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Evaluating the performance of TAG-IT for prediabetes detection in Indonesian population

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ABSTRACT

Early detection of prediabetes plays a critical role in preventing type 2 diabetes mellitus (T2DM), especially within primary care, where access to laboratory testing may be constrained. Non-laboratory-based risk assessment instruments, including the tool to assess the likelihood of fasting glucose impairment (TAG-IT), can facilitate preliminary risk screening. This study sought to determine the diagnostic accuracy of the TAG-IT questionnaire in detecting prediabetes, using the oral glucose tolerance test (OGTT) as the reference standard. A cross-sectional design was implemented across three community health centers in the Special Region of Yogyakarta, Indonesia. Although 308 individuals were initially enrolled, only 93 participants with complete datasets were eligible for final analysis. The discriminative capacity of TAG-IT was evaluated through receiver operating characteristic (ROC) curve analysis along with a contingency table. Among the participants analyzed, 24,7% (23/93) were classified as having prediabetes. The TAG-IT tool exhibited modest discriminatory performance, yielding an AUC of 0.656 (95% CI 0.525–0.786; p = 0.026). Using the identified optimal threshold, sensitivity reached 52.2% while specificity was 67.1%. The negative predictive value was 81.0%, indicating better performance in excluding low-risk individuals. Overall, TAG-IT demonstrated moderate utility as a preliminary screening instrument in primary healthcare, particularly for identifying individuals unlikely to have prediabetes.

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1. INTRODUCTION

Prediabetes, which encompasses impaired fasting glucose (IFG) and impaired glucose tolerance (IGT), represents an intermediate metabolic state associated with a substantially increased likelihood of developing type 2 diabetes mellitus (T2DM). This condition has been widely investigated due to its strong predictive value for future diabetes and its occurrence across diverse population groups [1]-[3]. According to recent estimates from the International Diabetes Federation (IDF), the global age-standardized prevalence in 2021 was approximately 9.1% for IGT and 5.8% for IFG. Projections suggest a further increase by 2045, reaching about 10.0% for IGT and 6.5% for IFG. The most marked relative growth is anticipated in low-income countries [1]. IDF reports also highlight that Indonesia ranks among the countries with the highest number of

adults living with diabetes, both currently and in future projections for 2050, and remains within the top ten nations for undiagnosed diabetes in 2024, with an estimated 73.2% of cases yet to be identified [3].

Prediabetes represents a reversible metabolic state that frequently remains undiagnosed in community settings [4]. Many individuals with prediabetes remain undiagnosed because elevated blood glucose levels typically do not produce noticeable clinical manifestations until progression to type 2 diabetes mellitus (T2DM) occurs [2]. Implementing screening strategies allows earlier identification and intervention during this intermediate metabolic stage, which is still potentially reversible and therefore critical for preventing long-term complications [2], [5], [6]. The diagnosis of prediabetes is commonly established through fasting plasma glucose (FPG), oral glucose tolerance testing (OGTT), or measurement of glycated hemoglobin (HbA1c) [5], [7]. Nevertheless, these diagnostic approaches depend on laboratory facilities and entail financial and logistical constraints, limiting their feasibility for widespread application in large populations such as Indonesia.

There is a clear need for screening instruments that are practical, noninvasive, well accepted by the community, and economically feasible to support early identification of prediabetes. An effective tool should demonstrate sufficient sensitivity to detect individuals at elevated risk while maintaining adequate specificity to reduce misclassification, including both false-positive and false-negative results [4], [8]-[11].

Several risk assessment instruments have undergone validation in the Indonesian setting, including the Indonesian Prediabetes Risk Score (INA-PRISC) and the American Diabetes Association (ADA) diabetes risk questionnaire. The INA-PRISC, which was specifically developed and tested within the Indonesian population, demonstrated a sensitivity of 55.11% and a specificity of 65.81% [12]. In addition, the ADA diabetes risk questionnaire has been translated and validated locally, yielding sensitivity and specificity values of 61% and 71%, respectively [13].

