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Optimizing Prediabetes Detection in Primary Care: Evaluating the Glucose Challenge Test

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ABSTRACT

Background: The rising incidence of prediabetes necessitates effective early detection strategies in primary care settings. While the Glucose Challenge Test (GCT) is well-established for gestational diabetes screening, its validity for prediabetes screening in the general non-pregnant population remains inadequately explored. **Objective:** This study aimed to evaluate the diagnostic validity of GCT as a screening tool for prediabetes in adults within the primary care context compared to the Oral Glucose Tolerance Test (OGTT) as the gold standard. **Methods:** An observational-analytical study with a cross-sectional diagnostic test design was conducted in three community health centers in Yogyakarta, Indonesia,from April to November 2018. . Participants aged 35-64 years were recruited using cluster sampling. Of 213 initially recruited participants, 65 completed the full diagnostic protocol. Data were analyzed using 2×2 contingency tables and Receiver Operating Characteristic (ROC) curve analysis. **Results:** The prevalence of prediabetes in the study population was 30.76%. The GCT demonstrated an Area Under the Curve (AUC) of 63.6% (95% CI: 47.8%–79.4%), indicating poor to fair diagnostic accuracy. At the optimal cut-off point, the GCT showed a sensitivity of 40% and a specificity of 80%. The positive predictive value (PPV) and negative predictive value (NPV) were 47.06% and 75%, respectively. **Conclusion:** Although the GCT is feasible for "any-time" screening in primary care due to its non-fasting nature, its low sensitivity suggests it may not be sufficient as a standalone screening tool for prediabetes in its current protocol. Further optimization of cut-off values or its use as an opportunistic tool in high-risk populations may be considered.

Keywords: *Glucose Challenge Test (GCT); Oral Glucose Tolerance Test (OGTT); prediabetes screening; primary health care,diagnostic validity*

BACKGROUND

The global burden of prediabetes continues to rise at an alarming rate, with projections indicating that more than 470 million people worldwide will have prediabetes by 2030[1]. In Southeast Asia, prediabetes prevalence was approximately 6.8% in 2013[2], while Indonesia reported 10% prevalence, projected to increase to 20.6% by 2025[3]. The Special Region of Yogyakarta (DIY) has the highest diabetes mellitus prevalence in Indonesia at 2.6%[3], yet prediabetes prevalence in this region remains unreported. This epidemiological pattern underscores the urgent need for effective early detection strategies in primary healthcare settings.

Screening is essential for identifying asymptomatic conditions such as prediabetes, as most affected individuals remain unaware of their diabetes risk[4]. The annual progression rate from prediabetes to type 2 diabetes mellitus (T2DM) ranges from 5-10%, with a lifetime risk estimated at 70%[4-5]. Furthermore, prediabetes independently increases cardiovascular disease and stroke risk, with some patients already experiencing microvascular and macrovascular complications at this stage[6]. Early identification through screening enables timely preventive interventions to reduce diabetes progression and associated complications.

Various prediabetes screening methods have been evaluated. Rolka et al.[7] found that questionnaire-based scoring systems had low specificity, while capillary blood glucose measurement had low sensitivity. Zhang et al.[8]

conducted a cost-analysis study assessing five detection methods, concluding that OGTT was most effective, whereas capillary glucose testing and risk assessment questionnaires were most cost-efficient. Phillips et al.[9] reported that GCT demonstrated reasonable efficiency with AUC values of 0.79 for prediabetes, 0.82 for dysglycemia, and 0.90 for diabetes diagnosis. Susairaj et al. demonstrated that random blood glucose measurement at an optimized cut-off can effectively identify dysglycemia in Asian community settings[10]. Lee et al. further showed that nonfasting screening tests detect dysglycemia with reasonable accuracy in routine clinical practice[11].

Current prediabetes diagnosis in Indonesia employs three tests: fasting blood glucose (FBG), OGTT, and hemoglobin A1c (HbA1c). FBG is simple and inexpensive but cannot detect isolated impaired glucose tolerance (IGT). OGTT, recognized as the gold standard by ADA, WHO, and IDF, is less practical due to procedural requirements[12]. HbA1c testing, recommended by the International Expert Committee in 2009[13], offers advantages in stability but is expensive and requires high-standard laboratory procedures. Aryandono[14] demonstrated that HbA1c sensitivity and specificity remain inadequate, potentially misclassifying substantial prediabetes cases. These additional diagnostic challenges across Asian populations[15,16] and alternative screening approaches, including 1-hour OGTT criteria[17].

A systematic review by Norris et al.[18] suggested that screening high-risk groups in primary healthcare settings can reduce prediabetes progression to diabetes through earlier lifestyle and pharmacological interventions. The European Academy of Teachers in General Practice/ Family Medicine (EURACT) emphasizes that primary care physicians manage all health problems and advocate for patients within the healthcare system[19]. Prediabetes represents a health issue requiring early detection and management in primary healthcare facilities.

