# Comparison of three methods for diabetes screening in a rural clinic in Honduras

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**ABSTRACT**

**Objective.** *To evaluate two alternatives to the fasting plasma glucose (FPG) test for diabetes screening in Latin America.*

**Methods.** *Eight hundred adults without diabetes were recruited in a primary care clinic in Honduras. An equation-based screening formula, incorporating a random capillary glucose test and other risk factors, was used for initial screening. All patients with a screening-based probability of diabetes ≥ 20%, plus one-fifth of those with a probability < 20%, were asked to return for FPG and point-of-care hemoglobin A1c (POC-A1c) tests. An FPG ≥ 126 milligrams per deciliter and a POC-A1c ≥ 6.5% were used as gold standards to assess the performance of the screening equation. The association between the POC-A1c and the FPG tests was examined as were patient factors associated with failure to return for follow-up and variation in diabetes risk across subgroups.*

**Results.** *The screening equation had excellent test characteristics compared with FPG and POC-A1c. Using the FPG gold standard, the POC-A1c had a sensitivity of 77.8% and a specificity of 84.9%. With an A1c cutoff of 7%, POC-A1c specificity increased to 96.2%. Thirty-four percent of patients asked to return for follow-up testing failed to do so. Those who failed to return were more likely to be men and to have hypertension.*

**Conclusions.** *Both the screening equation and POC-A1c are reasonable alternatives to an FPG test for identifying patients with diabetes. Given the barriers to currently recommended screening procedures, these options could have important public health benefits in Latin America.*

**Key words** Diabetes mellitus, type 2; rural population; diagnosis; diagnostic techniques and procedures; Honduras.

The global prevalence of diabetes mellitus is expected to double from 171 million to 366 million between 2000 and 2030, and developing countries will likely experience 80% of this burden (1, 2). Many countries in Latin America are witnessing an epidemiologic transition that is a fundamental cause of their growing diabetes epidemic (3). In particular, with the success of efforts to control communicable diseases and a demographic shift to lower fertility, the Honduran population is aging (3, 4). Lifestyle changes, such as less physical activity, are being documented throughout Latin America as a result of migration from rural to urban areas (1, 5). Moreover, direct foreign investment in the food sector and profits from heavily marketed processed foods and beverages have pushed Latin America into a nutrition transition from traditional diets toward diets rich in fats, sugar, and salt (1, 2).

Recent statistics demonstrate that rates of type 2 diabetes are increasing in Honduras. A study in the capital city of Tegucigalpa in 2003–2004 put the adult prevalence at 7.8% and indicated that 42% of people with the disease were unaware of their condition (6). This prevalence estimate is consistent with that reported in other large Latin American cities (e.g., 4.5% in Lima and 9.5% in Mexico City in

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2005) (7). In 2003, Honduras incurred social costs of diabetes (including lifetime forgone earnings due to premature mortality and disability) that approached US $126 million and direct medical costs of nearly $114 million (5). In a country where more than 87% of health care payments are out of pocket (8) and where diabetes-reporting programs are rare and underestimate the true prevalence of disease (6), the economic burden of diabetes is likely to be tremendous.

Currently, the American Diabetes Association recommends screening for type 2 diabetes if an individual has one or more of the following risk factors: diabetes diagnosed in a first-degree relative, hypertension, cardiovascular disease, lipid metabolism disorders, obesity (body mass index (BMI) > 27 kilograms per meter squared), history of gestational diabetes, or age greater than 45 years (9). However, there is little consensus about the most effective and efficient means of screening in developing countries that lack comprehensive health systems or adequate coverage for health care (10). In such areas, the lack of access to screening and diagnostic services may result in missed opportunities to detect diabetes (11).

According to the World Health Organization, the 75-gram oral glucose tolerance test (OGTT) remains the gold standard for diagnosing diabetes. However, the OGTT is difficult to implement and prohibitively costly for resource-poor health care systems (12–14). Many authorities prefer fasting plasma glucose (FPG) as a diagnostic test because it is more convenient for the patient than OGTT, less costly and time-consuming, and has superior repeat-test reproducibility (14). However, FPG testing often requires a second visit to ensure that the patient is fasting. The added out-of-pocket costs of those visits and the logistic burden may mean that large numbers of diabetes patients go unidentified (14), even if tests are free of charge (11, 15).

Laboratory-based glycosylated hemoglobin (A1c) testing has recently been recommended for diabetes screening by the American Diabetes Association, the European Association for the Study of Diabetes, and the International Diabetes Federation (14). Laboratory A1c tests are an attractive alternative to the FPG, because they do not require that the patient fast and they may provide more stable results given fluctuations in FPG concentrations (14). However, as with other laboratory-based measures, A1c testing may be unavailable in Latin American clinics with inadequate resources geographically distant from testing centers.

