ORIGINAL ARTICLE

Prevalence of Postpartum-abnormal Glucose Tolerance (P-AGT) and its Associated Factors among Women with Gestational *Diabetes mellitus* (GDM) in Klang, Selangor

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ABSTRACT

Introduction: Women with gestational *diabetes mellitus* (GDM) have a sevenfold risk of developing diabetes. The study aimed to determine the prevalence of postpartum-abnormal glucose tolerance (P-AGT), the level of knowledge on GDM and its associated factors for P-AGT among postpartum women with GDM attending public health clinics in Klang. **Materials and methods:** This cross-sectional study used convenience sampling and was conducted among GDM women attending the oral glucose tolerance test (OGTT) at six to 12 weeks postpartum. Sociodemographic factors, clinical characteristics, knowledge about GDM (using a validated questionnaire, GDMKQ) and postpartum OGTT results were collected. **Results:** A total of 439 participants, with the majority aged < 35-year-old (71.8%), Malay ethnicity (82.7%), and demonstrated adequate knowledge of GDM (92.9%) with mean GDMKQ score of 12.21 ± 2.22 over 15. P-AGT prevalence was 28.9% (95% CI:24.7, 33.4). Multiple logistic regression showed having a first-degree family history of diabetes carried 1.5 higher odds of developing P-AGT [aOR:1.55,95%CI:1.01,2.39;(p = 0.047)], gestational age at GDM diagnosis <24 weeks had 1.8 higher odds of developing P-AGT [aOR:1.85,95%CI:1.17,2.92;(p=0.009)] and women with 2HPP level of ≥7.8mmol/L upon GDM diagnosis had a threefold higher risk of developing P-AGT [aOR:2.95,95%CI:1.74,5.01;(p<0.001)]. **Conclusion:** This study revealed a doubled prevalence of P-AGT compared to previous local studies. Targeted monitoring and management strategies are crucial, especially for women diagnosed with GDM before 24 weeks of gestation, those who had an abnormal 2HPP level upon GDM diagnosis and those with a first-degree family history of diabetes to prevent the occurrence of P-AGT.
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Keywords: Gestational, Glucose intolerance, *Diabetes mellitus*, Knowledge, Risk factors

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INTRODUCTION

The prevalence of diabetes is increasing both globally and in Malaysia. The International Diabetes Federation (IDF) Diabetes Atlas reported that in 2021, there were 536.6 million people with diabetes, and this number is expected to rise to 783.2 million by 2045 (1). A similar trend is seen in local settings where the Malaysian National Health and Morbidity Survey (NHMS) 2019 reported that the prevalence of overall raised blood glucose in Malaysia in 2019 was 18.3%, an increase compared to findings from 2011(11.2%) and 2015(13.4%) (2).

Family history of diabetes, obesity, raised waist circumference and physical inactivity are recognized predictors of diabetes in the general population (3). A remarkable predictor of diabetes in women is gestational *diabetes mellitus* (GDM). Women with a history of GDM are at a high risk of developing diabetes, at least seven times higher compared to women with normoglycemia throughout their pregnancy (4). Hence, they form a remarkable group for targeted prevention and intervention programs to impede the development of diabetes.

The American Diabetes Association (ADA) recommends screening women with GDM at four to 12 weeks postpartum using a 75-g oral glucose tolerance testing (OGTT) (5), while the Malaysian guideline recommends the OGTT to be done at six weeks postpartum (6). Based on the OGTT result, they will be grouped either into postpartum-normal glucose tolerance (P-NGT) after which they will be advised to undergo yearly OGTT screening (6); or postpartum-abnormal glucose

tolerance (P-AGT). P-AGT includes prediabetes [either isolated impaired fasting glucose (IFG), isolated impaired glucose tolerance (IGT), or combined IFG and IGT] and diabetes.

The reported prevalence of P-AGT varies from one study to another, both locally and internationally. Around the globe, the prevalence of P-AGT ranges from 15.5% to 36.6% in the early postpartum period (7-10) and up to 56% in women undergoing OGTT in later periods of around one year postpartum (8, 11). In Malaysia, the reported prevalence of P-AGT ranges from 12.1% to 15.3% when measured in the early postpartum period (12-14) and reaches as high as 61.7% when the OGTT was performed up to 15 years postpartum (15).

Identifying women at risk for P-AGT is essential because it allows for early initiation of more focused and targeted effective interventional strategies, such as providing healthy nutritional advice and promoting a healthy lifestyle by increasing physical activity and achieving weight reduction or maintenance for an ideal body weight. These measures will prevent or delay the progression from GDM to diabetes or other metabolic disorders in the immediate postpartum period and continue 6through several years later (16).

In an effort to achieve adequate control and prevent adverse outcomes of a disease, knowledge about the disease is vital (17). Knowledge is defined as "the capacity to acquire, retain, and use information, and is a mixture of comprehension, experience, discernment, and skill" (18).

Most studies assessing the level of knowledge on GDM were done among antenatal women, regardless of their GDM status. The prevalence of good knowledge of GDM in these studies ranges from 7.8% to 51.5% (19, 20). On the other hand, studies assessing the level of knowledge on GDM among women with GDM, either in the antenatal or postpartum period, are limited (17, 21).

Knowledge may be another potential modifiable risk factor that can be targeted in applying interventions to reduce the risk of developing of diabetes and its complications. Hussain et al. found a significant association between good knowledge of GDM and better antenatal glycemic control (17). However, whether good knowledge will reduce the risk of P-AGT is yet to be explored.