Although GCT is traditionally used for gestational diabetes screening, its application for prediabetes screening in non-pregnant adults warrants investigation due to several practical advantages. Unlike OGTT, GCT does not require fasting and can be performed at any time, with patients consuming 50g oral glucose within five minutes and glucose levels measured one hour later[9,20]. This non-fasting, opportunistic nature makes GCT particularly attractive for primary care settings where patient compliance with fasting requirements may be challenging. Among available screening methods, GCT is feasible for implementation in primary healthcare settings due to its simplicity and minimal patient preparation requirements.

However, to date, no published data exist regarding GCT validity for prediabetes screening in Indonesian primary healthcare settings. Given that DIY has the highest DM prevalence in Indonesia, prediabetes screening in primary healthcare facilities in DIY represents an important research focus. This study aimed to evaluate the diagnostic validity of GCT compared to OGTT as the gold standard in primary care settings.

RESEARCH METHODS

This study employed an observational analytic design with a cross-sectional approach, where data collection was conducted at a single point in time. The study aimed to assess the diagnostic performance of GCT compared to OGTT as the gold standard. The study was conducted in three community health center (Puskesmas) service areas in DIY: Puskesmas Depok II and Puskesmas Ngaglik in Sleman Regency, and Puskesmas Banguntapan II in Bantul Regency. The study was conducted from April to November 2018. Sample size calculation was performed using diagnostic test validity formula considerations, anticipating a minimum required sample of 60 participants to achieve adequate statistical power. Cluster sampling was employed to select healthcare facilities and participants. The cluster sampling procedure involved: (1) selecting three Puskesmas from two regencies in DIY based on their representative patient populations and geographic distribution; (2) within each selected Puskesmas, recruiting participants from the general outpatient population aged 35-64 years who met the inclusion criteria; and (3) consecutive enrollment of eligible participants until the target sample size was achieved. **Inclusion criteria:** Individuals aged 35-64 years who provided informed consent and were able to communicate effectively. **Exclusion criteria:** Patients with a prior diagnosis of diabetes mellitus, those taking medications affecting glucose metabolism (including corticosteroids, thiazide diuretics, and antipsychotics), and individuals with medical conditions limiting participation (including acute illness, severe chronic disease, or physical disability preventing protocol completion). Data variables included demographic characteristics (age, gender, body weight, height, waist circumference, body mass index, family history of diabetes, and blood pressure status) and glucose measurements (fasting plasma glucose, GCT, and OGTT). Data collection included demographic characteristics and glucose measurements using standardized laboratory procedures. The research procedures followed the flowchart presented in Figure 1.

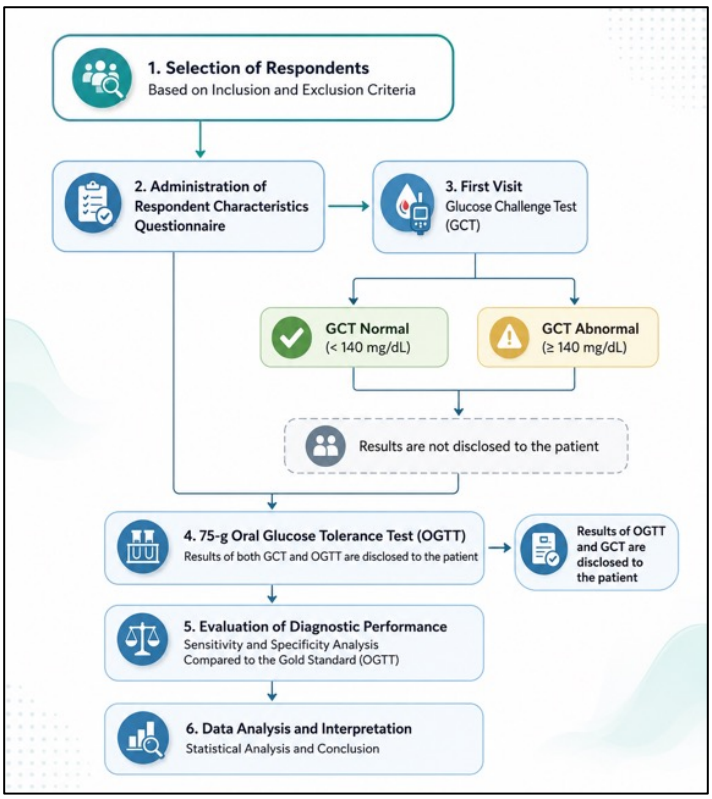

Figure 1. Research Flowchart

Initial Visit (Day 1): (1)Participant Selection: Respondents were selected based on inclusion and exclusion criteria. Questionnaire Administration: Participants completed a questionnaire on demographic characteristics, medical history, and risk factors. Glucose Challenge Test (GCT): Participants consumed 50g glucose solution within five minutes, regardless of fasting status. Blood glucose was measured one hour post-load from venous samples. The GCT was considered positive (abnormal) at a cut-off of ≥140 mg/dL, based on the standard threshold established by the American Diabetes Association (ADA) for screening purposes [21,22,23]. This threshold was selected as no validated Indonesian-specific cut-off exists for prediabetes screening using GCT in non-pregnant populations. Results were not disclosed to participants at this stage.