One alternative to lab-based A1c is the point-of-care A1c test (POC-A1c). A variety of POC-A1c devices are available, employing assays certified by the Diabetes Control and Complication Trial/National Glycohemoglobin Standardization Program and the International Federation of Clinical Chemistry (16). However, POC-A1c has not been recommended as a substitute for lab-based A1c tests because of concerns about quality control and the variability in POC instruments (16). Nevertheless, POC-A1c may be an important alternative to lab-based A1c tests, especially for patients facing financial or transportation constraints (17). A study comparing a POC-A1c with a lab-based A1c test showed a sensitivity of 81.8% and a specificity of 93.3% when using a POC-A1c cut point of 7% (18). To date, no POC-A1c test has been validated in Latin America.

In addition to the POC-A1c, a number of clinical strategies have been developed to predict patients' levels of glycemia and identify undiagnosed diabetes (19–27). All these strategies have involved some type of multivariate model to combine risk factor information into an overall index of patients' probability of disease. While most screening models use risk factors such as age, sex, BMI, blood pressure, and family history of diabetes, models limited to these characteristics often show only moderate test specificity. In contrast, a screening model that includes random capillary glucose data is associated with lower false-positive rates (13, 22). This model provides a substantial advantage in settings where a false-positive result can burden the individual and lead to overuse of scarce clinical resources. One particular screening algorithm developed by Tabaei et al. has shown excellent test characteristics in North America and Egypt (13, 22). In a prior brief report (28), this clinical equation was found to be reliable within a population of primary care patients in Honduras compared with the FPG method. Compared with other risk scores and predictive equations whose specificity have ranged from 55% to 78%, the specificity of the equation using random capillary glucose as a predictor is 96% to 97% with an FPG gold standard (11, 22).

As a follow-up to the prior brief report (28), this study presents the results of a three-way comparison of alternative methods for diabetes screening in rural clinics in Latin America: FPG testing, POC-A1c testing, and the use of a risk equation based on a random capillary blood sample. Also, the requirement of a follow-up clinic visit, which is typically necessary for FPG testing, was studied as a potential barrier to diabetes screening. Finally, the variation in patients' sociodemographic characteristics and clinical risk factors across subgroups with different levels of diabetes risk was examined.

## MATERIALS AND METHODS

### Setting, population, and sampling

The study was conducted between June and August 2008 in a primary care clinic in Yojoa International Medical Center, in Santa Cruz de Yojoa in central Honduras. The clinic serves a population of approximately 15 000 adult and pediatric patients from rural and semirural areas. Eight hundred study participants without a diagnosis of diabetes (self-report) were recruited for the initial screening. Patients were eligible if they had nonurgent medical visits, were 18 years or older, were not pregnant, and had not had a heart attack in the three months preceding participation (26). Participants were initially approached in the clinic waiting area and men were given selection preference because of limited representation in the clinical population. All patients provided informed consent. Patients completed a baseline survey and nonfasting blood glucose testing at the time of recruitment (as described below). A subset of patients were asked to return to the clinic for FPG and POC-A1c tests. The study was reviewed and approved by the University of Michigan Institutional Review Board.

### Initial screening

At the time of recruitment, eligible patients completed a survey, and a capillary random blood glucose test was performed with an Accu-Chek Aviva capillary glucose meter (29). These data were used to calculate participants' equation-based risk of diabetes with coefficient weights developed and reported previously (13). The survey was administered

in a face-to-face interview and participants were asked questions about demographic characteristics and recognized diabetes risk factors, including their education level, household income, number of people living in the household, relative wealth (30, 31), family history of diabetes (21), and history of giving birth to a macrosomic infant (> 4 500 grams) (32). Basic clinical measurements not requiring laboratory analysis were recorded, including BMI with height and weight measured while the patient wore light clothing and no shoes. Blood pressure was recorded with a standard mercury sphygmomanometer after 5 minutes of rest and as the average of two measurements. Waist circumference was measured midway between the lowest rib and the iliac crest (19). Self-reported postprandial time was recorded as the number of hours since the participant reported last eating or drinking anything other than water. Survey responses and clinical measurements were used to calculate patients' probability ($p$) of diabetes according to the following Tabaei et al. logistic regression (22) equation:

$$p(\text{diabetes}) = 1/[1 + \exp(-X)]; X = -10.0382 + 0.0331 \times \text{age} + 0.0308 \times \text{random capillary glucose} + 0.25 \times \text{self-reported postprandial time} + 0.562(\text{female}) + 0.0346 \times \text{BMI}.$$

Patients' risk was reported back to them along with general information about diabetes risk factors and how they could modify their risk through behavioral changes.

## Follow-up glucose testing

All participants with a screening-equation-based probability of diabetes ≥ 20% were asked to return for additional evaluation including FPG and POC-A1c tests. Additionally, every fifth participant with a screening-equation-based probability of diabetes < 20% was asked to return for follow-up testing. Patients selected for later evaluation were instructed to return to the clinic at least 24 hours after their initial visit, having fasted (no food or beverages other than water) for at least 8 hours. Participants who returned received a monetary incentive equivalent to US $5.

At the follow-up visit, FPG was measured with the HemoCue 200 glucose analyzer. This portable unit is widely recognized as a preferred laboratory reference and is intended for screening and diagnosing diabetes mellitus (33). FPG was measured with 10 microliters (μL) of capillary whole blood derived from a finger stick. The World Health Organization, International Diabetes Federation, and American Diabetes Association recognize FPG of equal to or greater than 126 milligrams per deciliter (mg/dL) (7.0 millimoles per liter) as diagnostic of diabetes (14, 33, 34).