The tool to assess the likelihood of fasting glucose impairment (TAG-IT) was originally introduced in the United States as a brief, questionnaire-based instrument designed to estimate the probability of impaired fasting glucose using demographic and clinical risk indicators. In its initial validation study, TAG-IT demonstrated better discriminative performance than body mass index (BMI) alone, achieving an area under the curve (AUC) of 0.744. When a cut-off score of ≥5 was applied, the tool showed high sensitivity (87.0%), supporting its use for large-scale screening purposes. Conversely, applying higher cut-off values (≥8 and ≥9) increased specificity to 78.8% and 87.9%, respectively, thereby improving its ability to correctly identify individuals without the condition [14]. Although these findings indicate favorable performance in the original study population, evidence regarding its applicability and diagnostic accuracy in the Indonesian context remains limited.

This study was conducted to assess the diagnostic performance of the TAG-IT questionnaire in identifying prediabetes among adults visiting three primary healthcare (PHC) centers in Yogyakarta, with the oral glucose tolerance test (OGTT) serving as the reference standard. The results are intended to provide evidence that may support the development of efficient and economically feasible screening approaches for prediabetes within PHC services. To the best of our knowledge, this investigation is the first study to examine the validity of TAG-IT in an Indonesian population.

2. METHOD

2.1. Study design

A cross-sectional diagnostic accuracy study was conducted to determine the ability of the TAG-IT questionnaire to detect prediabetes. The study reporting adhered to the STARD 2015 guidelines for diagnostic accuracy research. Ethical approval was obtained from the Faculty Research Ethics Committee prior to data collection.

2.2. Study setting

The research was carried out in three primary healthcare centers (PHCs) located in Yogyakarta, Indonesia. Participant recruitment and data collection took place between June-August 2019, encompassing initial screening, administration of questionnaires, and oral glucose tolerance testing (OGTT).

2.3. Participants and sampling

Individuals aged 20 years or older who were registered at the selected PHCs were approached using PHC records. Eligible participants had no previous diagnosis of diabetes mellitus, were able to complete the TAG-IT questionnaire, and provided written informed consent to undergo OGTT examination. Exclusion criteria comprised pregnancy, acute or severe medical conditions, current use of medications known to influence glucose metabolism, and inability to complete both the questionnaire and laboratory procedures. The minimum required sample size was estimated at 307 participants, calculated based on an anticipated sensitivity of 75%, a precision level of 5%, and a 95% confidence interval.

2.4. TAG-IT instrument and translation

The TAG-IT questionnaire includes demographic and clinical risk indicators such as age, sex, body mass index (BMI) category, family history of diabetes, and antihypertensive treatment status. The original English version was translated into Bahasa Indonesia using a forward-translation approach, followed by review by experts to ensure linguistic clarity and cultural appropriateness. A formal back-translation process and psychometric evaluation were not performed. The translation process is illustrated in Figure 1.

2.5. OGTT procedure

All enrolled participants underwent a standard 75-g oral glucose tolerance test in accordance with World Health Organization (WHO) recommendations [12]. Venous blood samples were obtained after overnight fasting and again two hours following glucose ingestion. Plasma glucose concentrations were measured in a certified laboratory facility. Prediabetes was defined as impaired fasting glucose (IFG; fasting plasma glucose 100–125 mg/dL), impaired glucose tolerance (IGT; 2-hour plasma glucose 140–199 mg/dL), or the presence of both abnormalities [13]. Samples affected by pre-analytical issues, including hemolysis or delayed processing, were documented and excluded when results were deemed unreliable.

2.6. Data collection procedure

Participants first completed the TAG-IT questionnaire, followed by anthropometric assessment prior to undergoing OGTT. Body measurements were obtained by trained PHC personnel using standardized procedures. The overall study process is presented in the flow diagram in Figure 2.