Subsequent Visit (Day 2): (1) Fasting Plasma Glucose (FPG): Collected after 8-12 hour overnight fast (obtained from the fasting sample before OGTT) Oral Glucose Tolerance Test (OGTT): Following an 8-12 hour overnight fast, participants consumed 75g glucose solution. Blood glucose was measured two hours post-load. Result Disclosure: Both GCT and OGTT results were communicated to participants after completion of all procedures. Participants diagnosed with prediabetes or diabetes were referred for appropriate clinical management according to standard guidelines. All blood samples were processed according to standardized laboratory protocols. Collaboration with a clinical laboratory was established for blood sample processing and storage to ensure sample integrity.

Data were analyzed using: (1)**2×2 contingency tables** to determine sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (LR+), negative likelihood ratio (LR-), and accuracy. (2) **Receiver Operating Characteristic (ROC) curve analysis** to evaluate diagnostic accuracy, with the area under the curve (AUC) classified as: poor (0.50-0.70), fair (0.70-0.80), good (0.80-0.90), or excellent (0.90-1.00). (3) **95% confidence intervals** calculated for all diagnostic parameters. (4)**Fagan's nomogram** to illustrate post-test probabilities. (4) **Diagnostic criteria: For diagnostic test evaluation, GCT results were categorized as positive (≥140 mg/dL) or negative (<140 mg/dL). Prediabetes status was determined using ADA criteria based on OGTT results: Impaired Fasting Glucose (IFG): FPG 100-125 mg/dL, Impaired Glucose Tolerance (IGT): 2-hour OGTT 140-199 mg/dL.**

Data were analyzed using SPSS software (version 22.0, IBM Corp., Armonk, NY, USA). Diagnostic parameters were calculated using standard diagnostic test formulas and Microsoft Excel for data management. Ethical approval was obtained from the Research Ethics Committee of the Faculty of Medicine, Universitas Islam Indonesia (No. 48/Ka.Kom.Et/70/KE/V/2018). All participants provided written informed consent before data collection. The study was conducted in accordance with the Declaration of Helsinki and Good Clinical Practice guidelines. Participants diagnosed with prediabetes or diabetes were referred for appropriate clinical management according to standard guidelines.

RESULTS

A total of 213 respondents agreed to participate initially. Following the full diagnostic protocol and quality control procedures, 65 participants were included in the final analysis. Reasons for exclusion included: respondent-

related factors (failure to attend second sample collection, non-compliance with fasting requirements), specimen-related factors (blood sample hemolysis, improper plasma separation timing, sample transportation and storage issues, and excessive time gap between sample collection and analysis), and researcher-related factors (inaccuracies in data recording, inadequate preparation of supporting equipment, and deficiencies in quality assurance during data collection).

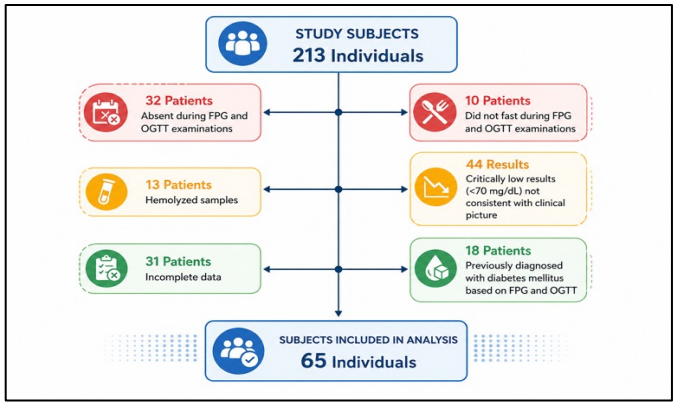

Figure 2. Flowchart of Study Subject Selection

The study included 65 respondents comprising 10 males (15.4%) and 55 females (84.6%). The mean age was 49.5 years (SD 7.4). Mean body weight and height were 61.7 kg (SD 11.407) and 153.3 cm (SD 6.3), respectively. A total of 30.8% belonged to the 55–59-year age group, and 53.8% were classified as having Grade 1 obesity (BMI 25.00–29.99 kg/m²). The mean waist circumference was 89.49 cm (SD 9.8), with 78.5% having central obesity.