Various predictors for P-AGT in women with GDM have been identified, such as advanced maternal age (10, 22, 23), non-white or Asian ethnicity (9, 22, 23), pre-pregnancy body mass index (BMI) indicating overweight or obesity (8, 10, 24), history of previous GDM (9, 24), having family history of diabetes (23, 25), early gestational age upon GDM diagnosis (14, 23, 26), high fasting plasma glucose (FPG) level (9, 10, 23, 26), elevated 2-hour postprandial (2HPP) level (14, 23, 25) and increase HbA1C upon GDM diagnosis (9, 13, 14, 23, 27) as well as the use of pharmacological treatment for GDM (13, 16, 22, 23, 25, 26). However, studies on the predictors for P-AGT in the Malaysian population are scarce (14). Only one local study has looked at the predictors of P-AGT; however, the diagnostic criteria for identifying GDM used were not based on the updated Malaysia Clinical Practice Guideline (CPG) for Diabetes in Pregnancy, released in 2017. The cut-off value for FPG of ≥5.6 mmol/L was used in their study (14) instead of ≥5.1 mmol/L as recommended in the updated guideline (6). Thus, the different cut-off values may have an impact on the prevalence and predictors of P-AGT. This justifies the need for this study.

The aim of our study was to determine the prevalence of P-AGT, the level of knowledge on GDM and the associated factors for P-AGT among postpartum women with GDM attending health clinics in the Klang district in the early postpartum period.

MATERIALS AND METHODS

Study Design and Setting

A cross-sectional study was conducted between February 2022 and July 2022 in five public health clinics in Klang, Selangor, Malaysia. There were twelve public health clinics in the Klang district. The five clinics were selected because they provide mother and child health (MCH) services and have higher attendance of GDM mothers, allowing greater clinical implications of the study towards the population.

Study population and eligibility criteria

The study population was postpartum women with GDM during their recent pregnancy who attended the health clinic for OGTT screening. They were eligible for this study if they met the following inclusion criteria: 1) Malaysian, 2) 18 years old or older, 3) had a singleton pregnancy during recent pregnancy, 4) had GDM in recent pregnancy – based on antenatal OGTT when FPG ≥5.1 mmol/L, 2HPP ≥7.8 mmol/L or both, and 5) OGTT between six to 12 weeks of the postpartum period. For this study, only Malaysians with singleton pregnancies were chosen to maintain the homogeneity of the population studied and its clinical risk factors. The exclusion criteria were as follows: 1) existing diabetes prior to pregnancy, 2) currently pregnant, 3) on medications that influence glucose metabolism such as steroids, statin, beta-blockers or anti-psychotics, or 4) unable to read and write in English or Malay.

Study instrument

This study used the Gestational *Diabetes Mellitus* Knowledge Questionnaire (GDMKQ) by Hussain et al. (17) to assess the level of knowledge on GDM. The questionnaire was divided into five domains: basic

knowledge about GDM, risk factors, food and diet values, management, and complications or outcomes of GDM. Each domain consists of three questions. There are 15 questions in total, presented in a multiple-choice format, each with four options, including one option as 'I don't know' to avoid unnecessary guessing by the participants.

A score of 1 was given to every correct response and 0 to every wrong response including 'I don't know', with a possible minimum score of 0 and a maximum possible score of 15. The knowledge score for individuals was calculated and summed up to give the total knowledge score. A score <9 (<60%) indicated inadequate knowledge, while score ≥9 (≥60%) indicated adequate knowledge of GDM in the manner suggested by the developer (17).

This questionnaire is readily available in both English and Malay languages. It is a brief and simple questionnaire with good reliability ($\alpha = 0.77$), making it suitable for this cross-sectional study. Permission to use the questionnaire was obtained from its developer.

Another data collection sheet was used to gather information on the sociodemographic data, clinical characteristics and the results of the postpartum OGTT.

Sample size calculation

The sample size was calculated using the OpenEpi Version 3.01 for "Sample size for Proportion or Descriptive Study" from https://www.openepi.com/SampleSize/SSPropor.htm. based on the study objectives. The sample size calculations were calculated based on the prevalence of P-AGT and the proportion of adequate knowledge of GDM among women with GDM. The first calculation was based on a study by Fatin et al. which found that 12.3% had P-AGT (13). At the study power of 80% and the significant level of 0.05, the estimated sample size was 166. Another sample size was calculated based on a study by Hussain et al. which found the proportion with adequate knowledge of GDM among women with GDM was 56.6% (17). At the study power of 80% and the significant level of 0.05, the estimated sample size was 378.

The equation used in the calculation above is as per the equation down below:

Sample size, $n = [DEFF \times Np(1-p)] / [(d^2/Z^2_{1-\alpha/2} \times (N-1) + p(1-p)]$

n = sample size

DEFF = Design effect (for cluster service) = 1

N = population size (for finite population factor) = 1000000

p = hypothesized % frequency of outcome factor in the population = 0.566

$Z^2_{1-\alpha/2}$ = confidence interval = 1.96

d = desired precision = 5%

Taking the larger sample size, which was 378 and adding a non-respondent rate of around 20%, the estimated sample size for this study was 454.

Participant Recruitment, Sampling Method and Data Collection

Convenience sampling was used for this study due to its practicality and ease of access to participants, though it may limit the generalizability of the findings due to potential selection bias. Participant recruitment was done by either the researcher or a trained research assistant from each health clinic. Research assistants were trained in the study procedures before the study conduct to standardize the data collection.

Routine postpartum care in public health clinics for women with GDM includes routine postpartum OGTT screening. Appointments for this screening were scheduled. Participants were approached and screened for eligibility during their appointment according to the inclusion and exclusion criteria. Eligible participants were invited to join the study. The purpose of the study, their role in the study, and the risks and benefits of joining the study were explained to the participants by the researcher or trained research assistant. A hardcopy of the patient information sheet was handed to the participants. Participants were allowed sufficient time to consider their participation in the study.

Once the participant understood and consented, a questionnaire (GDMKQ) was distributed for the participant to self-fill. The researcher or the research assistant was available to address any inquiries. Once the questionnaire was completed, participants returned it directly to the research team and its completeness was checked. The secondary data for the sociodemographic factors, clinical characteristics and the results of the postpartum OGTT were gathered from the medical records.

