverse pregnancy outcomes. The most frequent adverse outcomes were hypertensive disorders in pregnancy 132 (19.3%) and neonatal hypoglycemia 91 (13.3%). This validation achieved an area under the curve (AUC) of 0.70 (95% confidence interval (CI) 0.65 to 0.74), calibration-in-the-large of 0.17, a calibration slope of 1.34, and a Brier score of 0.20, respectively. The cut-off clinical risk probability of 27.5% can predict adverse outcomes with a sensitivity of 67.3%, specificity of 63.8%, a positive predictive value (PPV) of 46.7%, and a negative predictive value (NPV) of 80.5%.

Conclusion: The PeRSonal model maintains its predictive effectiveness in two-step glucose tolerance diagnostic criteria.

Keywords: adverse pregnancy outcome, gestational diabetes, prediction model

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J Health Sci Med Res
doi: 10.31584/jhsmr.20241111
www.jhsmr.org

Introduction

Gestational diabetes (GDM) is a widespread, global health issue encountered during pregnancy. In Southeast Asia, the prevalence is notably higher at 20.8%, impacting nearly one in five pregnant women[1]. These escalating global rates can be linked to the growing instances of obesity and diabetes that are influenced by factors; such as genetics, lifestyles, environments, and diagnostic standards[2-4]. The diversity in risk among affected women due to hyperglycemia varies widely among pregnant individuals, resulting in a spectrum of effects on both short-term and long-term maternal and child health[4-10].

GDM diagnosis involves a one-step 75-g oral glucose challenge test (OGTT), following the International Association of Diabetes and Pregnancy Study Groups (IADPSG) criteria, or a two-step method (50-g screening, then 100-g OGTT for positives by Carpenter-Coustan)[4]. Previous research has found that a two-step approach, with a 100-g OGTT, has comparable accuracy to the standard 75-g OGTT[11]. However, challenges still persist in accuracy, early diagnosis and the implementation of effective preventive management strategies tailored to specific risk groups that mitigate complications and enhance the efficiency of healthcare systems[9,12]. Currently, researchers are dedicated to developing a predictive model for diagnosis by integrating clinical risk characteristics and laboratory findings; such as glycated hemoglobin (HbA1c) levels as well as many other novel tests[13-18]. Nonetheless, limited applicability and practical costs hinder widespread adoption in low-resource settings where expensive technology is impractical. A cost-effective predictive model designed for predicting adverse outcomes, like the PeRSonal model, utilizing routine antenatal data and a 75-g OGTT test; as shown in Supplementary Table 1, serves as a viable alternative for accurate validation and care. Despite its potential, challenges remain in validating and applying it across diverse healthcare setups with varying GDM criteria[19].

Hence, this study aimed to validate the PeRSonal GDM model by using diagnostic criteria of 100-g OGTT for predicting adverse pregnancy outcomes in GDM in a tertiary hospital.

Material and Methods

Study design

A retrospective cohort study.

Study participants

Pregnant women eligible for participation had electronic medical records containing a GDM diagnosis and were delivered between October 1, 2020, and September 30, 2022, at our hospital, which is a hospital located in southern Thailand. Excluded participants consisted of: (1) pre-existing diabetes, (2) HIV infection, (3) a history of cancer, or (4) incomplete, essential datasets. Those with GDM risk factors underwent a 50-g glucose challenge test (GCT) during their initial visit or between 24-28 weeks of gestation, if one or more of the following conditions were present: age over 25 years, obesity, a family history of type 2 diabetes, a previous history of GDM or bad obstetric outcome, impaired glucose metabolism, or glucosuria. A positive screening result (exceeding 140 mg/dL or 7.8 mmol/L) led to confirmation with a 100-g OGTT. Diagnosis required at least two values surpassing specific cutoffs: 95, 180, 155, and 140 mg/dL (5.3, 10.0, 8.6, and 7.8 mmol/L); based on Carpenter and Coustan criteria[4].

Sample size calculation

Collins et al. recommend 100-200 events per 10 variables for external validation of a prognostic model[20]. The PeRSonal model, consisting of 12 variables in Table S1, necessitated 120-240 events. From a 25% incidence rate of pregnancy complications in our hospital records in 2022, data from 480-960 pregnant women with GDM were required to meet the necessary event count. This sample

size ensured an event per variable (EPV) ratio surpassing the commonly recommended threshold.