2.7. Statistical analysis

Diagnostic accuracy indicators were derived from a 2×2 contingency table (Table 1), including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive and negative likelihood ratios (LR+ and LR−), and overall accuracy. Receiver operating characteristic (ROC) curve analysis was performed to assess discriminative ability, and the area under the curve (AUC) was interpreted according to established benchmarks. The optimal cut-off point was determined using the Youden Index, as recommended in diagnostic validation studies [15]. The prevalence of prediabetes was calculated with corresponding 95% confidence intervals. Statistical analyses were conducted using SPSS version 22 (IBM Corp., Armonk, NY, USA), with two-sided p-values <0.05 considered statistically significant.

(Tool to Assess Likelihood of Fasting Glucose Impairmentт)

No.	Criteria		Score
1.	Age	20–27 years	0
2.	Sex	28–43 years	1
		44–59 years	2
		60 and abe	3
3.	Men	Men	1
4.	Body Mass Index (BMI) category	Less 2on	0
		25–29.9	2
5.	Family History of Diabetes	Yes	3
6.	Hypertension	Yes	0
		SBP/DBP	0
		SBP 90-99	1
		SBP 100-109	2
		Yes	5
7.	Other	No	1
	Total Score (maximum 16)		

Source: https://www.aanandmd.org/tag-it/content/full/66/5/1

Figure 1. Translation of TAG-IT into Indonesian language

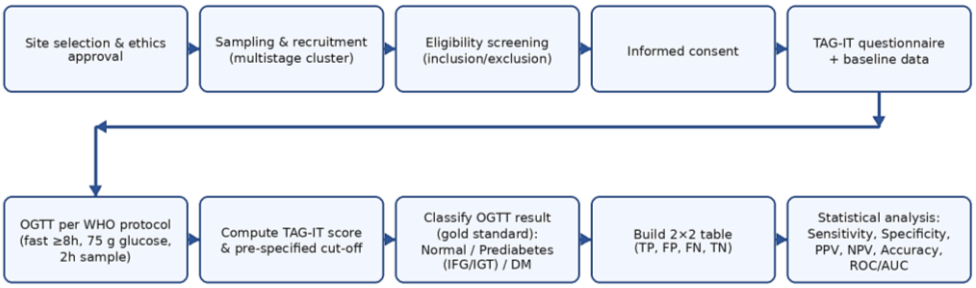

Figure 2. Research workflow for TAG-IT validation study

Table 1. Cross-tabulation of TAG-IT vs OGTT for prediabetes screening

TAG-IT	OGTT (Gold standard)	
	Positive (Prediabetes)	Negative (Normoglycemia)
TAG-IT Positive	TP	FP
TAG-IT Negative	FN	TN

3. RESULTS AND DISCUSSION

The study was carried out in two regencies within the Special Region of Yogyakarta, Indonesia, involving three primary healthcare centers *(puskesmas)*: Depok II and Ngaglik in Sleman Regency, and Banguntapan II in Bantul Regency. Ethical clearance was granted by the Medical and Health Research Ethics Committee, Faculty of Medicine, Universitas Islam Indonesia.

Initially, 308 individuals consented to participate and were enrolled in the study. However, only participants with complete and reliable datasets were included in the final analysis. Participant attrition occurred for several reasons. Respondent-related factors included failure to attend scheduled blood examinations and non-adherence to fasting instructions prior to OGTT. Laboratory-related issues comprised hemolyzed samples, delayed plasma processing, improper transportation or storage conditions, and extended time intervals between specimen collection and analysis. Additionally, research-related factors such as documentation errors and suboptimal quality control procedures contributed to data exclusion. Consequently, incomplete or unreliable records were removed from the final dataset.

3.1. Participant flow and characteristics

A total of 93 participants met all study criteria and were included in the final analysis. The demographic and clinical profiles are presented in Table 2. Among the participants, 27 (29.0%) were male, and 66 (71.0%) were female, with the majority belonging to the middle-aged category. The largest age group was 45–64 years, representing 45.2% of the sample.