Variables definition

Variable definitions for the dependent which was P-AGT and independent variables are listed in Table I.

Table I: Dependent and Independent Variables Definition

Dependent Variables - Outcome of Postpartum OGTT[1]	**Variables Definition**
Postpartum Normal Glucose Tolerance (P-NGT)	FPG: < 6.0 mmol/L AND 2HPP: <7.8 mmol/L
Postpartum Abnormal Glucose Tolerance (P-AGT)	FPG: ≥ 6.0 mmol/L OR/AND 2HPP: ≥ 7.8 mmol/L
• Prediabetes	FPG: 6.1-6.9 mmol/L OR 2HPP: 7.8-11.0 mmol/L
▪Impaired Fasting Glucose (IFG)	FPG: 6.1-6.9 mmol/L AND 2HPP: < 7.8 mmol/L
▪Impaired Glucose Tolerance (IGT)	FPG: < 6.0 mmol/L AND 2HPP: 7.8-11.0 mmol/L
▪IFG and IGT	FPG: 6.1-6.9 mmol/L AND 2HPP: 7.8-11.0 mmol/L
•Diabetes	FPG: ≥ 7.0 mmol OR 2HPP: ≥ 11.1 mmol/L
Independent Variables	**Variables Definition**
Age	
Normal Maternal Age	Age < 35 years old during data collection
Advanced Maternal Age (≥35)	Age ≥35 years old during data collection
Education Level	
Higher Education	Attended higher level of education, e.g. Certificate, Diploma etc.
Lower Education	Not attended or attended school up to Form 6
Pre-pregnancy Body Mass Index (BMI)	
Non-obese	Had pre-pregnancy BMI <30kg/m^2
Obese	Had pre-pregnancy BMI ≥ 30 kg/m^2
FPG level upon GDM diagnosis	
Normal	During antenatal OGTT, had FPG <5.1 mmol/L
Abnormal	During antenatal OGTT, had FPG ≥5.1 mmol/L
2HPP level upon GDM diagnosis	
Normal	During antenatal OGTT, had 2HPP <7.8 mmol/L
Abnormal	During antenatal OGTT, had 2HPP ≥7.8 mmol/L
Treatment for GDM	
Diet control	Treated with Medical Nutrition Therapy (MNT) alone
Medication	Combined with pharmacological treatment, either metformin alone, insulin alone or a combination of both
Gestational Weight Gain (GWG)	
Total weight gain during pregnancy was calculated and compared with the expected GWG depending on their pre-pregnancy BMI as below[1].	
Pre-pregnancy BMI (kg/m^2)	Expected GWG (kg)
Underweight (<18.5 kg/m^2)	12.5-18.0
Normal weight (18.5-24.9 kg/m^2)	11.5-16.0
Overweight (25.0-29.9 kg/m^2)	7.0-11.5
Obese (≥30 kg/m^2)	5.0-9.0
Insufficient GWG	Below expected GWG
Adequate GWG	Between expected GWG
Excessive GWG	More than expected GWG
Infant's birthweight	
Abnormal	Infant's birthweight <2500g or ≥4000g
Normal	Infant's birthweight 2500-3999g
GDMKQ Level of knowledge	
Inadequate knowledge	The total mark for GDMKQ is <9/15
Adequate knowledge	The total mark for GDMKQ is ≥9/15

[1] Adopted from Malaysia Clinical Practices Guideline Management of Type 2 *Diabetes Mellitus* (6th edition), 2020

Data Entry and Statistical Analysis

Data entry and analysis were performed using the latest IBM Statistical Package for Social Sciences (SPSS) version 28.0. The prevalence of P-AGT was calculated using descriptive statistics and confidence intervals. Descriptive statistics were also used to describe the sociodemographic factors, the clinical characteristics and the level of knowledge of GDM. Normality testing was conducted for continuous variables using the Kolmogorov–Smirnov test. Mean ± Standard Deviations (SD) was used to describe continuous data with normal distribution while frequencies and percentages were used to describe categorical data. Pearson Chi-Square and Fisher's exact test were used to analyse the

differences in the proportion of categorical variables. Inferential analysis was conducted to determine the association between the sociodemographic factors, the clinical characteristics, and the level of knowledge of GDM with P-AGT. Univariate analysis was conducted using simple logistic regression to identify factors with p-value of <0.25. These factors were then analysed using multiple logistic regression to control for any confounding factors. Statistical significance was taken at p-value <0.05.

Ethical Clearance

This study was reviewed and approved by the Universiti Teknologi MARA Research Ethics Committee and the National Institute of Health and Medical Research Ethics Committee, Ministry of Health Malaysia (NMRR ID-21-02013-CTK).

RESULTS

A total of 465 postpartum women with GDM were approached and invited to participate in the study. Out of this, 18 (3.9%) did not meet the inclusion and/or exclusion criteria [n=7 (twin pregnancy), 8 (non-Malaysian), 3 (>12 weeks postpartum)] and 2 (0.4%) refused to participate. Despite measures taken, there were 6 (1.3%) responses with missing data, leaving 439 participants for the final analysis. The study response rate was 94.4% (Figure 1).