Maternal characteristics and laboratory biomarkers

Maternal characteristics; including age, ethnicity, pre-pregnancy body mass index (BMI), weight gain during pregnancy, gestational age at GDM diagnosis, nulliparity, and obstetric risk factors (family history of diabetes, previous GDM, history of pre-eclampsia, history of macrosomia, history of shoulder dystocia, blood sugar level from a 100-g OGTT, and insulin treatment), were collected to assess pregnancy adverse outcomes. Management of individuals with GDM involves self-blood glucose monitoring, diet control, lifestyle modification, and if necessary, insulin treatment at the endocrinologist's discretion. Regular antenatal scans were conducted after 28-30 weeks gestation for fetal growth assessment at 2-3 week' intervals, and induction of labor was scheduled after completing 38-39 weeks' gestation, if no other indication for delivery existed. Outcomes of interest included: hypertensive disorders in pregnancy (new onset of blood pressure ≥140/90 mm Hg taken 6 hours apart after 20 gestational weeks; with or without proteinuria ≥300 mg/24 hours), macrosomia (birth weight above the 90th percentile for gestational age), shoulder dystocia, neonatal hypoglycemia (blood glucose <40 mg/dL using heel stick within 2 hours of birth requiring intravenous therapy), and any birth injuries or fetal deaths during pregnancy.

Statistical analysis

All analyses were performed using R version 4.3.1 software (2023-06-16).

Categorical data were analyzed using descriptive statistics and presented as frequencies and percentages. Continuous quantitative data were analyzed using descriptive statistics, with a focus on measures of central tendency (mean), measures of dispersion (standard deviation) for normally distributed data, and median and interquartile range for non-normally distributed data. Discriminative performance was assessed using AUROC, with a 95% confidence interval (CI), and depicted with an ROC curve showing overall sensitivity and specificity. Calibration was evaluated through calibration in the large and calibration slopes using a calibration plot. The overall performance was assessed using the Brier score.

All analyses were conducted using imputed complete cases. A p-value<0.05 was considered statistically significant. Model validation involved assessing predictors and calculating risk using the PeRSonal model formula; as outlined in Supplementary Table 2.

Results

The validation dataset initially included 764 pregnant women diagnosed with gestational diabetes. After excluding 79 incomplete essential datasets and specific cases, a total of 685 GDM datasets were retained for the final analysis; as depicted in the dataset flow chart in Figure 1.

Table 1 presents the baseline characteristics of 685 pregnant women based on adverse outcomes of GDM. Among those with GDM, individuals experiencing adverse events were older (34 vs. 32, p-value=0.028), had a higher BMI (28.4 vs. 25.2, p-value<0.001), and had a higher rate of history for pre-eclampsia (3.2% vs. 0.2%, p-value=0.002). They were diagnosed with GDM at an earlier gestational age (24 vs. 26 weeks, p-value<0.001) and had higher glucose levels during fasting (96 vs. 90, p-value<0.001), at 1 hour (198 vs. 195, p-value=0.003), and at 2 hours (180 vs. 173, p-value<0.001), respectively.

There was no significant difference in adverse event outcomes based on the use of insulin. The composite adverse pregnancy outcome was 31.8% (218 out of 685), with some pregnancies experiencing multiple complications; as illustrated in Figure 2. The most prevalent adverse