Table 1. Respondent Demographics

Characteristic	Prediabetes (n=20)	Normoglycemia (n=45)
Gender		
Male	4 (20%)	6 (13.3%)
Female	16 (80%)	39 (86.7%)
Age		
Mean ± SD (years)	49.75 ± 7.03	49.42 ± 7.66
Range (years)	39–63	35–64
Age Classification		
35-39 years	1 (5%)	5 (11.1%)
40-44 years	5 (25%)	9 (20%)
45-49 years	3 (15%)	7 (15.6%)
50-54 years	4 (20%)	7 (15.6%)
55-59 years	6 (30%)	14 (31.1%)
60-64 years	1 (5%)	3 (6.7%)
Body Weight		
Mean ± SD (kg)	63.95 ± 11.49	60.80 ± 10.87
Range (kg)	36–82	41–92
Height		
Mean ± SD (cm)	153.40 ± 7.31	153.25 ± 5.99
Range (cm)	144–169	142–166
Waist Circumference		
Mean ± SD (cm)	86.2 ± 10.38	87.34 ± 10.79
Range (cm)	58–98	67–113
Body Mass Index (BMI)*		
Underweight (<18.5 kg/m²)	1 (5%)	4 (8.9%)
Normal weight (18.5-22.9 kg/m²)	1 (5%)	10 (22.2%)
Overweight/Pre-Obese (22-24.9 kg/m²)	3 (15%)	4 (8.9%)
Obesity Class I (25-29.9 kg/m²)	11 (55%)	24 (53.3%)
Obesity Class II (≥30 kg/m²)	4 (20%)	3 (6.7%)
Mean BMI ± SD (kg/m²)	27.11 ± 4.2	25.80 ± 3.74
Central Obesity (M ≥90 cm, F ≥80 cm)		
No	4 (20%)	10 (22.2%)
Yes	16 (80%)	35 (77.8%)
Family History of DM		

No	19 (95%)	45 (100%)
Yes	1 (5%)	0
Blood Pressure Status**		
Normotension (BP <120/80)	8 (40%)	23 (51.1%)
Prehypertension (BP 120-139/80-89)	8 (40%)	9 (20%)
Hypertension Stage 1 (BP 140-159/90-99)	2 (10%)	11 (24.4%)
Hypertension Stage 2 (BP ≥160/100)	2 (10%)	2 (4.4%)
Mean Systolic BP ± SD (mmHg)	126 ± 17.3	118.78 ± 16.13
Mean Diastolic BP ± SD (mmHg)	83.75 ± 11.1	82 ± 11.2

* WHO BMI criteria for Asia Pacific.
** Classification based on JNC VIII.

Prevalence and Glucose Measurements

The prevalence of prediabetes in this study was 30.76% (20 out of 65 participants). The prevalence of impaired fasting glucose (IFG) and impaired glucose tolerance (IGT) among individuals aged 35–64 years was 10.8% and 20%, respectively. Mean fasting blood glucose was 89.49 mg/dL. Mean glucose levels from OGTT and GCT were 120.3 mg/dL and 122.49 mg/dL, respectively.

Diagnostic Performance of GCT

ROC Curve Analysis

ROC curve analysis yielded an AUC of 63.6% (95% CI: 47.8%–79.4%). This indicates that if GCT is used for screening prediabetes among 100 patients, an accurate conclusion will be obtained for approximately 63 individuals. The AUC value does not significantly differ from 50% ($p > 0.05$), indicating that GCT's discrimination ability is not statistically better than chance. Clinically, the AUC is unsatisfactory as it falls below the minimum expected AUC of 80%.

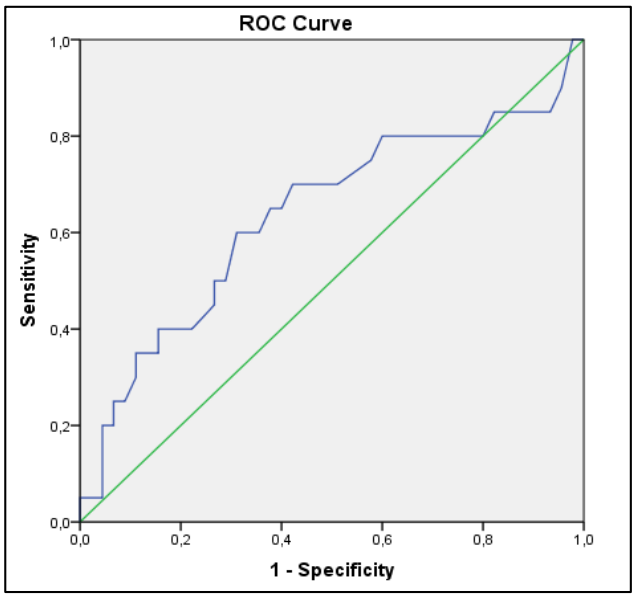

Figure 3. AUC Curve of ROC Method for GCT Values AUC: 63.6% (95% CI: 47.8%–79.4%), p-value: 0.082 (p > 0.05).

The hypothesis test conducted using SPSS compared the obtained AUC of GCT with a reference AUC of 50%. The resulting p-value > 0.05 indicates that the GCT AUC value does not significantly differ from 50%. Clinically, the GCT AUC value is unsatisfactory, as it is lower than the minimum expected AUC of 80%.