Central obesity was highly prevalent, observed in 61 participants (65.6%), while 43.0% were categorized as having class I obesity. Based on OGTT results, the prevalence of prediabetes was 24.7% (23 out of 93 participants). Specifically, 7.5% were classified as having impaired fasting glucose (IFG), and 17.2% had impaired glucose tolerance (IGT). Among individuals identified with prediabetes, the mean fasting plasma glucose level was 92.52 ± 9.88 mg/dL, and the mean 2-hour post-load glucose concentration was 146.95 ± 28.9 mg/dL.

Table 2. Basic characteristics of study participants

	Characteristic	Prediabetes (n=23)	Normoglycemia (n=70)
Sex, n (5)	Male	6 (26.1)	21 (30.0)
	Female	17 (73.9)	50 (70.0)
Age (years)	Mean ± SD	45.3 ± 12.9	39.0 ± 13.1
	Age group 45–64 years, n (%)	13 (56.5)	29 (41.4)
Anthropometric measures	Body weight (kg), mean ± SD	61.5 ± 13.0	65.1 ± 15.1
	Height (cm), mean ± SD	155.0 ± 9.3	155.6 ± 8.6
	Waist circumference (cm), mean ± SD	87.3 ± 12.8	85.9 ± 11.5
BMI category, n (%)*	Normal or underweight (<23 kg/m²)	4 (17.4)	25 (35.7)
	Overweight/pre-obese (23–24.9 kg/m²)	2 (8.7)	8 (11.4)
	Obesity (≥25 kg/m²)	17 (73.9)	37 (52.9)
	Mean BMI (kg/m²), mean ± SD	26.2 ± 3.9	25.3 ± 4.2
Central obesity, n (%)	Yes	17 (73.9)	44 (62.9)
Family history of diabetes, n (%)	Yes	4 (17.4)	0 (0.0)
Blood pressure (mmHg)	Systolic BP, mean ± SD	122.2 ± 17.3	118.8 ± 13.5
	Diastolic BP, mean ± SD	80.4 ± 10.2	78.1 ± 8.7
Plasma glucose levels (mg/dL)*	Fasting plasma glucose, mean ± SD	92.5 ± 9.9	83.0 ± 10.8
	2-hour OGTT glucose, mean ± SD	147.0 ± 28.9	103.2 ± 17.03

3.2. Diagnostic performance of TAG-IT

The performance of the TAG-IT questionnaire in detecting prediabetes was evaluated using two analytical approaches: receiver operating characteristic (ROC) curve analysis and calculation of diagnostic accuracy measures derived from a 2×2 contingency table (see Table 3).

3.2.1. ROC curve analysis

As illustrated in Figure 3, ROC curve analysis produced an area under the curve (AUC) of 0.656 (95% CI 0.525–0.786; p = 0.026), indicating modest discriminative capacity of TAG-IT in differentiating individuals with prediabetes from those with normal glucose tolerance (Figure 4). The optimal cut-off value determined using Youden's index demonstrated comparable diagnostic performance to the predefined scoring threshold.

Although the AUC reflects limited accuracy, it remained significantly above the reference value of 0.50, suggesting that the instrument performs better than random classification.