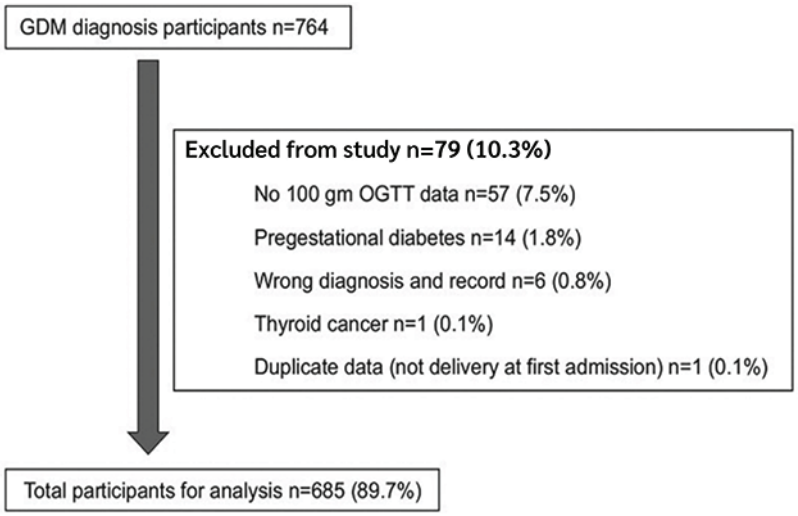
outcome was hypertensive disorders in pregnancy (19.3%, 132 out of 685), followed by neonatal hypoglycemia (13.3%, 91 out of 685), and preterm labor (11.4%, 78 out of 685), respectively. The model validation achieved an AUC of 0.70 (95% CI 0.65 to 0.74), a Brier score of 0.20, a Calibration-in-the-large of 0.17, and a calibration slope of 1.34; as depicted in Table 2, Figure 3 and Figure 4, respectively. A clinical probability cut-off of 27.5% can predict adverse outcomes, with a sensitivity of 67.3%, specificity of 63.8%, PPV of 46.7%, and NPV of 80.5%.

Table 1 Characteristics of validation cohorts; based on adverse outcome

Characteristics	All (n=685)	No adverse outcome n=467 (68.2%)	Adverse outcome 218 (31.8%)	p-value
Social/demographic factors, n (%)				
Maternal age, years	33 (29, 37)	32 (28, 36)	34 (29, 37)	0.028
Number of fetuses				0.340
Singleton	674 (98.4)	461 (98.7)	213 (97.7)	
Twins	11 (1.6)	6 (1.3)	5 (2.3)	
Ethnicity, n (%)				0.218
Thai	616 (89.9)	416 (89.1)	200 (91.7)	
Burmese	60 (8.8)	46 (9.9)	14 (6.4)	
Cambodian	1 (0.1)	1 (0.2)	0 (0.0)	
Loa	7 (1.0)	4 (0.9)	3 (1.4)	
Other	1 (0.1)	0 (0.0)	1 (0.5)	
Obstetric and family history, n (%)				
Nullipara	137 (20.0)	93 (19.9)	44 (20.2)	0.935
Gravida median (IQR)	2 (2, 3)	2 (2,3)	2.5 (2, 3.8)	0.490
Prior GDM	22 (3.2)	13 (2.8)	9 (4.1)	0.352
Prior large for gestational birth	35 (5.1)	21 (4.5)	14 (6.4	0.286
Prior pre-eclampsia	8 (1.2)	1 (0.2)	7 (3.2)	0.002
Prior shoulder dystocia	4 (0.6)	2 (0.4)	2 (0.9)	0.596
Family history of diabetes	258 (37.7)	172 (36.8)	86 (39.4)	0.510
Physical characteristics, mean S.D.				
Pre-pregnancy body mass index, kg/m^2	25.9 (22.7, 30.1)	25.2 (22.3, 28.7)	28.4 (24.4, 32)	<0.001
Gestational weight gain to GDM diagnosis, kg	0.2 (0.1, 0.3)	0.2 (0.1, 0.3)	0.2 (0.1, 0.3)	0.286
Disease characteristics median (IQR)				
Gestational age at GDM diagnosis, weeks	25 (17, 29)	26 (17.5, 29)	24 (15, 28)	<0.001
Fasting glucose from diagnostic OGTT, mg/dL	91 (84, 100)	90 (82, 98)	96 (87, 103)	<0.001
1-hour glucose from diagnostic OGTT, mg/dL	196 (183, 213)	195 (182, 210)	198 (185, 219)	0.003
2-hour glucose from diagnostic OGTT, mg/dL	175 (162, 193)	173 (161, 190)	180 (165, 202)	<0.001
3-hour glucose from diagnostic OGTT, mg/dL	144 (123.5, 160)	144 (124, 158)	143 (121, 162)	0.963
Insulin therapy (%)	243 (35.5)	160 (34.3)	83 (38.1)	0.331

Values are presented as median IQR (interquartile range) or number (%)