To measure A1c, the Bio-Rad Laboratories in2it A1c point-of-care analyzer was used (16, 35). The in2it assay requires 10 μL of capillary blood from a fingerstick and uses boronate affinity chromatography to provide results that are free from hemoglobin variant interference and traceable to the Diabetes Control and Complications Trial reference (http://www.bio-rad.com/). In 2009, a study in Singapore showed that the in2it assay had a satisfactory total precision (coefficient of variance) of < 5% and performed better than some other POC-A1c devices (35). As recognized by multiple professional guidelines (14), a POC-A1c of ≥ 6.5% was considered highly suggestive of diabetes and increased risk of microvascular complications. At follow-up, patients with an FPG result ≥ 126 mg/dL or an A1c ≥ 6.5% were referred to one of the onsite physicians for diabetes counseling and further diagnostic evaluation.

## Analysis

Initial analyses compared the sociodemographic characteristics of participants who returned for confirmatory diagnostic testing and those who were asked to return but did not. For these analyses, a Pearson's $\chi^2$ test was used for categorical variables and a Student's $t$-test was used for continuous variables. Among the subset of patients asked to return for follow-up testing ($n$ = 200), logistic regression models were constructed to identify sociodemographic and clinical characteristics independently associated with returning for follow-up and controlling for patients' baseline screening-equation-based diabetes risk score.

In general, the analytic process for evaluating the screening measures was as follows: Step 1, calculate a continuous probability of diabetes based on data collected during the initial screening and the screening equation; Step 2, use these data with the 20% risk cutoff to identify a sample for follow-up that represented a broad range of continuous screening risk scores; Step 3, on the basis of the sample at follow-up, calculate the sensitivity and specificity of the continuous screening score and POC-A1c results across the scores' entire continuous ranges and plot those sensitivity-specificity results using receiver-operator characteristic (ROC) curves; and Step 4, on the basis of those curves, identify the ideal cutoff for each measure and the sensitivity and specificity at those cut points.

The prognostic significance of the screening equation was validated against two gold standards: FPG ≥ 126 mg/dL and POC-A1c ≥ 6.5% (14, 15). Results from the comparison of the screening equation with FPG were reported previously (28) but are repeated here to compare them with the screener performance when evaluated against the POC-A1c gold standard. The ROCFIT procedure within STATA was used to fit maximum-likelihood ROC curves by plotting the sensitivity of screening scores against the false-positive rate (1 – specificity). The method originally developed by Dorfman and Alf (36) and the ROCCOMP procedure were used to compare the area under the screening equation curves (the measure of the screening equation's validity) using both the FPG and POC-A1c results. The POC-A1c test was then evaluated as an alternative to the laboratory-based A1c by constructing a separate ROC curve comparing various POC-A1c cut points against the FPG gold standard.

In additional analyses, all 800 recruited patients were assigned to levels of diabetes risk according to their initial screening equation and POC-A1c test results. Group 1 (low-risk) patients included subjects who were either "low-risk confirmed" (screening-equation-based risk < 20% and POC-A1c < 6.5%) or "low-risk unconfirmed" (screening-based risk < 20% without a confirmatory POC-A1c). Group 2 (high-risk) patients included subjects who were either "high-risk unconfirmed" (screening-equation-based risk ≥ 20% but no confirmatory POC-A1c) or "high-risk confirmed" (equation-based risk ≥ 20% and POC-A1c ≥ 6.5%). Between-group and within-group comparisons of patients' sociodemographic characteristics and other risk factors were conducted with $\chi^2$ and Student's $t$-test.

## RESULTS

### Patient recruitment and follow-up

Eight hundred participants were recruited including 266 (33.2%) men and 534 (66.8%) women. Mean age was 38.5 years and patients lived an average 10.5 kilometers (6.5 miles) from the clinic. Average monthly household income was US $319. Figure 1 provides basic descriptors of the 800 participants based on their glycemic test results and whether they returned for follow-up evaluation. Of the original sample, 67 patients (8.4%) were identified by the screening equation as having a 20% or greater risk of diabetes and were asked to return for confirmatory testing. The remaining 733 patients were found to have a < 20% risk, and one-fifth of them ($n$ = 133) were asked to return for confirmatory FPG and A1c tests. Two-thirds (66.5%) of all patients asked to participate in follow-up testing returned to the clinic, with no difference in the proportion returning between those with an initial risk of ≥ 20% versus < 20%. In logistic regression models examining the factors predictive of returning for follow-up among all patients asked to return ($n$ = 200), those who failed to return for follow-up were more likely to be male (adjusted odds ratio (AOR) = 2.9, 95% confidence interval (CI) = 1.4–6.2) and to have hypertension (AOR = 2.3; 95% CI = 1.0–5.3). Among the subset of patients initially identified with a 20% or greater risk of diabetes ($n$ = 67), those who failed to return for follow-up were more likely to be men (AOR = 13.6, 95% CI = 1.0–181.4) and to have hypertension (AOR = 7.1, 95% CI = 1.1–50.0).