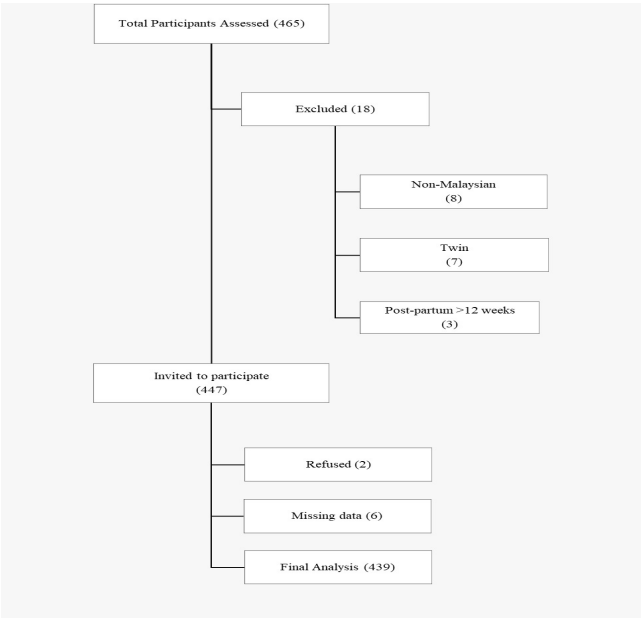

Figure 1: Flow diagram on participants recruitment and exclusion.

Prevalence of P-AGT

The prevalence of P-AGT was 28.9% (95% CI: 24.7, 33.4), out of which 86.6% were prediabetes while 13.4% were diabetes, as shown in Table II. Among the prediabetes group, 7.3% had IFG, 90.0% had IGT, and 2.7% had a combination of both IFG and IGT (Figure 2). Sociodemographic and clinical characteristics of participants.

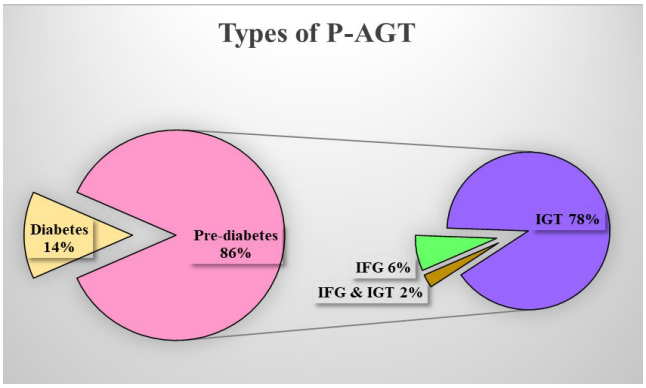

Figure 2: The prevalence of diabetes and pre-diabetes (IFG, IGT, or both) in individuals with P-AGT

Table II: Outcome of postpartum OGTT and prevalence of P-AGT

Parameters	n (%)
Postpartum OGTT	
P-NGT	312 (71.1)
P-AGT	127 (28.9)
Types of P-AGT	
Pre-diabetes	110 (86.6)
• IFG	• 8 (7.3)
• IGT	• 99 (90.0)
• IFG and IGT	• 3 (2.7)
Diabetes	17 (13.4)

OGTT: Oral Glucose Tolerance Test; P-AGT: Postpartum-Abnormal Glucose Tolerance; P-NGT: Postpartum-Normal Glucose Tolerance; IFG: Impaired Fasting Glucose; IGT: Impaired Glucose Tolerance

The sociodemographic and clinical characteristics of the participants are shown in Table III. The majority of the participants were aged <35 years old (71.8%) and of Malay ethnicity (82.7%). Most participants (76.1%) had a pre-pregnancy BMI of <30kg/m2, 28.0% had GDM in the past and 37.1% had a first-degree relative of diabetes. Among these participants, 25.5% required pharmacological treatment for their GDM, out of which 56.3% took metformin alone, 22.3% used insulin alone and 21.4% needed both metformin and insulin. The majority (93.6%) delivered at term and had normal infant birthweights (89.1%).

Table III: Sociodemographic, clinical characteristics and level of knowledge on GDM among women with GDM comparing between P-NGT and P-AGT (n=439)

Variable	n (%)			p-value
	Total (n= 439)	P-NGT (n=312)	P-AGT (n= 127)	
Age				
Normal Maternal Age (<35)	315 (71.8)	229 (73.4)	86 (67.7)	0.231[a]
Advanced Maternal Age (≥35)	124 (28.2)	83 (26.6)	41 (32.3)	
Ethnicity				
Malay	363 (82.7)	253 (81.1)	110 (86.6)	
Chinese	30 (6.8)	24 (7.7)	6 (4.7)	0.343[a]
Indian	28 (6.4)	23 (7.4)	5 (3.9)	
Bumiputra Sabah/ Sarawak	18 (4.1)	12 (3.8)	6 (4.7)	

CONTINUE

Table III: Sociodemographic, clinical characteristics and level of knowledge on GDM among women with GDM comparing between P-NGT and P-AGT (n=439)

