Comparison of a Clinical Model, the Oral Glucose Tolerance Test, and Fasting Glucose for Prediction of Type 2 Diabetes Risk in Japanese Americans

MARGUERITE J. MCNEELY, MD[1]
EDWARD J. BOYKO, MD[1,2,3]
DONNA L. LEONETTI, PHD[4]
STEVEN E. KAHN, MB, CHB[1,2]
WILFRED Y. FUJIMOTO, MD[1]

OBJECTIVE — To test the validity of a published clinical model for predicting incident diabetes in Japanese Americans.

RESEARCH DESIGN AND METHODS — A total of 465 nondiabetic Japanese Americans (243 men, 222 women), aged 34–75 years, were studied at baseline and at 5–6 years. A total of 412 subjects were studied at 10 years. The clinical model included age, sex, ethnicity, BMI, systolic blood pressure, fasting plasma glucose (FPG), HDL cholesterol, and family history of diabetes at baseline. Diabetes status at 5–6 and 10 years was determined by 75-g oral glucose tolerance test. The clinical model, 2-h glucose, and FPG were compared using receiver-operating characteristic (ROC) curves.

RESULTS — The diabetes risk associated with BMI, sex, and HDL cholesterol differed by age ($P \leq 0.011$). At 5–6 years, the clinical model ROC curve area (0.896) was higher than that for FPG (0.776, $P = 0.008$), but not for 2-h glucose (0.851, $P = 0.341$), for subjects aged ≤55 years. For older subjects, the clinical model ROC curve area (0.599) was lower than that for 2-h glucose (0.792, $P \leq 0.001$), but not for FPG (0.627, $P = 0.467$). At 10 years, there were no significant differences between the clinical model, FPG, and 2-h glucose ROC curve areas in either age group.

CONCLUSIONS — In Japanese Americans aged ≤55 years, a clinical model was better than FPG for predicting diabetes after 5–6 years but not after 10 years. The model was not useful in older Japanese Americans, whereas 2-h glucose was useful for predicting diabetes risk regardless of age.

Diabetes Care 26:758–763, 2003

Three large clinical trials have demonstrated a reduction in type 2 diabetes incidence with lifestyle or pharmaceutical intervention (1–3), and the results of at least one other similar study will be published soon (4). These findings prompted the American Diabetes Association (ADA) to issue a position statement in support of screening for "prediabetes" (4). This position paper acknowledges a fundamental problem with translating diabetes prevention research into clinical practice. The research evidence for type 2 diabetes prevention is based on identification of individuals with impaired glucose tolerance (IGT) using the 2-h glucose measurement from an oral glucose tolerance test (OGTT). However, the OGTT is not commonly performed in clinical practice because it is more time consuming, costly, and inconvenient and less reproducible than fasting glucose. Therefore, the ADA supports the use of either impaired fasting glucose (IFG) based on fasting glucose or IGT to define "prediabetes," and has called for more research on the use of fasting glucose for predicting diabetes risk.

Stern et al. (5) recently published a clinical model to predict diabetes risk using fasting glucose and other routine clinical data, including age, sex, ethnicity, systolic blood pressure, HDL cholesterol, BMI, and family history of diabetes. This clinical model predicted 7.5-year incidence of diabetes better than 2-h glucose in 1,791 Mexican-American and 1,112 non-Hispanic white participants in the San Antonio Heart Study. The clinical model was fit using study data, so it may not perform as well for predicting diabetes risk in other samples of Mexican Americans or non-Hispanic whites or in other ethnic groups. The purpose of this study was to assess the validity of this clinical model in Japanese Americans.

RESEARCH DESIGN AND METHODS

Study subjects

Study subjects included second-generation (Nisei) and third-generation (Sansei) Japanese-American participants in the Japanese American Community Diabetes Study. Recruitment methods and comparison of Nisei participants with nonparticipants residing in King County, WA, have been previously described (6). Subjects with diabetes at baseline were excluded (7). This study was approved by

From the [1]Department of Medicine , University of Washington, Seattle, Washington; the [2]Veterans Affairs Puget Sound Health Care System, Seattle, Washington; the [3]Veterans Affairs Epidemiologic Research and Information Center, Seattle, Washington; and the [4]Department of Anthropology, University of Washington, Seattle, Washington.

Address correspondence and reprint requests to Marguerite J. McNeely, MD, MPH, Division of General Internal Medicine, Box 356429, Seattle, WA 98196-6429. E-mail: mcneely@u.washington.edu.

Received for publication 6 May 2002 and accepted in revised form 16 October 2002.

Abbreviations: FPG, fasting plasma glucose; IFG, impaired fasting glucose; IGT, impaired glucose tolerance; LR, likelihood ratio; OGTT, oral glucose tolerance test; ROC, receiver-operating characteristic.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

See accompanying editorial, p. 940.

the University of Washington Institutional Review Board, and all participants provided written informed consent.