### Predictive validity of the screening equation using the two gold standards

As reported previously, the screening instrument had good predictive accuracy compared with the gold standard of an FPG ≥ 126 mg/dL (Figure 2) (28). The overall area under the curve (AUC) was 0.89 (95% CI = 0.80–0.98). Overall classification accuracy was maximized by using a $p$(diabetes) value of 0.42. With that criterion, 74% of all patients with diabetes confirmed by FPG were correctly classified by the screening equation (i.e., a sensitivity of 74%), and 97% of patients without diabetes were correctly identified by the screening equation (specificity of 97%). With the 0.42 cut point and assuming a diabetes prevalence of 7.4% (the best estimate based on this sample), the test had a positive predictive value of 68% and a negative predictive value of 98%.

Using a gold standard of a POC-A1c result ≥ 6.5%, the screening equation maintained good predictive accuracy, with an AUC of 0.87 (Figure 2; 95% CI = 0.81–0.94). A $\chi^2$ test comparing screening performance using the two gold standards identified no significant difference between the AUCs ($p$ = 0.82). Considering the same 0.42 screening cut point and using the POC-A1c gold standard, the

**FIGURE 1. Flow of study participants through initial screening and confirmatory diabetes testing. Cell entries are No. (%) or mean ± standard deviation. DM = diabetes mellitus, FPG = fasting plasma glucose, mg/dl = milligrams per deciliter, M = male, F = female, km = mean distance from residence to clinic in kilometers**