Variable	n (%)			p-value
	Total (n= 439)	P-NGT (n=312)	P-AGT (n= 127)	
Education Level				
Higher Education	236 (53.8)	170 (54.5)	66 (52.0)	0.631[a]
Lower Education	203 (46.2)	142 (45.5)	61 (48.0)	
Employment status				
Employed	255 (58.1)	182 (58.3)	73 (57.5)	0.870[a]
Unemployed	184 (41.9)	130 (41.7)	54 (42.5)	
Parity (No of previous pregnancy)				
Parity = 1	147 (33.5)	107 (34.3)	40 (31.5)	0.573[a]
Parity ≥ 2	292 (66.5)	205 (65.7)	87 (68.5)	
Pre-pregnancy Body Mass Index (BMI)				
Non-obese (<30kg/m^2)	334 (76.1)	238 (76.3)	96 (75.6)	0.878[a]
Obese (≥ 30 kg/m^2)	105 (23.9)	74 (23.7)	31 (24.4)	
Hypertension				
Yes	9 (2.1)	8 (2.6)	1 (0.8)	0.457[b]
No	430 (97.9)	304 (97.4)	126 (99.2)	
First-degree family history of diabetes				
Yes	163 (37.1)	106 (34.0)	57 (44.9)	0.032[a]
No	276 (62.9)	206 (66.0)	70 (55.1)	
Previous History of GDM				
Yes	123 (28.0)	76 (24.4)	47 (37.0)	0.007[a]
No	316 (72.0)	236 (75.6)	80 (63.0)	
Gestational age upon GDM diagnosis				
< 24 weeks	275 (62.6)	184 (59.0)	91 (71.7)	0.013[a]
≥ 24 weeks	164 (37.4)	128 (41.0)	36 (28.3)	
FPG level upon GDM diagnosis				
Normal (< 5.1mmol/L)	191 (43.5)	137 (43.9)	54 (42.5)	0.790[a]
Abnormal (≥ 5.1mmol/L)	248 (56.5)	175 (56.1)	73 (57.5)	
2HPP level upon GDM diagnosis				
Normal (< 7.8 mmol/L)	134 (30.5)	113 (36.2)	21 (16.5)	<0.001[a]
Abnormal (≥ 7.8 mmol/L)	305 (69.5)	199 (63.8)	106 (83.5)	
Treatment for GDM				
Diet control	327 (74.5)	239 (76.6)	88 (69.3)	0.111[a]
Treatment for GDM				0.111[a]
Medication	112 (25.5)	73 (23.4)	39 (30.7)	
Types of medication				
Metformin alone	63 (56.3)	49 (77.8)	14 (22.2)	<0.001[a]
Insulin alone	25 (22.3)	17 (68.0)	8 (32.0)	
Metformin and Insulin	24 (21.4)	7 (29.2)	17 (70.8)	
Gestational Weight Gain (GWG)*				
Adequate	148 (33.7)	107 (34.3)	41 (32.3)	0.921[a]
Insufficient	206 (46.9)	145 (46.5)	61 (48.0)	
Excessive	85 (19.4)	60 (19.2)	25 (19.7)	
Gestation week of delivery				
Term (≥ 37 weeks)	411 (93.6)	294 (94.2)	117 (92.1)	0.413[a]
Pre-term (<37 weeks)	28 (6.4)	18 (5.8)	10 (7.9)	
Mode of Delivery				
Vaginal delivery	308 (70.2)	220 (70.5)	88 (69.3)	0.800[a]
Caesarean section	131 (29.8)	92 (29.5)	39 (30.7)	
Infant's birthweight				
Normal (2500-3999g)	391 (89.1)	284 (91.0)	107 (84.3)	0.039[a]
Abnormal (<2500g or ≥4000g)	48 (10.9)	28 (9.0)	20 (15.7)	
NICU admission				
Yes	88 (20.0)	57 (64.8)	31 (35.2)	0.145[a]
No	351 (80.0)	255 (72.6)	96 (27.4)	
History of neonatal hypoglycaemia				
Yes	13 (3.0)	8 (2.6)	5 (3.9)	0.535[b]
No	426 (97.0)	304 (97.4)	122 (96.1)	
Breastfeeding exclusivity				
Yes	296 (67.4)	212 (67.9)	84 (66.1)	0.714[a]
No	143 (32.6)	100 (32.1)	43 (33.9)	
GDMKQ Level of knowledge				
Adequate knowledge (≥9/15)	408 (92.9)	288 (92.3)	120 (94.5)	0.419[a]
Inadequate knowledge (<9/15)	31 (7.1)	24 (7.7)	7 (5.5)	

* Refer to Table II for variable definition
[a] Pearson Chi-Square test [b] Fisher's exact test
GDM: Gestational *Diabetes Mellitus*; P-NGT: Postpartum-Normal Glucose Tolerance; P-AGT: Postpartum-Abnormal Glucose Tolerance; FPG: Fasting Plasma Glucose; 2HPP: 2 Hours-Post Prandial; NICU: Neonatal Intensive Care Unit; GDMKQ: Gestational *Diabetes Mellitus* Knowledge Questionnaire

Level of knowledge on GDM

The majority (92.9%) of the participants scored ≥9/15

in GDMKQ and were considered to have adequate knowledge, as shown in Table III. There was no significant difference in adequate knowledge observed between GDM women with P-NGT and P-AGT (p=0.419).

The total mean score of GDMKQ was 12.21 ± 2.22 out of a maximum score of 15. The mean knowledge score for each domain is presented in Table IV. The highest mean ± SD score for GDMKQ was from domain 3 (2.82 ± 0.49) which assessed food and diet value, followed by domain 5 (2.76 ± 0.59) which assessed complications or outcome of GDM. The lowest total mean score was seen in domain 4 (2.06 ± 0.80) which assessed management of GDM.

Table IV: Mean score for each domain and percentages of right and wrong responses to all GDMKQ questions

Questions	Mean score for each domain (±sd) (min-max 0-3)	No. of correct responses (%)	No. of wrong responses (%)
Domain 1 Basic knowledge about GDM	2.35 ± 0.78	-	
Q1 GDM is the type of diabetes that occur:	-	361 (82.2)	78 (17.8)
Q2 In uncontrolled GDM the blood sugar level is:	-	358 (81.5)	81 (18.5)
Q3 What is the best way for testing blood glucose level for GDM patients?	-	312 (71.1)	127 (28.9)
Domain 2 Knowledge about risk factors	2.21 ± 0.72	-	
Q4 You are at increased risk of developing GDM if you are:	-	409 (93.2)	30 (6.8)
Q5 You have increased chances of developing GDM if:	-	163 (37.1)	276 (62.9)
Q6 You are more likely to develop GDM if you have:	-	396 (90.2)	43 (9.8)
Domain 3 Knowledge about diet/food values	2.82 ± 0.49	-	
Q7 If you have GDM, you should avoid food containing high content of:	-	406 (92.5)	33 (7.5)
Q8 Which of the following food can be eaten without restriction during GDM:	-	417 (95.0)	22 (5.0)
Q9 What is the type of nutritional source mainly provided by rice?	-	417 (95.0)	22 (5.0)
Domain 4 Knowledge about management of GDM	2.06 ± 0.80	-	
Q10 The most common sign of hyperglycaemia (high blood sugar) is:	-	185 (42.1)	254 (57.9)
Q11 The normal value of FPG is:	-	349 (79.5)	90 (20.5)
Q12 If you feel the onset of hypoglycaemic (low blood sugar) symptoms, you should:	-	372 (84.7)	67 (15.3)
Domain 5 Knowledge about GDM complications/outcomes	2.76 ± 0.59	-	
Q13 In uncontrolled GDM your baby may be:	-	414 (94.3)	25 (5.7)
Q14 If you have GDM, you have:	-	382 (87.0)	57 (13.0)
Q15 GDM is a condition that:	-	417 (95.0)	22 (5.0)
Total mean score for GDMKQ (min-max 0-15)	12.21±2.22	-	