GDM=gestational diabetes mellitus, BMI=body mass index, OGTT=oral glucose tolerance test, S.D.=standard deviation, mg/dL=milligrams per deciliter, kg=kilogram, kg/(m)^2=kilogram per square metre



GDM=gestational diabetes mellitus, OGTT=oral glucose tolerance test

Figure 1 Dataset flow chart

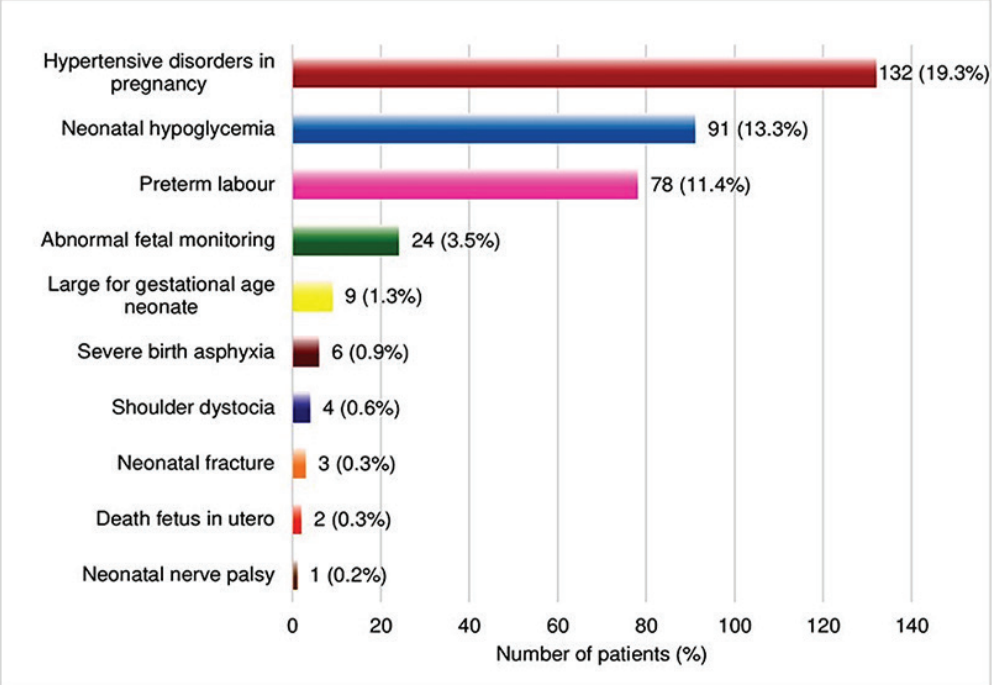


Figure 2 Adverse pregnancy outcomes of GDM

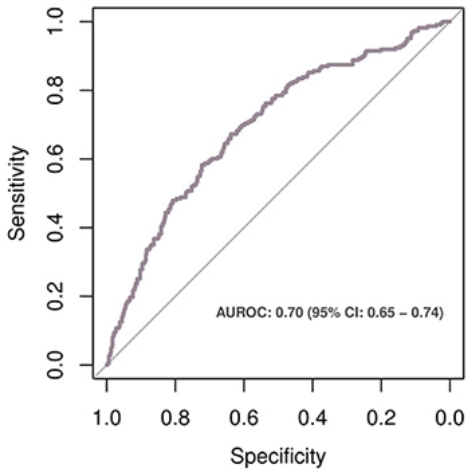


Figure 3 ROC curve depicting discriminative performance, with AUROC and 95% confidence interval