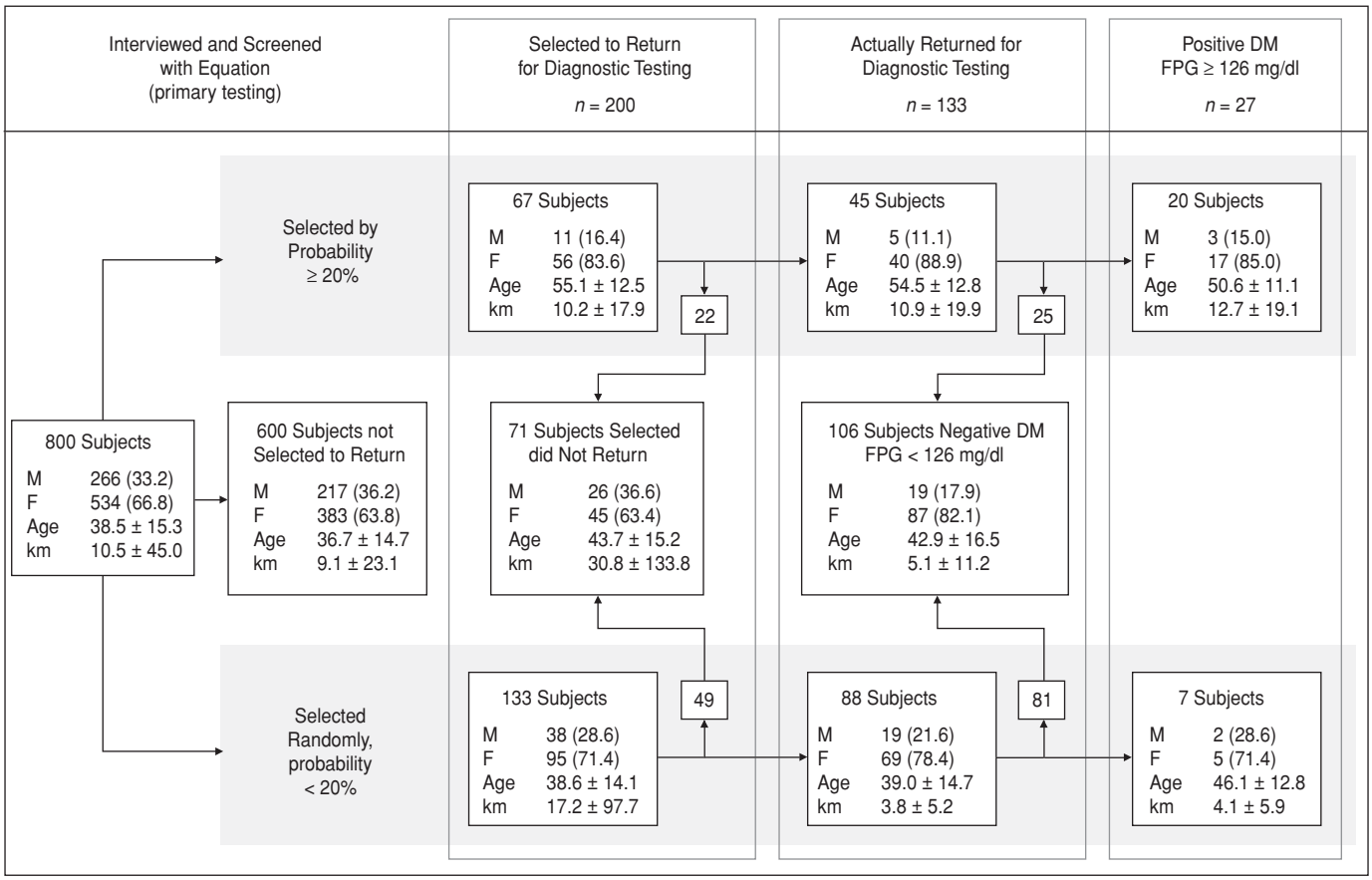


**FIGURE 2. Receiver operator characteristic curves evaluating sensitivity and specificity of the diabetes screening equation against the fasting plasma glucose (FPG) and point-of-care hemoglobin A1c (POC-A1c) gold standards. Diagonal reference line defines points where the test would predict diabetes no better than by chance. Sensitivity and specificity of the screening instrument were calculated using as gold standards an FPG of ≥ 126 milligrams per deciliter and a POC-A1c ≥ 6.5%. The areas under the FPG and POC-A1c curves were not statistically different (*P* = 0.82); se = standard error**

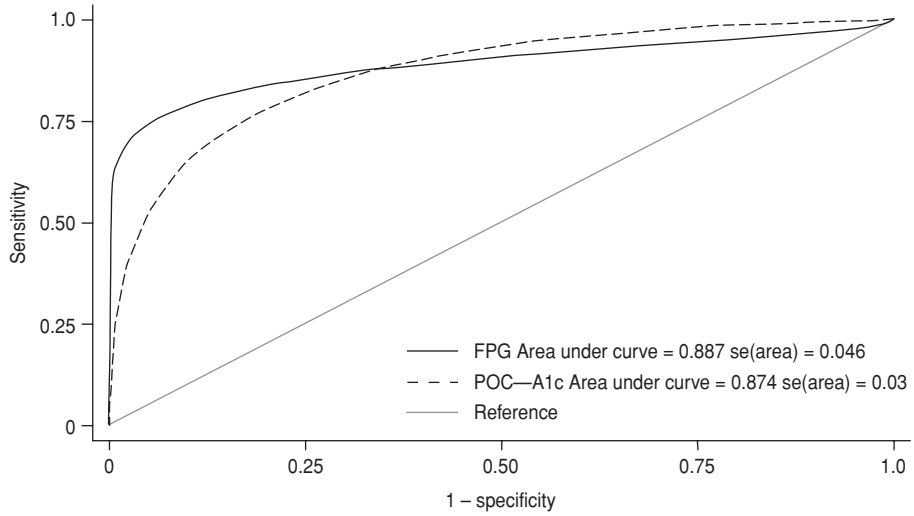
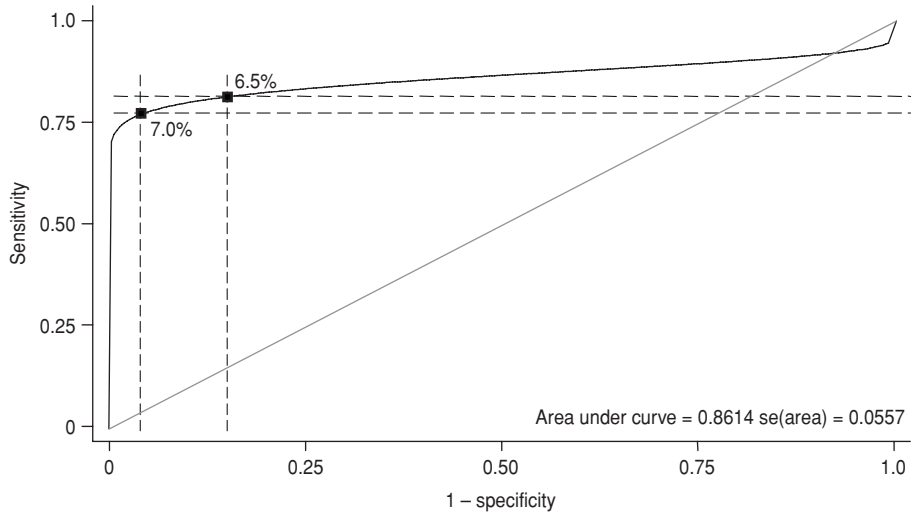



**FIGURE 3. Receiver operator characteristic curve evaluating sensitivity and specificity of the point-of-care hemoglobin A1c (POC-A1c) test against the fasting plasma glucose (FPG) gold standards. Gray band represents 95% confidence interval. Diagonal reference line defines points where the test would predict diabetes no better than by chance. Sensitivity and specificity of the POC-A1c test were calculated using an FPG of ≥ 126 milligrams per deciliter as the gold standard. Dashed horizontal lines highlight the sensitivity and specificity for cutpoints of POC-A1c ≥ 6.5% and ≥ 7.0%; se = standard error**




screener showed a lower sensitivity (54%) than when compared with the FPG but the same specificity (97%). On the basis of the POC-A1c gold standard, the screening equation had a positive predictive value of 57% and a negative predictive value of 96%.