Score 1 was given to every correct answer, and score zero was given to every wrong answer. Maximum score is 15 and minimum is 0. GDMKQ: Gestational *Diabetes Mellitus* Knowledge Questionnaire ; GDM: Gestational *Diabetes Mellitus*; FPG: Fasting Plasma Glucose

Percentages of the total for correct and wrong responses to each question in GDMKQ are represented in Table IV. Questions with the highest number of correct responses were question 8, asking about the choice of healthy food in GDM (95.0%); question 9, recognising rice as a carbohydrate source; and question 15, testing the impact of GDM on mother and baby (95.0%). Questions with the lowest number of correct responses were noted for question 5, which assessed on risk factors for developing GDM (37.1%), followed by question 10, which assessed participants' knowledge of the signs of hyperglycaemia (42.1%).

Predictors of P-AGT

Simple logistic regression showed having a first-degree family history of diabetes, previous history of GDM, gestational age upon GDM diagnosis <24 weeks, 2HPP level upon GDM diagnosis ≥7.8mmol/L and an infant with abnormal birthweight had a higher risk of developing P-AGT as shown in Table V.

Multiple logistic regression analysis, as seen in Table V, showed that having a first-degree family history of diabetes carried 1.5 higher odds of developing P-AGT [aOR: 1.55, 95% CI: 1.01, 2.39; (p = 0.047)], while women with gestational age upon GDM diagnosis <24 weeks had 1.8 higher odds of developing P-AGT compared to women with gestational age upon GDM diagnosis ≥24 weeks [aOR: 1.85, 95% CI: 1.17, 2.92; (p=0.009)]. Meanwhile, women with a 2HPP level ≥7.8mmol/L upon GDM diagnosis had a threefold higher risk of developing P-AGT compared to women with a 2HPP level <7.8mmol/L upon GDM diagnosis [aOR: 2.95, 95% CI: 1.74, 5.01; (p<0.001)].

Table V: Univariate & multivariate analysis on factors associated with P-AGT.

Variables		Crude OR[a] (95% CI)	p-value[a]	Adj OR[b] (95% CI)	p-value[b*]
Age	Normal Maternal Age (<35)	1	Ref.	-	-
	Advanced Maternal Age (≥35)	1.32 (0.84, 2.06)	0.23	-	-
Ethnicity	Malay	1	Ref.	-	-
	Chinese	0.58 (0.23, 1.45)	0.24	-	-
	Indian	0.50 (0.19, 1.35)	0.17	-	-
	Bumiputra Sabah/Sarawak	1.15 (0.42, 3.14)	0.79	-	-
Education Level	Higher Education	1	Ref.	-	-
	Lower Education	0.90 (0.60, 1.37)	0.63	-	-
Employment status	Employed	1	Ref.	-	-
	Unemployed	1.034 (0.68, 1.57)	0.87	-	-
Parity (No of previous pregnancy)	Parity = 1	1	Ref.	-	-
	Parity ≥ 2	1.14 (0.73, 1.77)	0.58	-	-
Pre-pregnancy Body Mass Index (BMI)	Non-obese (<30kg/m^2)	1	Ref.	-	-
	Obese (≥ 30 kg/m^2)	1.04 (0.64, 1.68)	0.88	-	-
Hypertension	Yes	1	Ref.	-	-
	No	3.33 (0.41, 26.79)	0.26	-	-
First-degree family history of diabetes	No	1	Ref.	1	Ref.
	Yes	1.58 (1.04, 2.41)	0.03	1.55 (1.01, 2.39)	0.047
Previous History of GDM	No	1	Ref.	-	-
	Yes	1.82 (1.17, 2.84)	0.01	-	-
Gestational age upon GDM diagnosis	≥24 weeks	1	Ref.	1	Ref.
	<24weeks	1.76 (1.13, 2.75)	0.01	1.85 (1.167, 2.92)	0.009
FPG level upon GDM diagnosis	Normal (<5.1 mmol/L)	1	Ref.	-	-
	Abnormal (≥5.1 mmol/ L)	1.06 (0.70, 1.61)	0.79	-	-
2HPP level upon GDM diagnosis	Normal (<7.8 mmol/L)	1	Ref.	1	Ref.
	Abnormal (≥7.8 mmol/L)	2.87 (1.70, 4.83)	<0.001	2.95 (1.74, 5.01)	<0.001
Treatment for GDM	Diet control	1	Ref.	-	-
	Medication	1.45 (0.92, 2.30)	0.11	-	-
Gestational weight gain (GWG)	Adequate	1	Ref.	-	-
	Insufficient	1.10 (0.69, 1.75)	0.70	-	-
	Excessive	1.09 (0.60, 1.96)	0.78	-	-
Gestation week of delivery	Term (≥ 37 weeks)	1	Ref.	-	-
	Pre-term (<37 weeks)	1.40 (0.63, 3.11)	0.42	-	-
Mode of delivery	Vaginal delivery	1	Ref.	-	-
	Caesarean section	1.06 (0.68, 1.66)	0.80	-	-
Infant's birthweight	Normal (2500g-3999g)	1	Ref.	-	-
	Abnormal (<2500g or ≥4000g)	1.90 (1.03, 3.51)	0.04	-	-
NICU admission	No	1	Ref.	-	-
	Yes	1.45 (0.88, 2.37)	0.15	-	-
History of neonatal hypoglycaemia	No	1	Ref.	-	-
	Yes	1.56 (0.50, 4.86)	0.45	-	-
Breastfeeding exclusivity	Yes	1	Ref.	-	-
	No	1.09 (0.70, 1.68)	0.71	-	-
GDMKQ Level of knowledge	Adequate	1	Ref.	-	-
	Inadequate	1.43 (0.60, 3.41)	0.42	-	-