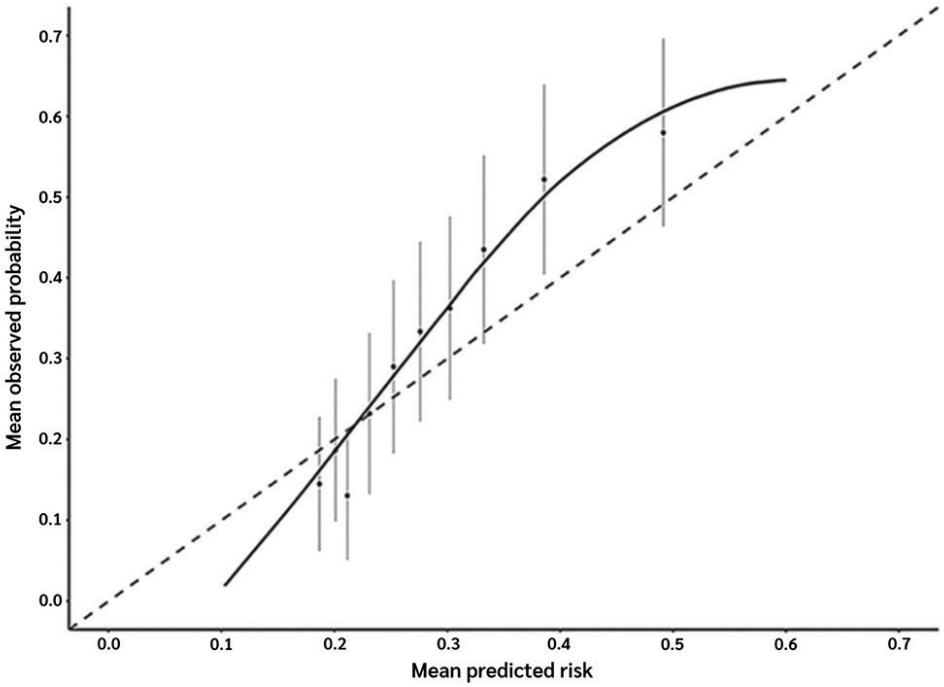


Figure 4 The calibration plot demonstrates the consistency between the predicted values and the real outcomes of validation

Table 2 The performance of the validation model in comparison to the PeRSonal GDM model

Performance measures (95% CI)	Development cohort (n=1747)	Validation cohort (n=955)	External validation cohort (n=685)
C-statistic	0.68 (0.65, 0.71)	0.68 (0.64, 0.72)	0.70 (0.65, 0.74)
Calibration slope	1.16 (0.96, 1.35)	0.99 (0.75, 1.23)	1.34
Calibration-in-the-large	0.01 (-0.10, 0.12)	-0.05 (-0.20, 0.11)	0.17
Brier score	-	-	0.20

CI=confidence interval, GDM=gestational diabetes mellitus

Discussion

Our external validation of the PeRSonal GDM model, incorporating routine characteristic data with two-step glucose tolerance diagnostic criteria, demonstrated good predictive performance, with an AUC of 0.70 (95% CI 0.65 to 0.74); comparable to the PeRSonal model's AUC of 0.68 (95% CI 0.65 to 0.71). The overall performance, as indicated by a Brier score of 0.20, a Calibration-in-the-large of 0.17 and a calibration slope of 1.34, suggests potential underestimation when compared to the PeRSonal model, which has a slope of 1.16 (95% CI 0.96 to 1.35). Additionally, considering the PeRSonal model's utility across a range of predicted probability thresholds (0.15 to 0.85), these findings support the principle of validating existing models rather than developing new ones[19].

In this study, approximately one-third (31.8%, 218/685) of women with gestational diabetes experienced adverse pregnancy outcomes, with some facing multiple complications; this was slightly higher than the PeRSonal model. The most prevalent outcomes included: hypertensive disorders in pregnancy (19.3%, 132/685), followed by neonatal hypoglycemia (13.3%, 91/685), and preterm labor (11.4%, 78/685), respectively. This study revealed that 41% of preterm neonates (32/78) were born prematurely due to treatment-related complications arising from hypertensive disorders in pregnancy. In contrast to the PeRSonal model, the most common adverse outcome was neonatal hypoglycemia (11.6%, 203/1,747), followed by LGA baby (10.6%, 186/1,747), and hypertensive disorders in pregnancy (7.4%, 130/1,747). The rate of LGA baby, neonatal injury, or perinatal death was 1.3% or less in this study, which is lower than the PeRSonal model.

The significant predictors identified included maternal age, a history of preeclampsia, BMI, gestational age at the first diagnosis and abnormal values of OGTT, aligning with the factors emphasized in the PeRSonal model. This alignment is explained by the metabolic burden on women, which accompanies weight gain and glucose intolerance resulting from insulin resistance during pregnancy[5]. A study by Kim et al.[21] demonstrated similar trends, showing that factors associated with adverse outcomes over a 10-year period (2006 to 2015) in a single tertiary center were linked to older maternal age (34 vs. 33, p-value<0.001) and increased pre-pregnancy BMI (23.4 kg/m^2 vs. 21.8 kg/m^2, p-value=0.001).