## Comparing POC-A1c results with FPG results

Of patients who returned for follow-up, 27 had a FPG ≥ 126 mg/dL, and 37 had an A1c ≥ 6.5% for a total of 43 patients who tested positive on one or the other test. Of this group, 21 participants tested positive with both FPG and POC-A1c, and 22 participants were identified with one test but not the other. Specifically, 16 patients with an A1c ≥ 6.5% were not identified by the FPG test, and 6 patients with an FPG ≥ 126 mg/dL were

**TABLE 1. Characteristics of study participants according to estimated diabetes risk based on initial screening and confirmatory testing (POC-A1c ≥ 6.5%) for returning subjects (*n* = 800)**

| Characteristic | Group 1 (Low risk) | | Group 2 (High risk) | | *P*[e] |
|---|---|---|---|---|---|
| | Confirmed DM negative[a] No. = 96 | Unconfirmed DM negative[b] No. = 645 | Confirmed DM positive[c] No. = 37 | Unconfirmed DM positive[d] No. = 22 | |
| Age | 42.9 ± 16.9[f] | 36.8 ± 14.6 | 49.9 ± 10.8[f] | 56.5 ± 12.2 | N/A |
| Sex | | | | | N/A |
| Male | 17 (17.7)[g] | 236 (36.6) | 7 (18.9) | 6 (27.3) | |
| Female | 79 (82.3)[f] | 409 (63.4) | 30 (81.1) | 16 (72.7) | |
| Physician diagnosed BP | | | | | |
| Problems | 23 (23.9) | 154 (23.9) | 17 (45.9) | 13 (61.9) | < 0.0001 |
| Taking BP medication | 12 (12.8) | 52 (8.1) | 7 (18.9) | 8 (38.1) | < 0.0001 |
| Weekly physical activity | | | | | 0.014 |
| None | 5 (5.21)[g] | 44 (6.8) | 5 (13.5) | 4 (19.1) | |
| Some activity | 59 (61.5) | 313 (48.5) | 21 (56.8) | 13 (61.9) | |
| Vigorous activity = 2× | 18 (18.8) | 132 (20.5) | 5 (13.5) | 13 (61.9) | |
| Vigorous activity > 2× | 14 (14.6) | 156 (24.2) | 6 (16.22) | 3 (14.3) | |
| Oral inflammation | 34 (35.8) | 300 (46.9) | 13 (35.1) | 6 (28.6) | 0.061 |
| Years of school | | | | | 0.036 |
| None | 16 (16.7)[g] | 70 (10.9) | 5 (13.5) | 7 (33.3) | |
| 1–6 | 57 (59.4) | 334 (51.9) | 24 (64.9) | 9 (42.9) | |
| 7–9 | 9 (9.4) | 66 (10.3) | 3 (8.1) | 3 (14.3) | |
| 10–12 | 7 (7.3)[f] | 124 (19.3) | 5 (13.5) | 2 (9.5) | |
| 13 or more | 7 (7.3) | 50 (7.8) | 0 (0) | 0 (0) | |
| Worked in past 12 months | 38 (39.6)[f] | 379 (58.9) | 16 (43.2) | 8 (38.1) | 0.026 |
| Number of children | | | | | < 0.0001 |
| None | 10 (10.4)[g] | 118 (18.3) | 2 (5.4) | 1 (4.8) | |
| 1–3 | 44 (45.8) | 294 (45.6) | 11 (29.7) | 3 (14.3) | |
| 4–6 | 22 (22.9 ) | 144 (22.3) | 11 (29.7) | 8 (38.1) | |
| ≥ 7 | 20 (20.8 )[f] | 89 (13.8) | 13 (35.1) | 9 (42.9) | |
| Household income | | | | | |
| Male | 27.5 ± 5.1 | 27.0 ± 5.3 | 31.1 ± 1.5 | 31.8 ± 4.0 | |
| Female | 27.9 ± 5.5 | 28.0 ± 6.2 | 29.8 ± 5.5 | 30.6 ± 6.1 | |
| Waist circumference (cm) | | | | | |
| Male | 89.7 ± 11.5 | 90.7 ± 13.6 | 106.5 ± 5.3 | 105.3 ± 5.6 | < 0.0001 |
| Female | 87.2 ± 11.1 | 86.1 ± 12.7 | 93.0 ± 10.8 | 95.1 ± 13.0 | 0.0001 |
| Postprandial time (hours) | 4.6 ± 3.5[g] | 3.3 ± 2.5 | 4. 2 ± 3.2 | 5.6 ± 4.3 | N/A |
| Systolic BP (mmHg) | 113.2 ± 23.6 | 113.6 ± 17.6 | 121.1 ± 14.9[f] | 131.4 ± 23.7 | < 0.0001 |
| Random glucose (mg/dL) | 106.3 ± 29.9[f] | 100.7 ± 18.2 | 210.2 ± 111.1 | 202.7 ± 116.5 | N/A |
| FPG (mg/dL) | 96.5 ± 14.1 | … | 167.7 ± 91.4 | … | < 0.0001 |
| HbA1c (%) | 5.8 ± 0.4 | … | 9.0 ± 2.4 | … | < 0.0001 |