2x2 Contingency Table Analysis

Table 2. Diagnostic Test of GCT Method Compared to Prediabetes Status

GCT (Prediabetes)	Prediabetes (IFG & IGT)		Total
	Yes	No	
Yes	8	9	17
No	12	36	48
Total	20	45	65

Key Diagnostic Indicators:

- **Sensitivity:** 40% (95% CI: 19.1%–63.9%)
- **Specificity:** 80% (95% CI: 65.4%–90.4%)
- **Positive Predictive Value (PPV):** 47.06% (95% CI: 24.4%–71.1%)
- **Negative Predictive Value (NPV):** 75% (95% CI: 61.5%–85.7%)
- **Positive Likelihood Ratio (LR+):** 2.00 (95% CI: 0.90–4.42)
- **Negative Likelihood Ratio (LR-):** 0.75 (95% CI: 0.51–1.10)
- **Accuracy:** 67.69%
- **Pre-test Probability:** 30.77%

The sensitivity of GCT was 40%, indicating that 40% of individuals with prediabetes were correctly classified. The specificity was 80%, meaning 80% of healthy subjects were correctly classified. The overall accuracy was 67.69%. The PPV was 47.06%, meaning that if an individual was categorized as prediabetic by GCT, the probability of actually having prediabetes was 47.06%. The NPV was 75%, meaning that if classified as non-prediabetic by GCT, there was a 75% probability of truly not having prediabetes.

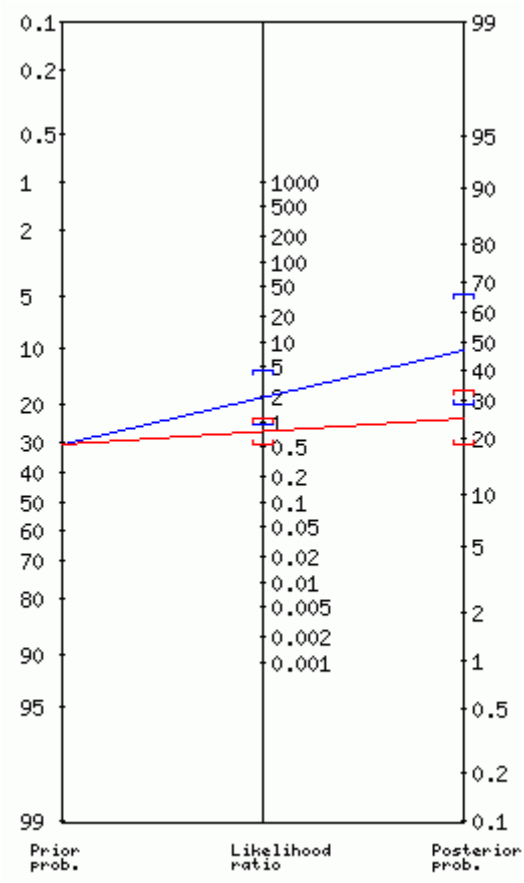

Figure 4. Schematic Comparison of GCT Method and Prediabetes Status

http://araw.mede.uic.edu/cgi-bin/testcalc.pl?DT=8&Dt=12&dT=9&dt=36&2x2=Compute

The LR+ of 2 indicates that a positive GCT result is twice as likely in prediabetic patients compared to healthy individuals. The LR- of 0.75 indicates that a negative result is 0.75 times as likely in prediabetic patients compared to healthy individuals. A PLR ≥10 and NLR ≤0.1 are considered significant for clinical usefulness; GCT does not meet these thresholds.

Using Fagan's nomogram, with a pre-test probability of 30.77% and LR+ of 2, the post-test probability of having prediabetes after a positive test is 47% (95% CI: 29%–66%). One in 2.1 individuals with a positive GCT result is a prediabetic patient. With LR- of 0.75, the post-test probability of not having prediabetes after a negative test is 25% (95% CI: 18%–33%). One in 1.3 individuals with a negative GCT result is normoglycemic.

Subgroup Analysis: GCT Performance for IFG and IGT

Tabel 3. Diagnostic Test of the GCT Method with Impaired Fasting Glucose (IFG) Status

GCT (Prediabetes)	IFG (Impaired Fasting Glucose))		Total
	Yes	No	
Yes	2	15	17
No	5	43	48
Total	7	58	65

Performance for IFG:

- Sensitivity: 28.57% (95% CI: 3.7%–71.0%)
- Specificity: 74.14% (95% CI: 61.1%–84.7%)
- PPV: 11.76% (95% CI: 1.5%–36.4%)
- NPV: 89.58% (95% CI: 80.7%–95.5%)
- LR+: 1.10 (95% CI: 0.32–3.86)
- LR-: 0.96 (95% CI: 0.59–1.58)
- Accuracy: 69.23%

Based on the 2x2 table calculation in Table 5.4, the sensitivity of the Glucose Challenge Test (GCT) compared to IFG status is 28.57%. This indicates that 28.57% of IFG patients are classified as having prediabetes based on GCT results when compared to IFG status. The specificity of the GCT method is 74.14%, meaning that 74.14% of healthy subjects are correctly classified as not having IFG based on GCT results compared to IFG status. The overall accuracy of the GCT method in comparison to IFG status is 69.23%.