A recent study by Tenenbaum-Gavish et al.[22] suggests an efficient prediction of GDM development as early as the first trimester. The combination of high BMI, insulin, sCD163, and TNFα yielded an AUC of 0.95, with a detection rate of 89.0% at a 10.0% false positive rate (FPR). Other, more recent predictive models that incorporate factors such as HbA1C, PAPP-A, free β-hCG, glucose, triglycerides, leptin, and lipocalin-2, have shown promise in identifying high-risk women in the first or early second

trimester[13–18]. Various risk prediction models have been developed globally; such as those in China and Thailand[13,17], that incorporate factors like triglycerides and the American College of Obstetricians and Gynecologists risk factors. For instance, the GDM risk score in China, developed from 1,640 participants, integrates several potential clinical features with routine biochemical measures of GDM; including predictors collected at the first antenatal care visit for early prediction of GDM. This model utilizes fasting blood glucose (FBG) and triglyceride values during 14–20 gestational weeks. The total, final risk score yielded an AUC of 0.886 (95% CI= 0.856–0.916)[13]. However, these studies and models have frequently been utilized to predict the diagnosis of GDM rather than adverse outcomes, and their applicability in general practice is limited due to their high cost and lack of affordability. In the integrated model study of Thailand, significant predictors included a history of GDM (adjusted odds ratio [aOR], 5.15; 95% CI, 1.82–14.63; p-value =0.004), HbA1c threshold ≥5.3% (aOR, 2.61; 95% CI, 1.44–4.74; p-value=0.002), and a family history of dyslipidemia (aOR, 2.68; 95% CI, 1.37–5.21; p-value=0.005). The integrated nomogram model demonstrated that a history of GDM had a substantial impact on the risk of early GDM, with discrimination and mean absolute error values of 0.76 and 0.009, respectively[17]. The lack of a definitive cutoff threshold as well as the unreliability of HbA1C for early screening of GDM or preexisting diabetes presents significant challenges. However, HbA1C levels exceeding 5.9% (39.0 mmol/mol) may suggest an elevated risk of adverse outcomes; including a higher likelihood of developing GDM at a later stage[15]. Despite these good model performances, their investigations often extend beyond routine antenatal care within our hospitals.

Adopting a one-step strategy, post-2010 is expected to significantly increase GDM incidence (from 5.0-6.0% to 15.0-20.0%) due to a single abnormal value, rather than two in the two-step approach[4,5]. This rise leads to more treatments and interventions with no significant difference in pregnancy and perinatal outcomes[4,5]. This highlights the necessity of implementing the 100 g OGTT, and aligning screening timing between 24-28 weeks in our hospital, as it helps mitigate significant impacts on costs and medical infrastructure. This study found no significant adverse event differences with the use of insulin in the second trimester of pregnancy however, it also highlights a challenge in reliably identifying women at risk of gestational diabetes earlier in pregnancy, wherein early intervention could be beneficial[4,5,12,16].

This study proposes developing an affordable clinical probability for community hospital guidelines, utilizing an electronic PeRSonal GDM risk calculator (available at https://www.personalgdm.com/outcomes)[19]. As we consider the Youden method, which weights the false negative over the false positive group at 2.5 for a risk-stratified approach, the clinical probability cut-off of 27.5% can predict adverse outcomes, with a sensitivity of 67.3%, specificity of 63.8%, PPV of 46.7%, and NPV of 80.5%. Having a probability of 27.5%, the model correctly identifies 67.3% of patients with adverse outcomes. Additionally, it is moderately successful in excluding 63.8% that do not experience adverse outcomes. We acknowledge relatively lower reliability in predicting positives at 46.7%; however, found it to be more reliable in predicting non-adverse outcomes, with an 80.5% accurate chance. Given the diminished positive predictive value, our preference is to reassess additional GDM patients within the PPV group for safety, and move them back to the community hospital along the antenatal pathway with increased confidence, rather than keeping them at a community hospital until they experience an adverse event; as outlined in Table 3 and 4. This study effectively applies statistical methods to filter risks using unique laboratory values, distinct from those of other systems. Furthermore, it affirms the efficacy of the PeRSonal predictive model and its appropriateness for crafting a personalized GDM care

model by assessing the risk of adverse outcomes through a clinical risk probability. This approach enhances the health service system in developing countries by eliminating the need for additional complex tests, thereby, streamlining processes and maintaining efficiency.