Data are: means ± standard deviation or No. (%); POC-A1c = point-of-care hemoglobin A1c; DM = diabetes mellitus; N/A = not applicable; BP = blood pressure; BMI = body mass index; cm = centimeters; mmHg = millimeters of mercury; mg/dL = milligrams per deciliter; FPG = fasting plasma glucose; HbA1c = glycosylated hemoglobin; . . . indicates no data are available.
[a] Screening *p* (DM) < 20% and HbA1c ≤ 6.5%.
[b] Screening *p* (DM) < 20% and no HbA1c.
[c] Screening *p* (DM) ≥ 20% and HbA1c ≥ 6.5%.
[d] Sreening *p* (DM) ≥ 20% and no HbA1c.
[e] Student's *t* test for continuous variables and $\chi^2$ test for categorical variables, performed between groups one and two.
[f] Significance of < 0.05 within groups, either one or two.
[g] Significance of < 0.0001 within groups, either one or two.

not identified by the POC-A1c. Using the FPG test as a gold standard and the recommended A1c cutoff of ≥ 6.5%, the POC-A1c had a sensitivity of 78% and a specificity of 85%. With an A1c cutoff of 7%, sensitivity decreased slightly (to 74.1%) but specificity increased substantially (96%). Figure 3 shows the performance of the POC-A1c test against the gold standard of FPG ≥ 126 mg/dL.

### Variation in patient characteristics across diabetes risk levels

Table 1 illustrates the variation in patient characteristics across the four subgroups with increasing risk of diabetes as determined by their initial screening result and (for those returning for follow-up) POC-A1c test findings. Between low-risk (Group 1) and high-risk (Group 2) groups, significant differences were observed in the proportion of patients with a physician-diagnosed blood pressure problem, use of antihypertensive medication, levels of physical activity, educational attainment, employment status, number of children, waist circumference, and blood pressure. Within the high-risk group (Group 2), those who failed to return for follow-up had higher systolic blood pressure (mean = 131 mmHg vs. 121 mmHg, $p < 0.0001$). Diastolic values of those who failed to return for follow-up also were higher, although the result was not statistically significant (mean diastolic = 78 mmHg vs. 71 mmHg, $p = 0.11$).

## DISCUSSION

Type 2 diabetes poses a growing health threat to Honduras and to much of Latin America due to the epidemiologic transition from communicable to chronic diseases (1). Many people with diabetes go undiagnosed until a major health event such as cardiovascular dis-

ease manifests (1–6, 8, 10, 33). Therefore, it is critical that a simple, noninvasive, and inexpensive means of recognizing individuals at increased risk for diabetes be identified for use in these at-risk populations. This study evaluated two options: (1) a formula-based screening tool that includes a random capillary glucose test, information about postprandial time, and basic information about other risk factors; and (2) a POC-A1c test. With respect to the screening equation, comparisons of the area under the ROC in this study with prior studies of the same screening tool show that the equation performed at least as well if not better in Honduras as in other parts of the world. Specifically, when the model was developed in Egypt in 2002, the ROC analyses showed an AUC of 0.88 (compared with 0.89 and 0.87 in this study). When the model was validated in a U.S. population in 2005, it was associated with an AUC of 0.82 (13, 22). No statistical difference was found between results evaluating the screening equation against the FPG and the POC-A1c tests.

The POC-A1c had good test characteristics compared with the internationally recognized standard of the FPG. As the use of POC-A1c devices becomes more feasible in busy clinical settings, it is important that the less-than-ideal precision of these devices and the differences with laboratory reference methods be understood by the users (16). POC-A1c is an imperfect predictor of undiagnosed diabetes yet some correlation with laboratory A1c and other gold standards reduces some of the uncertainty. In this study, it was found that the internationally recommended cutoff of 6.5% may maximize test sensitivity but at the price of a false-positive rate in excess of 15%. In resource-constrained health systems, a POC-A1c cutoff of 7% should be considered, as this study found it to have a false-positive rate of < 4% with only a slightly lower sensitivity. Repeated testing using that threshold may increase the sensitivity for a given patient over time while still avoiding the investment of clinical resources for confirmatory testing based on a false-positive screening result.

Individuals of lower socioeconomic status were found to be at higher risk of undiagnosed diabetes. Patients who had limited education, had not worked in the past year, and had lower household income were more likely to be in the high-risk group. Targeting these individuals is far more feasible with an inexpensive screening tool that provides results in a single visit than one that requires a follow-up visit. A large proportion of patients (including as many as 35% identified as high risk based on their screening results) did not return for those follow-ups and therefore were not appropriately diagnosed. Those who failed to return were not a random subset of the at-risk population. Specifically, the odds of not returning for confirmatory testing were significantly higher for males and for individuals with hypertension. These patients may have been more likely to miss their follow-up visits because of work commitments, less appreciation of the importance of managing asymptomatic conditions such as diabetes, or other reasons. Because these groups are at heightened risk for undiagnosed diabetes and diabetes complications, the alternative screening methods suggested by this study may help to target those subgroups with especially poor outcomes.