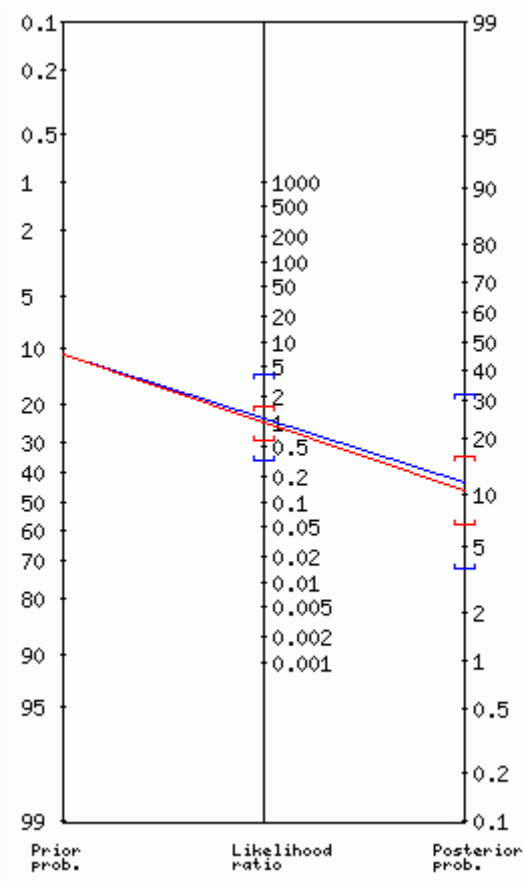

Figure 5. Fagan's Nomogram of the GCT Method with IFG Status

Table 4. Diagnostic Test Table of the GCT Method with IGT Status

GCT (Prediabetes)	IGT (Impaired Glucose Tolerance)		Total
	Yes	No	
Yes	6	11	17
No	7	41	48
Total	13	52	65

Performance for IGT:

- Sensitivity: 46.15% (95% CI: 19.2%–74.9%)
- Specificity: 78.85% (95% CI: 65.4%–88.9%)
- PPV: 35.29% (95% CI: 14.2%–61.7%)
- NPV: 85.42% (95% CI: 74.9%–92.4%)
- LR+: 2.18 (95% CI: 0.99–4.80)
- LR-: 0.68 (95% CI: 0.40–1.15)
- Accuracy: 72.31%

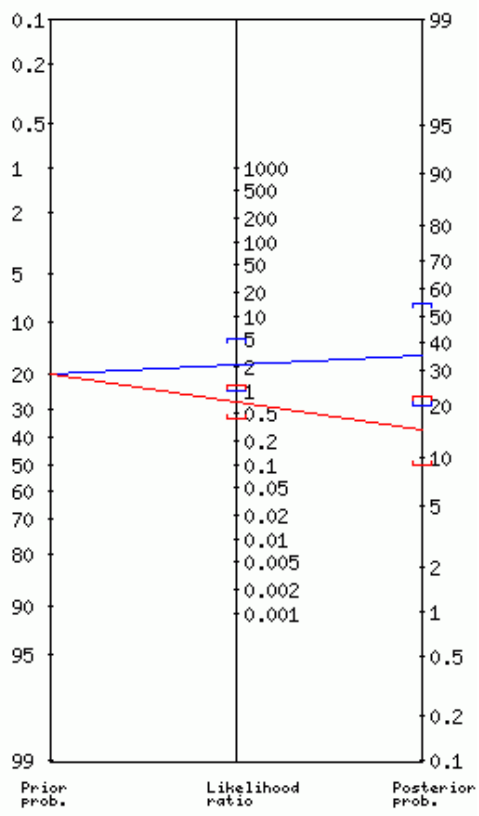

Figure 6. Fagan's Nomogram Simulation of the GCT Method with TGT Status

The subgroup analyses reveal important differences in GCT performance for detecting different prediabetes phenotypes. The sensitivity for IFG (28.57%) was notably lower than for IGT (46.15%), suggesting that GCT may be particularly poor at detecting isolated fasting hyperglycemia. This finding is consistent with the physiological basis of these conditions: IFG primarily reflects hepatic insulin resistance and impaired basal insulin secretion, while IGT is more associated with peripheral insulin resistance and postprandial hyperglycemia. Since GCT measures the post-glucose load response, it performed better for IGT than IFG, though still insufficient for clinical use.

DISCUSSION

The prevalence of prediabetes in this study (30.77%) is comparable to previous findings by Yunir et al.[17] in Jakarta (24.91%) and in Depok (24.25%)[18], but higher than the national estimate of 10% [19] and Southeast Asian estimate of 6.8%[19]. These differences may reflect variations in demographic characteristics, age distribution, socioeconomic status, and cultural factors[20,21,22,23]. The higher prevalence observed in our study population might also indicate the increasing burden of metabolic diseases in urbanizing areas of Indonesia, particularly in regions with high rates of obesity and sedentary lifestyles. These rates are consistent with reports from Pontianak, North Sumatra, East Java, and other Indonesian urban centers[19,24,25]. Recent epidemiological studies in North Sumatra and East Java reported prediabetes prevalence rates of 28.4% and 26.7%, respectively, confirming the widespread nature of this condition across the Indonesian archipelago[26,27].