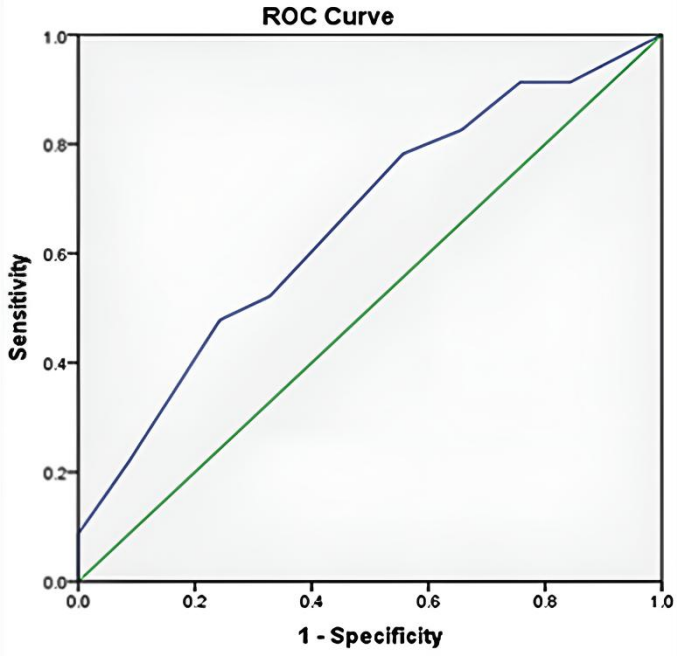

Figure 3. AUC Curve from the ROC Method for TAG-IT Values. Area under the curve (AUC): 65.6% (95% CI: 52.5%–78.6%), p-value: 0.026 ($p < 0.05$)

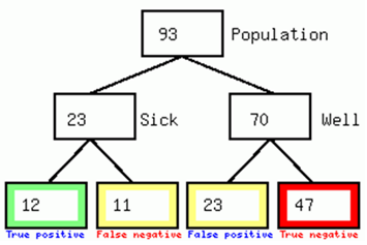

Figure 4. Schematic comparison of TAG-IT compared with OGTT-based prediabetes status

3.2.2. Contingency table analysis

To provide a clearer representation of the agreement between TAG-IT classification and OGTT-confirmed prediabetes status, Figure 4 presents the distribution of true positive, false positive, false negative, and true negative results derived from the 2×2 contingency table (Table 3). Among the 93 participants analyzed, 23 were diagnosed with prediabetes based on OGTT, corresponding to a pre-test probability of 24.7%, while 70 were classified as normoglycemic. TAG-IT correctly identified 12 true positive and 47 true negative cases; however, 11 individuals with prediabetes were misclassified as low risk (false negatives), and 23 normoglycemic participants were incorrectly categorized as high risk (false positives).

These distributions correspond to a sensitivity of 52.2% and a specificity of 67.1%, with an overall classification accuracy of 63.4%. The positive predictive value was 34.3%, whereas the negative predictive value reached 81.0%, indicating better performance in excluding individuals without prediabetes. The positive likelihood ratio (LR+) of 1.58 and negative likelihood ratio (LR−) of 0.71 further suggest modest shifts from pre-test to post-test probability, consistent with the moderate discriminative ability observed in this study.

To further illustrate the clinical implications of the diagnostic performance of TAG-IT, a Fagan's nomogram was constructed (Figure 5). This graphical tool demonstrates how the likelihood ratios derived from the study modify the pre-test probability of prediabetes into a post-test probability. As shown in Figure 5, using

a pre-test probability of 24.7%, a positive TAG-IT result (LR+ = 1.58) increases the post-test probability only modestly, indicating limited ability to substantially confirm prediabetes. Conversely, a negative TAG-IT result (LR− = 0.71) reduces the probability to a lower level, although the reduction is moderate. These findings suggest that TAG-IT has greater utility as an initial risk stratification tool to help exclude individuals at lower risk rather than as a definitive diagnostic instrument.

Table 3. Diagnostic performance of TAG-IT compared with OGTT-based prediabetes status

TAG-IT result	Prediabetes	Normoglycemia	Total
Positive	12	23	35
Negative	11	47	58
Total	23	70	93