Strengths

Initially, the study benefited from the external validation of a disparate population, with a sizable sample size of 18 EPV, enhancing the reliability of its findings. Secondly, routine maternal characteristics and OGTT values were used in different GDM diagnostic criteria from a personalized model to calculate risk. This demonstrated good predictive performance and generalizability for clinical utility in a low-resource setting. Finally, our outcome predicts a composite of adverse events rather than a single outcome, quantifying multiple risks in addition to being more translatable into clinical practice.

Table 3 Recommendation according to risk-stratified probability of an adverse pregnancy outcome

Risk group	Management
Low risk (probability <27)	Follow routine antenatal pathway. Implement diet lifestyle modification. Engage in self-monitoring blood glucose level. Regular monitor blood pressure. Assess the risk of preeclampsia and start low-dose aspirin (between 12-28 weeks) for individuals with moderate to high risk. Arrange a transfer if signs or symptoms of preeclampsia appear.
High risk (probability ≥27)	Arrange prompt transfer for specialized evaluation by maternal-fetal medicine specialists and endocrinologists.

The specific score threshold (represented by X) for categorizing low and high risk should be determined based on established medical guidelines and individual patient assessments.

Table 4 Clinical utility of using the external validation model compared to managing all women with gestational diabetes mellitus, as if they will have an adverse pregnancy outcome over the range of threshold probabilities.

Weight, false negative/ false positive	Threshold (%)	Sensitivity (%)	Specificity (%)	ppv (%)	npv (%)
1.0	36.7	33.6	88.4	57.7	73.9
1.5	32.3	48.0	80.8	54.0	76.7
2.0	29.8	58.3	72.3	49.8	78.6
2.5	27.5	67.3	63.8	46.7	80.5
3.0	23.6	81.6	47.1	42.1	84.5
3.5	23.5	82.1	46.5	42.0	84.6
4.0	22.8	85.2	41.2	40.6	85.5

Weight, false positive/false negative, Threshold probability (%), Net reduction in women unnecessarily managed (%)
ppv=positive predictive value, npv=negative predictive value

Limitations

As a referral and tertiary hospital, delayed initiation of antenatal care led to deferred investigations and hindered early diagnosis and treatment. This contributed to a higher incidence of adverse outcomes compared to those that began care earlier, impacting our statistics and underestimating the calibration slope of 1.34, emphasizing reliance on retrospective data over predictive measures. Future research should collect and evaluate real-world data, based on the original risk scores from the PeRSonal calculator and develop an application that calibrates weight scores to accurately reflect the risk profiles of populations in developing countries. Additionally, as this study was conducted at a single center, we suggest conducting extensive multicenter prospective studies involving a large population to further validate and develop the model.

Conclusion

This external validation study confirms that the PeRSonal model effectively predicts adverse outcomes, making it suitable for personalized care. In assessing the model, net benefit weighed its pros and cons in clinical decision support. Our external validation of the PeRSonal GDM model excels in identifying high-risk women using routine antenatal data at 24-28 weeks, potentially reducing stress, costs and healthcare burden.

Ethics approval and consent to participate

This study was approved by the Research Ethics Committee at Hat Yai Hospital (Protocol Number HYH EC 012-66-01), and waived informed consent as the study population was a retrospective cohort.

Authors' contribution

Conceptualization, design, planning, conduct, supervision: SS, SwS. Acquisition and curation of data, Formal analysis, Writing – original draft, administrative technical or material support, Writing – review & editing: SS, SwS, KK. Final manuscript approving: all authors had full access to the data in the study and accept responsibility for the decision to submit for publication.

Availability of data and materials

All data generated and analyzed during this study are available upon request, and included in this published article. Data sharing is dependent upon permission from the health service and ethics approval.