[a]Simple Logistic Regression [b]Multiple Logistic Regression

*Forward Logistic Regression (LR) - Adjusted for age, ethnicity, first-degree family history of diabetes, previous history of GDM, gestational age upon GDM diagnosis, 2HPP level upon GDM diagnosis, treatment for GDM, infant's birthweight and NICU admission. R^2 = 0.15, Hosmer-Lemeshow Test p=0.92, Overall Percentage = 71.1, Area Under ROC Curve = 0.66 (95% CI: 0.60, 0.71). The model reasonably fits well. Model assumptions are met. There are no interactions, no multicollinearity and no outliers. P-AGT: Postpartum-Abnormal Glucose Tolerance; FPG: Fasting Plasma Glucose; 2HPP: 2 Hours-Post Prandial; NICU: Neonatal Intensive Care Unit; GDMKQ: Gestational *Diabetes Mellitus* Knowledge Questionnaire

DISCUSSION

This study showed that the prevalence of P-AGT in the early postpartum period among women with GDM is 28.9%. This prevalence is higher than previous local studies which ranges from 12.1% to 15.3% conducted between 2013 to 2016 (12-14). The increasing trend aligns with the rising prevalence of diabetes in Malaysia's general population, from 11.2% in 2011 to 18.3% in 2019 (2). Among the contributing factors to this rising prevalence are the increasing obesity rates and physical inactivity (28), which possibly be the contributing factors to the increasing prevalence of P-AGT as well.

Additionally, this study utilised the updated GDM diagnostic criteria with a lower FPG cut-off which was 5.1mmol/L compared to 5.6mmol/L in the studies by Logakodie et al. and Nurain et al. (12, 14). This may lead to more GDM diagnoses and more women had subsequent postpartum OGTT screenings, thereby detecting a higher prevalence of P-AGT.

Despite the increased prevalence, the distribution of P-AGT remains consistent, with 86.6% classified as prediabetes, aligning with a local study by Nurain et al. which found 88.2% were prediabetes (14). Likewise, 13.4 % of P-AGT in this study were diabetes comparable to 11.8% found by Nurain et al. (14).

This study identified the prevalence of P-AGT in the early postpartum period within six to 12 weeks postpartum, as it allows earlier intervention. This is important as these women are in childbearing age, and despite they have a higher risk for P-AGT, they might be loss to follow up. They might only return to care during the next pregnancy, with diabetes and its complications, that impact both the mother and the foetus. Apart from that, educating on the importance of periodic screening is also essential as a study by Chew et al. showed a higher prevalence of postpartum abnormal OGTT; 61.7% when screening done between 3 months to 15 years postpartum compared to early postpartum period. This showed that the longer time elapsed between the index pregnancy of GDM and the time of OGTT carries a higher risk of having abnormal OGTT (15).

Studies showed the prevalence of good level of GDM knowledge among antenatal women regardless of their GDM status ranges from 7.8% to 51.5% (19, 20). However, studies on the level of knowledge on GDM specifically among women with GDM were limited (17, 21). Only two studies done which used GDMKQ, a similar instrument to our study. A study by Gonzalez et al. on postpartum women with GDM found that 95.3% had adequate knowledge of GDM (21). This is comparable to the prevalence observed in this study which was 92.3% (21). On the other hand, Hussain et al. revealed only 56.6% of antenatal women with GDM have adequate knowledge of GDM (17). The better knowledge in postpartum women likely reflects their longer experience managing GDM.

In this study, the lowest total mean score observed in GDMKQ was in the management of GDM domain, consistent with study findings by Gonzalez et al. and Hussain et al. (17, 21). The questions for the management of GDM domain assessed the knowledge related to signs and symptoms of hyperglycaemia and hypoglycaemia as well as the normal range of blood sugar level. The low total mean score was possibly due to the majority of our participants were on diet control for the treatment of GDM, which implies the majority of them had good sugar control throughout the pregnancy. They were possibly less likely to experience hyperglycaemia or hypoglycaemia states, explaining their unfamiliarity with these conditions. Hence, it is essential to improve our practice in delivering education on GDM management for improved self-care and safety netting for our GDM population regardless of their treatment modalities.

A meta-analysis found that the significant sociodemographic factors in predicting diabetes in women with GDM were advanced maternal age with a relative risk (RR) of 1.21, non-white ethnicity with an RR of 1.49, while multiparity carried an RR of 1.23 and family history of diabetes carried an RR of 1.70 (23). Among these, only family history of diabetes was found to be the significant sociodemographic predictor for P-AGT in our study which carried a 1.5-fold higher risk. This is supported by a study among postpartum women with GDM in a Brazilian cohort by Weinert et al., which reported similar findings but with higher odds of 2.41 (25). While a few other studies found no significant association (14, 26), family history as a predictor of diabetes is well-established, hence its significance in predicting P-AGT should not be neglected.