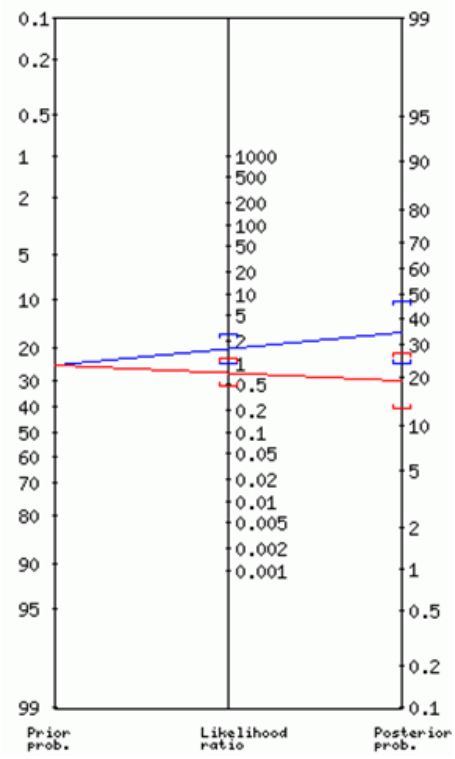

Figure 5. Fagan's Nomogram of TAG-IT compared with OGTT-based prediabetes status

3.3. Interpretation of findings

This study was conducted to assess the validity of TAG-IT as a screening instrument for prediabetes in Indonesian primary healthcare settings. To the best of our knowledge, this represents the first attempt to examine the performance of TAG-IT within an Indonesian population. The findings indicate that the tool has limited discriminative capacity, as reflected by a relatively modest area under the ROC curve. Although specificity was moderate, sensitivity ranged from low to moderate, suggesting that a considerable proportion of individuals with prediabetes may not be correctly identified. In addition, the calculated likelihood ratios produced only small shifts in post-test probability, limiting its value as a single, stand-alone screening method. Collectively, these results imply that TAG-IT may be better utilized for preliminary risk stratification rather than as a replacement for confirmatory laboratory-based glucose testing.

The diagnostic performance observed in this study appears lower than that reported in the original development and validation research conducted in the United States by Koopman et al., where the tool achieved an AUC of approximately 0.74 for detecting impaired fasting glucose and previously undiagnosed diabetes using NHANES population data [14]. A later modification designed for adolescent populations (TAG-IT-A) demonstrated reduced discriminative ability, with an AUC of around 0.61, suggesting diminished performance when applied to different age groups [16]. Compared with these prior findings, the lower AUC and sensitivity identified in the present study indicate that TAG-IT performance may decrease when implemented in populations with distinct demographic characteristics, body composition patterns, and metabolic risk profiles.

These results underscore the importance of conducting local validation studies and, when necessary, contextual adaptation before applying risk prediction tools across diverse populations [17].

When evaluated alongside other commonly used non-laboratory risk assessment tools, the diagnostic accuracy of TAG-IT in this study appears comparatively lower. Previous investigations have shown that the Finnish Diabetes Risk Score (FINDRISC) generally achieves moderate discriminative performance in identifying prediabetes and undiagnosed diabetes, with reported AUC values frequently ranging between 0.70 and 0.80 in diverse populations [18]-[23]. A systematic review including 25 cross-sectional studies documented AUC estimates spanning 0.649 to 0.755, sensitivity ranging from 53.1% to 84.7%, and false-positive rates between 21.8% and 54.8% [24]. Comparable levels of discrimination have also been reported for the ADA diabetes risk test, which has demonstrated moderate AUC values in both Western and Asian populations [12], [13], [20], [25], [26].

In comparison, the AUC obtained for TAG-IT in the present study was lower and accompanied by reduced sensitivity, suggesting a more limited capacity to differentiate individuals with prediabetes from those with normal glucose regulation. Although TAG-IT, FINDRISC, and the ADA risk test share the advantage of being questionnaire-based and non-invasive, the findings indicate that TAG-IT may offer less discriminatory strength relative to other instruments that have undergone broader validation and, in some cases, adaptation to specific populations.