The sensitivity (40%) and specificity (80%) of GCT at the 140 mg/dL cut-off differ considerably from Phillips et al.[28] (73% and 68%) and Jackson et al.[29] (both 70%). These discrepancies may be attributable to differences in race, gender distribution, and BMI characteristics between study populations. The lower sensitivity observed suggests that GCT, as currently configured with the standard 140 mg/dL cut-off, may be inadequate for detecting prediabetes in the Indonesian population, potentially due to physiological differences in glucose metabolism among different ethnic groups. The relatively high specificity (80%) indicates that GCT performs reasonably well in correctly identifying individuals without prediabetes, as reported in systematic reviews on GCT accuracy across different populations[30,31].

The AUC of 0.63 was lower than the 0.79 reported by Phillips et al.[28] and 0.76 by Jackson et al.[29]. This lower accuracy may be attributed to: (1) limited sample size resulting in unstable estimates; (2) differences in study populations with varying demographics; and (3) the possibility that GCT performance varies across different ethnic groups. The AUC falls within the "poor to fair" category, confirming that GCT's overall diagnostic accuracy is suboptimal for prediabetes screening in this population.

The selection of the 140 mg/dL GCT cut-off point in this study was based on the standard threshold established by the American Diabetes Association (ADA) for gestational diabetes screening[20]. This cut-off was adopted because no validated Indonesian-specific threshold exists for using GCT in prediabetes screening among non-pregnant adults. However, previous studies have investigated various GCT cut-off values for prediabetes screening in non-pregnant populations, demonstrating considerable variability in optimal thresholds, requiring population-specific evaluation[32,33].

Phillips et al.[28] evaluated GCT performance using multiple cut-off points and reported that 140 mg/dL provided reasonable diagnostic efficiency with an AUC of 0.79 for prediabetes detection. Jackson et al.[29] found that lower cut-offs (130-135 mg/dL) improved sensitivity but

reduced specificity, with optimal performance varying by population characteristics. In a study of U.S. veterans, the optimal cut-off for detecting prediabetes was identified at 130 mg/dL, while for diabetes detection, 140 mg/dL performed better[29].

Our finding of low sensitivity (40%) at the 140 mg/dL cut-off suggests that this standard threshold may be too high for detecting prediabetes in the Indonesian population. This discrepancy could be attributed to several factors. First, Asian populations, including Indonesians, tend to have higher postprandial glucose responses despite similar fasting glucose levels compared to Western populations, potentially necessitating lower GCT cut-offs for optimal sensitivity. Second, the predominance of IGT (20%) over IFG (10.8%) in our study population suggests that post-load glucose abnormalities are more common, which may affect the performance of a screening test that measures post-load response. Third, the high proportion of participants with obesity (53.8% Class I, 10.8% Class II) and central obesity (78.5%) reflects a population with significant insulin resistance, which may alter the glucose response curve.

The ROC curve analysis in our study indicated that the optimal cut-off for balancing sensitivity and specificity might differ from the standard 140 mg/dL. However, due to our limited sample size, we were unable to determine a statistically robust optimal cut-off for the Indonesian population. Future research with larger sample sizes should explore population-specific cut-off values that maximize diagnostic accuracy while considering the trade-off between sensitivity and specificity. Such studies should also evaluate the cost-effectiveness and clinical utility of different cut-off thresholds in the Indonesian primary care context. optimal cut-off studies and 1-hour post-glucose criteria for Asian populations[34-35]. Bergman et al. proposed replacing traditional OGTT criteria with 1-hour post-load plasma glucose thresholds of >=155 mg/dL, which may improve early detection of dysglycemia in clinical practice[36].

The positive and negative likelihood ratios (2.0 and 0.75, respectively) suggest only modest changes in post-test probability, indicating limited clinical utility. Although stringent thresholds (PLR >=10, NLR <=0.1) indicate strong clinical utility, GCT's modest LR values suggest limited standalone diagnostic impact. This reinforces the conclusion that GCT, in its current form, provides insufficient diagnostic information to be clinically valuable as a standalone screening tool.

The subgroup analyses reveal important insights. The sensitivity for IFG (28.57%) was notably lower than for IGT (46.15%), suggesting that GCT may be particularly poor at detecting isolated fasting hyperglycemia. This is consistent with the physiological basis of these conditions: IFG primarily reflects hepatic insulin resistance and impaired basal insulin secretion, while IGT is more associated with peripheral insulin resistance and postprandial hyperglycemia. Since GCT measures the post-glucose load response, it performed better for IGT than IFG.

The clinical implications of these findings are significant. An ideal screening test should accurately distinguish between at-risk and healthy individuals. The low sensitivity of GCT (40%) suggests it is not suitable as an initial screening tool, as it may fail to detect many prediabetic individuals who could benefit from early intervention. However, its relatively high specificity (80%) allows it to be considered as a secondary screening option before a confirmatory gold standard test. GCT may be combined with high-sensitivity screening tools, such as risk factor scoring or simple assessments like waist-to-height ratio, to improve overall screening performance. Dadwani et al. demonstrated that alternative screening strategies incorporating HbA1c-based approaches can reduce the number of undiagnosed diabetes cases in high-risk populations[37].