Acknowledgement

The authors would like to express their sincere appreciation to Professor Helena Teede of the Diabetes and Endocrine Unit at Monash University, for her generous permission and willingness to share her invaluable insight in conducting the external validation study for this research. The authors thank Professor Tippawan Liabsuetrakul and Professor Chitkasaem Suwanrath for their essential comments.

Conflict of interest

No potential conflicts of interest are reported.

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Supplementary Table 1 Final PeRSonal model after LASSO selection with selected predictors, coefficients with bootstrap; 95% confidence intervals and odds ratios[19]

Predictors in the model	Coefficient	Bootstrap 95% CI	Odds ratio	95% CI
Maternal age	0.01	(0.00, 0.04)	1.01	(1.00, 1.04)
Pre-pregnancy BMI	0.04	(0.02, 0.06)	1.04	(1.02, 1.06)
Fasting glucose OGTT	0.32	(0.17, 0.50)	1.38	(1.19, 1.65)
1-hour glucose OGTT	0.06	(0.00, 0.13)	1.06	(1.00, 1.14)
Gestation at GDM diagnosis	−0.02	(−0.05, −0.00)	0.98	(0.95, 1.00)
Southern and Central Asian	−0.65	(−1.01, −0.39)	0.52	(0.36, 0.68)
East Asian	−0.14	(−0.64, 0.08)	0.87	(0.53,1.08)
Nulliparity	0.17	(0.00, 0.47)	1.18	(1.00, 1.60)
Previous LGA baby	0.53	(0.00, 1.26)	1.70	(1.00,3.53)
Previous pre-eclampsia	0.93	(0.41, 1.50)	2.53	(1.51, 4.48)
Gestational weight gain to GDM diagnosis per week	0.54	(0.02, 1.36)	1.71	(1.02, 3.90)
Family history of diabetes	−0.07	(−0.437, 0.00)	0.94	(0.65, 1.00)
Intercept	−4.11	(−5.53, −2.87)	0.02	(0.00, 0.06)

LASSO=Least Absolute Shrinkage and Selection Operator, CI=confidence interval, BMI=body mass index, OGTT=oral glucose tolerance test, LGA=large-for-gestational age, GDM=gestational diabetes mellitus

Supplementary Table 2 Full prediction model to allow predictions for individuals[19]

percent risk=exp() ⁄ (1+exp()) * 100
where Y=−4.11+(0.04 * pre-pregnancy body mass index in kg⁄m^2)+(0.01 * maternal age in years)+(0.32 * oral glucose tolerance test, fasting glucose in mmol⁄L†)+(0.05* oral glucose tolerance test, 1-hour glucose mmol⁄L†)−(0.02 * Gestational age at GDM diagnosis in weeks completed)−(0.65 * South or Central Asian)−(0.14 * East Asian)+(0.17 * Nulliparous)+(0.53 * Past history of delivery of a large-for-gestational-age baby)+(0.93 * Past history of pre-eclampsia)+(0.53 * Gestational weight gain to GDM diagnosis per week in kilograms)−(0.07 * Family history of diabetes)

The equation of the PeRSonal GDM prediction model for risk of adverse pregnancy outcomes in women with GDM from a logistic regression model was as follows:
percent risk ¼ exp_YÞ=_1 þ expðYÞ 100 where Y=4.11+(0.04 * pre-pregnancy body mass index in kg⁄m^2)+(0.01 * maternal age in years)+(0.32 * oral glucose tolerance test, fasting glucose in mmol⁄ Ly)+(0.05* oral glucose tolerance test, 1-hour glucose mmol⁄Ly)−(0.02 * Gestational age at GDM diagnosis in weeks completed)−(0.65 * South or Central Asian)−(0.14 * East Asian)+(0.17 * Nulliparous)+(0.53 * Past history of delivery of a large-for-gestational-age baby)+(0.93 * Past history of pre-eclampsia)+(0.53 * Gestational weight gain to GDM diagnosis per week in kilograms)−(0.07 * Family history of diabetes).
All variables are coded as binary (1 when present and 0 when absent); except for body mass index, maternal age, oral glucose tolerance test glucose levels and gestational age at GDM diagnosis these being continuous. y to convert glucose from conventional (mg⁄dL) to SI units (mmol⁄L), multiple by 0.06.