Apart from findings from the meta-analysis that found non-white ethnicity carried an RR of 1.49 to develop P-AGT, Benhalima et al. also found Asian ethnicity as a significant predictor, which carried higher odds of 5.10 (9, 23). Contrary, ethnicity is not found to be significant among our population. This could be related to the higher prevalence of diabetes in Malaysia was associated with Indian ethnicity (28), but the majority of our participants were Malay ethnicity (82.7%), thus might not well represent our diverse Malaysian ethnicity. The same meta-analysis also reported that the maternal characteristics that were associated with future diabetes were pre-pregnancy BMI with RR of 1.95, early gestational age at GDM diagnosis which had RR of 2.13, along with raised FPG (RR 3.57), elevated 2HPP (RR 3.46) and increased HbA1C level (RR 2.56) upon GDM diagnosis. Other significant maternal characteristics includes insulin use during pregnancy, which carried an RR of 3.66, hypertensive disorders in pregnancy with an RR of 1.38, and preterm delivery with an RR of 1.81 (23). Among these maternal characteristics, abnormal

2HPP level upon GDM diagnosis and GDM diagnosis before 24 weeks of gestation were found to be significant predictors for P-AGT in this study.

This study reported that abnormal 2HPP level upon GDM diagnosis was associated with a threefold increased risk of P-AGT. This is aligned with studies done by Nurain et al. and Inoue et al. but with lower odds which were 1.39-fold and 1.04-fold respectively (14, 27). This may reflects beta cell dysfunction in producing insulin (27) or an increase in peripheral insulin resistance, i.e. the skeletal muscle (16). Benhalima et al. speculated that these derangements may have developed pre-pregnancy, making them have a higher risk of P-AGT (9).

In our study, diagnosis of GDM before 24 weeks of gestation was associated with a 1.8-fold higher risk of P-AGT. This finding is supported by the study by Nouhjah et al. and Nurain et al., which showed the gestational age upon GDM diagnosis was a significant predictor, whereby the odd was found to be 0.92. This means the earlier gestational age upon GDM diagnosis carried a higher risk of postpartum abnormal OGTT (14, 26). Earlier gestational age upon GDM diagnosis may indicate that the impaired glucose homeostasis has been present pre-pregnancy (9), making this predictor significantly associated with P-AGT.

Two of our significant predictors for P-AGT were similar to another Malaysian study findings: abnormal 2HPP level and earlier gestational age upon GDM diagnosis (14). This highlights the significance of these factors in predicting P-AGT in the Malaysian population. The study also found that the HbA1C level upon GDM diagnosis was significantly associated with postpartum abnormal OGTT; however, this variable was not included in this study (14).

Knowledge of GDM was proven to be significantly associated with better glucose control among women with GDM during the antenatal period (17), hence similar association was expected to be seen during the postpartum period in this study. However, no association was found indicating the level of knowledge is not a significant predictor for P-AGT among our population.
This study, along with other local research, did not explore the factors associated with the level of knowledge about GDM. In contrast, a study conducted in Australia with a multi-ethnic population found that ethnicity significantly influences knowledge about GDM (29). It also showed that higher education was associated with better knowledge which supported by other studies (29-31). However, these studies did not examine the impacts of GDM knowledge on the risk of developing diabetes. This highlights the need for future research to explore predictors of GDM knowledge, including cultural and behavioural factors, and their impact on the risk of developing diabetes.

All three significant predictors found in this study are recognisable at the point of GDM diagnosis. Identifying high-risk women at GDM diagnosis enables early lifestyle interventions and closer follow-up, reducing the risk of being lost to follow-up and ensuring periodic OGTT screening. A systematic review showed that lifestyle interventions including breastfeeding, healthy diets, and regular exercise reduced postpartum weight, BMI, and waist circumference (32). These changes also help lower the risk of developing diabetes (32, 33). The efficacy of these interventions is improved when goals are personalized to each woman's specific needs and providing continuous support and care during the postpartum period (33).

Education is a crucial intervention in emphasising their significant risk to develop P-AGT and the importance of lifestyle interventions. It also serves as a reminder of the necessity of periodic OGTT screening. Minhat et al. found that majority of respondents demonstrated poor knowledge on postpartum OGTT screening, which associated to their lower education levels and self-efficacy. This highlights the need for continuous education and health promotion to ensure better adherence to screening (34).

Future studies should explore behavioural factors in women with GDM and their risk of P-AGT. Understanding these factors will help devise targeted interventions and preventive measures focused on lifestyle interventions.

Strengths And Limitations

This study was the first local study to examine the predictors of P-AGT after the updated criteria for GDM diagnosis in 2017. It also examined the level of knowledge on GDM among postpartum GDM women, which was scarce in the literature.

A limitation of this study was that it may have selection bias as we used the convenience sampling method. We only include women with GDM who presented for early postpartum OGTT; thus, it might not represent true prevalence, as data on women who did not come were not included. It was also found that most of participants were Malays, which might not well represent the diverse Malaysian society.

CONCLUSION

In summary, this study found that almost one-third of women with GDM develop P-AGT in the early postpartum period and this prevalence is higher compared to other local studies done in previous years highlighting the need for early and targeted interventions.

The low knowledge scores on the management aspects of GDM highlight the critical educational gaps. Addressing these deficiencies through comprehensive, structured

education programs among GDM patients may enhance self-management, improve glycaemic control, and reduce the risk of adverse clinical outcomes such as progression to diabetes or metabolic complications.

Apart from that, recognition of the high-risk group for P-AGT; women with GDM which diagnosed before 24 weeks of gestation, had deranged 2HPP level upon GDM diagnosis and having a first-degree family history of diabetes; may be done as early as upon the GDM diagnosis. Consistent follow-up practices that incorporate education programs as early as during the antenatal period and continuing postpartum, by enrolling them into pre-pregnancy clinic (PPC) can ensure they are not lost to follow-up. Future studies should evaluate the impact of such interventions on reducing P-AGT prevalence and inform the development of tailored prevention strategies.

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