Several prediabetes screening strategies have been identified: (1) opportunistic screening based on age or BMI; (2) clinical prediction rules using electronic medical records and machine learning; and (3) risk scales and questionnaires[38]. The American Diabetes Association recommends risk-based screening for individuals over 10 years old who are overweight or obese and have at least one additional risk factor [20]. According to the 2015 Consensus on Type 2 Diabetes Mellitus Management and Prevention in Indonesia, prediabetes screening is performed in two at-risk populations: asymptomatic high-risk individuals and those over 45 years old without additional risk factors. High-risk asymptomatic individuals include those with BMI ≥23.5 kg/m² and at least one additional risk factor. several validated screening instruments for Indonesian populations, including FINDRISC translations and digital risk assessment tools[39, 40]. The U.S. Preventive Services Task Force recommends screening for prediabetes in adults aged 40-70 years who are overweight or obese[41]. The 50-gram GCT has also been shown to be feasible for detecting dysglycemia in special populations such as patients with cystic fibrosis[42].

GCT has several practical advantages that make it attractive for primary care settings: no fasting requirement, suitability for any time of day, and consistent glucose level measurements[28]. If adopted as a standard screening practice, healthcare providers could administer glucose upon patient registration, collecting blood samples an hour later, optimizing efficiency[29]. GCT is relatively accurate, convenient, widely applicable, and cost-effective for populations such as Indonesia[28,29].

However, our findings suggest that the current GCT protocol with the 140 mg/dL cut-off may not be optimal for prediabetes screening in Indonesian primary care settings. Several modifications could be considered to improve its performance: (1) adjusting the cut-off value based on local population characteristics, as shown by the ROC curve analysis where optimal cut-off values may differ from standard thresholds; (2) combining GCT with risk factor assessment to create a more comprehensive screening approach; (3) using GCT as a secondary screening tool following initial risk stratification; and (4) implementing GCT specifically in high-risk populations where the pre-test probability is higher, potentially improving its positive

predictive value.

This study has several limitations. First, it was conducted in a single region of Indonesia, with most participants being Malay-Mongoloid, limiting generalizability. Second, female participants predominated (84.6%), which may not reflect the general population distribution. Third, the sample size was insufficient for statistically significant results, as reflected in wide confidence intervals. The large reduction from 213 initially recruited participants to 65 included in the final analysis may have introduced selection bias. A post-hoc power calculation indicated that the study had approximately 35% power to detect an AUC of 0.65 significantly different from 0.50 at $\alpha = 0.05$, well below the conventional 80% threshold. Fourth, the study did not include HbA1c as a comparative diagnostic method. Fifth, the cross-sectional design limits assessment of GCT's prognostic value in predicting future diabetes development.

Future research should address these limitations through: larger, multicenter studies with diverse populations; studies specifically designed to determine optimal GCT cut-off values for different demographic groups; cost-effectiveness analyses comparing GCT with other screening strategies; prospective studies evaluating long-term outcomes; and studies examining the combination of GCT with other simple screening tools to enhance diagnostic performance.

CONCLUSIONS

The prevalence of prediabetes in this study population was 30.77%, comparable to other urban Indonesian populations but higher than national estimates. The GCT demonstrated sensitivity of 40%, specificity of 80%, and AUC of 63.6% (95% CI: 47.8%–79.4%; $p = 0.082$), indicating poor diagnostic accuracy that does not significantly differ from chance. With 20 prediabetes cases ($N = 65$), the wide confidence intervals preclude precise estimation of GCT performance.

As a pilot study, these findings do not support the use of GCT at the standard 140 mg/dL cut-off as a standalone prediabetes screening tool in Indonesian primary care. However, the sample size was insufficient to determine whether modified cut-off values or multi-stage screening strategies could improve performance. Larger, adequately powered studies (estimated $N \geq 230$) are needed to establish population-specific cut-off values and to evaluate GCT as part of a multi-stage screening algorithm before any clinical recommendation can be made. Screening tests help identify at-risk individuals but are not diagnostic; individuals with positive findings should seek medical evaluation for confirmation and appropriate management.

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AUTHOR CONTRIBUTIONS

Conceptualization, Y.A.J., R.Y., and E.M.; methodology, Y.A.J., R.Y., and H.A.W.; validation, R.Y., R.N.A., and L.R.; formal analysis, Y.A.J. and H.A.W.; investigation, Y.A.J., R.Y., H.A.W., R.N.A., L.R., and E.M.; resources, Y.A.J., R.Y., and E.M.; data curation, Y.A.J., H.A.W., and R.N. WeA.; writing—original draft preparation, Y.A.J., H.A.W., and R.N.A.; writing—review and editing, Y.A.J., R.Y., L.R., and E.M.; visualization, Y.A.J. and H.A.W.; supervision, Y.A.J., R.Y., and E.M.; project administration, Y.A.J. and R.Y.; funding acquisition, Y.A.J. and E.M. All authors have read and approved the final manuscript.

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