More generally, screening methods that do not require follow-up fasting visits may substantially improve the accessibility of care for rural patients in Latin America. In an unpublished survey of the same clinic population, we found that 43% of patients with chronic illnesses reported having to cancel a clinic appointment at least once in the prior year because of transportation problems. Services that require fewer face-to-face encounters could dramatically improve the impact of health education. Moreover, in the context of scarce resources, services that can identify undiagnosed diabetes patients and begin disease management early could prevent complications, thereby lowering overall acute care costs. In communities where there are few employment options for individuals with functional limitations due to neuropathy, retinopathy, or other diabetes-related disorders, such early detection programs may increase the overall productivity of the population, thereby boosting the economy and lessening reliance on aid such as remittances from relatives living abroad.

At present, the practicalities of implementing a diabetes screening program are unresolved, especially in resource-poor areas of the world (37). Individual countries should attempt to develop and evaluate setting-specific diabetes risk identification and prevention strategies based on available resources (37). Convenient, informative clinical measures like POC-A1c testing and equation-based screening may encourage participation and improve rates of appropriate treatment initiation (15). The specifics about which screening method should be used and for whom will depend on factors such as the true prevalence of undiagnosed diabetes, the cost of diagnostic testing, and treatment availability for those identified as having disease.

A limitation of this study is possible selection bias introduced in the initial stage of participant selection. Researchers approached all potential participants in the clinic waiting room but it was not done at random. While this procedure may bias estimates of the prevalence of diabetes, it is unlikely that it would influence the overall performance of the screening tests or the association between patients' likelihood of having diabetes and other risk factors such as their BMI or blood pressure. However, it should be stressed that because this sample is not an entirely representative one, these results cannot be used to predict the prevalence of undiagnosed diabetes within the greater Honduran population. Additionally, the FPG test was given only once to each returning participant and was not administered twice, as is recommended for eliminating some of the fluctuations in glucose concentrations. This factor may account for some of the lack of overlap in the FPG versus POC-A1c positive outcomes. Finally, prior studies have found variation in the performance of POC-A1c devices (15) and only one such device was used here. Further study, including the use of multiple POC-A1c tests in the same population, would help to confirm the estimates reported here.

With these caveats, it can be concluded that the screening equation based on a random capillary glucose test and the POC-A1c are reasonable alternatives to laboratory-based A1c and FPG tests for identifying patients with diabetes in rural clinics in Latin America. These alternatives should be given serious consideration, as laboratory A1c testing is often unavailable in resource-poor areas and FPG testing may miss large numbers of patients most at risk because of the need to return for a fasting visit and because of their low socioeconomic status. These alternatives may be particularly important in Latin America, because pa-

tients who fail to return for follow-up are more likely to be men and to have hypertension—two groups at particularly high risk for undiagnosed diabetes and cardiovascular disease. If POC-A1c testing is adopted for screening, clinicians should carefully consider the trade-off between sensitivity and specificity associated with a 6.5% versus 7% cutoff. A cutoff of 7% may identify nearly as many patients at risk while minimizing the expenditure of resources on patients with false-positive test results.

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## Comparación de tres métodos para el tamizaje de la diabetes en un consultorio rural en Honduras

**RESUMEN**

***Objetivo.*** Evaluar dos alternativas a la prueba de glucemia en ayunas para el tamizaje de la diabetes en América Latina.

***Métodos.*** Se seleccionaron 800 adultos sin diabetes que acudían a un dispensario de atención primaria en Honduras. Para el tamizaje inicial se utilizó una fórmula de tamizaje mediante la aplicación de ecuaciones, que incluía una prueba aleatoria de la concentración de glucosa capilar y otros factores de riesgo. A todos los pacientes cuyos tamizajes revelaron una probabilidad de diabetes ≥ 20%, y a una quinta parte de los pacientes con una probabilidad < 20%, se les solicitó que regresaran para un examen de glucemia en ayunas y para una de glucohemoglobina (HbA1c) en el lugar de atención. Se utilizaron los siguientes criterios de referencia para evaluar el desempeño de la ecuación del tamizaje: glucemia en ayunas ≥ 126 mg por decilitro y HbA1c ≥ 6,5%. Se analizó la asociación entre las prueba de HbA1c y la de glucemia en ayunas, así como los factores de los pacientes asociados con faltas a las citas de seguimiento y la variación del riesgo de diabetes a través de los subgrupos.

***Resultados.*** La ecuación de tamizaje presentó excelentes características de análisis en comparación con el examen de glucosa en ayunas y con la prueba de HbA1c. Usando el criterio de referencia del examen de glucosa en ayunas, el HbA1c mostró una sensibilidad de 77,8% y una especificidad de 84,9%. Con un límite de A1c de 7%, la especificidad de la prueba de HbA1c aumentó a 96,2%. No se presentaron para el seguimiento de la prueba 34% de los pacientes a quienes se les solicitó que regresaran. La probabilidad de no regresar para el seguimiento fue mayor en hombres y que tenían hipertensión.

***Conclusiones.*** Tanto la ecuación de tamizaje como la prueba HbA1c son alternativas razonables al examen de glucosa en ayunas. Teniendo en cuenta las barreras actuales a la aplicación de los procedimientos de tamizaje recomendados, estas opciones podrían representar beneficios importantes para la salud pública en América Latina.

**Palabras clave** Diabetes mellitus tipo 2; población rural; diagnóstico; técnicas y procedimientos diagnósticos; Honduras.