Evidence from Asian countries, including Indonesia, further emphasizes the importance of validating diabetes risk scores within local contexts. Research conducted in Southeast Asia has demonstrated considerable variability in the performance of widely used tools such as FINDRISC and the ADA risk test, with AUC values ranging from moderate to good depending on population characteristics and metabolic risk profiles [12], [13], [20], [25], [26]. In Indonesia, validation studies of the ADA risk questionnaire and modified versions of FINDRISC have typically shown moderate discrimination, yet consistently high sensitivity or specificity has not been observed across different regions [19], [25]. Within this regional perspective, the performance of TAG-IT identified in the present study does not appear to exceed that of other non-laboratory screening tools previously evaluated in Indonesian settings. Overall, these findings reinforce the notion that the effectiveness of risk prediction models is strongly influenced by demographic and epidemiological differences, underscoring the necessity of population-specific validation prior to large-scale implementation in primary healthcare services.

Several methodological and population-specific considerations may account for the relatively lower AUC and sensitivity of TAG-IT identified in this study. First, variations in demographic and metabolic characteristics, such as age distribution, central adiposity patterns, and genetic predisposition, may limit the transferability of a risk score originally derived from Western populations. It is well established that Asian populations, including Indonesians, tend to develop dysglycemia at lower body mass index (BMI) and waist circumference thresholds compared with Western cohorts, potentially reducing the discriminative performance of tools that apply conventional anthropometric cut-offs [27]-[29].

Second, the moderate prevalence of prediabetes observed in this sample may have influenced predictive measures and overall test performance, as disease prevalence directly affects predictive values and may indirectly impact sensitivity and AUC estimates. Third, discrepancies in the reference standard used could also contribute to performance variation. While TAG-IT was initially designed to detect impaired fasting glucose, the present study employed the oral glucose tolerance test (OGTT) as the diagnostic benchmark, thereby identifying a broader range of dysglycemic conditions, including isolated impaired glucose tolerance. Collectively, these biological, epidemiological, and methodological differences likely contributed to the diminished performance of TAG-IT in this context and highlight the importance of contextual modification and recalibration before applying the tool in Indonesian primary healthcare settings.

Overall, the comparative results suggest that although TAG-IT may have utility for preliminary risk assessment, it should not be regarded as a substitute for laboratory-based diagnostic testing in Indonesian primary care. This interpretation aligns conceptually with experiences from other non-invasive risk scores, such as FINDRISC, which demonstrated improved accuracy in Asian populations after adjustments to anthropometric thresholds and recalibration of risk weighting [30]. In contrast, TAG-IT has not yet undergone systematic modification for Indonesian or broader Asian populations, which may explain its limited discriminative capacity in the current study. These findings therefore provide empirical justification for locally recalibrating internationally developed screening tools prior to integration into national screening strategies. Population-specific adaptation may enhance diagnostic sensitivity and clinical applicability, ensuring that screening approaches are tailored to local epidemiological profiles and healthcare needs.

With appropriate adjustments, TAG-IT may still offer value as a complementary screening instrument within Indonesian primary healthcare settings. In Puskesmas, where access to laboratory examinations can be constrained, a brief and non-invasive questionnaire such as TAG-IT could help healthcare providers identify individuals who warrant further biochemical evaluation. By functioning as an initial triage tool, it may enhance

the efficiency of case detection and optimize the allocation of limited diagnostic resources. This approach is consistent with national efforts to strengthen early identification of non-communicable diseases through Posbindu PTM and primary care–based initiatives promoted by the Ministry of Health of Indonesia [31], [32]. Within this framework, a sequential screening model, applying a risk score as a preliminary filter followed by confirmatory blood glucose testing, may represent a practical and economically feasible strategy to expand prediabetes detection while avoiding unnecessary laboratory procedures.

Several considerations are important when interpreting the present findings. Although the sample size was initially calculated to achieve adequate statistical precision, the final number of participants included in the analysis was considerably reduced. This attrition resulted from participant non-compliance, pre-analytical laboratory issues affecting specimen quality, and data management challenges encountered during field implementation. The smaller analytical sample may have reduced the precision of diagnostic accuracy estimates, as reflected in relatively wide confidence intervals, and may have influenced sensitivity and specificity calculations. Therefore, this study should be regarded as a preliminary or exploratory validation of TAG-IT within the Indonesian primary care context rather than a conclusive evaluation of its performance. While the results provide useful initial insights into the applicability of the tool, further confirmation through larger, multi-center investigations with strengthened quality control procedures is warranted.

4. CONCLUSION

In summary, this study presents locally generated evidence regarding the diagnostic performance of TAG-IT in Indonesian primary healthcare settings, indicating that its ability to discriminate individuals with prediabetes is modest when applied without population-specific modification. As the first study to examine TAG-IT in an Indonesian context, the findings add to the broader literature suggesting that internationally developed, non-laboratory risk assessment tools require local validation before implementation.

Rather than suggesting immediate widespread use, the results emphasize the importance of contextual adaptation and thoughtful integration of risk-based screening instruments into existing healthcare systems. The present findings therefore serve as an initial reference point for improving prediabetes screening approaches in Indonesia and support ongoing efforts to refine or recalibrate tools so that they better reflect the characteristics and risk profiles of the local population.

5. STUDY LIMITATIONS

Several limitations of this study merit consideration. First, the number of participants included in the final analysis was considerably lower than the initially calculated minimum sample size, which may have diminished statistical power and reduced the precision of the estimated diagnostic accuracy measures. Second, as the research was conducted in only three primary healthcare centers in Yogyakarta, the findings may not be fully representative of other regions across Indonesia. Third, the cross-sectional nature of the study confines interpretation to concurrent diagnostic performance and does not permit evaluation of the tool's ability to predict future progression to diabetes.

Diagnostic accuracy studies may be influenced by sample size constraints and spectrum bias, particularly when conducted in single-center primary care settings. Additionally, risk score performance is known to vary across populations due to ethnic and epidemiological differences [4], [15], [17]. These limitations may restrict the broader applicability of the study findings. In addition, potential pre-analytical and analytical challenges in blood specimen processing may have influenced OGTT measurements, despite the implementation of quality control procedures. Furthermore, several risk factors were obtained through self-report, introducing the possibility of recall bias. Taken together, these limitations suggest that the results should be interpreted with caution and reinforce the need for larger-scale, prospective studies to validate and extend the present findings.

6. FUTURE RESEARCH

The limitations observed in this study suggest several avenues for subsequent investigation. Future research should focus on tailoring TAG-IT to the Indonesian population through recalibration of risk factor weighting and adjustment of anthropometric thresholds, particularly for body mass index and waist circumference, to better reflect local metabolic risk patterns. Such modifications may enhance sensitivity and improve overall discriminative capacity in Asian populations.

Moreover, prospective cohort studies are necessary to evaluate the predictive value of TAG-IT in identifying individuals at risk of progressing from prediabetes to overt diabetes, as this longitudinal assessment cannot be addressed within a cross-sectional framework. Further studies could also examine the feasibility of integrating simplified risk scores into digital screening platforms, facilitating linkage with existing non-

communicable disease surveillance systems and routine primary healthcare services. Advancing these research directions would contribute to the development of scalable and context-specific screening strategies, thereby strengthening the implementation of risk-based approaches in diabetes prevention efforts across Indonesia.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest, affirming the integrity and objectivity of this study.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study. All participants were informed about the study objectives, procedures, potential risks, and benefits, and they voluntarily agreed to participate by signing a written consent form prior to data collection.

ETHICAL APPROVAL

The research related to human use has complied with all relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration. This study was reviewed and approved by the Research Ethics Committee of the Faculty of Medicine, Universitas Islam Indonesia (Approval No. 24/Ka.Kom.Et/70/KE/VII/2018).

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, [YAJ], upon reasonable request. Due to privacy and ethical restrictions, the dataset is not publicly available as it contains information that could compromise the confidentiality of research participants.

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