Measurements

Study subjects were examined in the General Clinical Research Center at the University of Washington at baseline and at 5–6 years and 10 years after baseline. Subjects who reported a parent or sibling with adult-onset diabetes at baseline were considered to have a positive family history of type 2 diabetes. Medication use was verified by direct observation of medication containers provided by the subject at each examination. Standing height (cm) and weight (kg) were measured without shoes in light clothing. Supine blood pressure was measured in the right arm three times by auscultation using a mercury manometer, and the average of the last two measurements was used for analysis.

Blood samples for measurement of glucose, lipids, and lipoprotein were collected after a 10-h fast. A blood sample collected 2 h after a 75-g oral glucose load was used to measure 2-h plasma glucose. Plasma glucose was assayed by an automated glucose oxidase method. Lipids and lipoproteins were measured at the Northwest Lipid Research Laboratory using described methods (8–10).

IFG was defined as fasting plasma glucose (FPG) ≥6.1 mmol/l (110 mg/dl) and <7.0 mmol/l (126 mg/dl) (7). IGT was defined as 2-h plasma glucose ≥7.8 mmol/l (140 mg/dl) and <11.1 mmol/l (200 mg/dl). IFG and IGT classifications were assigned independently; therefore, subjects with IFG at baseline may or may not have had IGT at baseline. Subjects were classified as having diabetes if any of these criteria were met: FPG ≥7.0 mmol/l (126 mg/dl), 2-h glucose ≥11.1 mmol/l (200 mg/dl), or reported use of insulin or an oral hypoglycemic medication prescribed for management of diabetes by a physician (7). Diabetes status was determined at the 10-year follow-up, independent of diabetes status at the 5- to 6-year follow-up visit.

Subject retention and comparison of participants with nonparticipants

Of 518 eligible subjects studied at baseline, 465 (89.8%) completed the 5- to 6-year examination, and 412 (79.5%) completed the 10-year examination. Reasons for missing the 5- to 6-year examination included refusal ($n = 29$), illness ($n = 10$), death ($n = 6$), relocation ($n = 4$), and inability to locate ($n = 4$). By 10 years after baseline, 23 subjects had died (13 of cancer, 8 of cardiovascular disease, 1 of pneumonia, and 1 of trauma). Compared with participants, subjects who missed a follow-up examination had lower baseline systolic blood pressure ($P = 0.047$ at 5–6 years, no significant difference at 10 years) and diastolic blood pressure ($P = 0.011$ at 5–6 years, $P = 0.028$ at 10 years) and higher HDL cholesterol ($P = 0.050$ at 5 years, no significant difference at 10 years). There were no significant differences in age, sex, family history of diabetes, BMI, fasting or 2-h glucose, IGT, IFG, total cholesterol, LDL cholesterol, or triglycerides.

Statistical analysis

All statistics were calculated using Stata software, version 7 for Windows (Stata Corporation, College Station, TX). All *P* values were two-sided. Baseline characteristics of subjects in whom diabetes developed and in those who remained nondiabetic were compared using the Wilcoxon's rank-sum test or the χ^2 test.

The probability of developing diabetes at baseline was calculated for each study subject using a published clinical model (5): probability of incident diabetes = $1/(1 + e^{-x})$, where $x = -13.415 + 0.028$ (age in years) + 0.661 (0 if male, 1 if female) + 0.412 (ethnicity) + 0.079 (FPG in mg/dl) + 0.018 (systolic blood pressure in mmHg) – 0.039 (HDL cholesterol in mg/dl) + 0.070 (BMI in kg/m^2) + 0.481 (0 if no family history, 1 if family history present). Family history is defined as the presence of type 2 diabetes in a parent or sibling. The published model coded ethnicity as non-Hispanic white = 0 and Mexican American = 1. We coded ethnicity for Japanese Americans = 1, which affects the absolute value of the calculated probability of diabetes but does not affect statistical comparisons because all subjects have the same value for ethnicity. To distinguish between the validity of the published coefficients for this model and the validity of these clinical variables for determining diabetes risk in Japanese Americans, we also calculated the probability of developing diabetes at 5–6 years and at 10 years using logistic regression models that included the same independent variables as those in the published clinical model, except for ethnicity. This model is referred to as the "clinical model using study data." We also tested to determine whether adding one additional independent variable or first-order multiplicative interaction term improved the clinical model using study data. Nested models were compared using the likelihood ratio test.

Accuracy of predicting incident diabetes at 5–6 years or 10 years was analyzed using receiver-operating characteristic (ROC) curves (11). An ROC curve is a graph of sensitivity versus 1-specificity (or false-positive rate) for various cutoff definitions of a positive diagnostic test result. Statistical differences in the area under the ROC curves were compared using the method of DeLong et al. (12). Sensitivity, specificity, and likelihood ratio (LR) for a positive (LR+) or negative (LR–) test result were calculated for various cutoffs. The LR is the ratio of the frequency of a test result in patients with disease to the frequency of the same test result in patients without disease (13); therefore, an LR of 1.0 reflects no diagnostic value. For 2-h glucose and FPG, the cutoffs for IGT and IFG were used. We also used a cutoff for FPG of ≥5.6 mmol/l (100 mg/dl), as previously suggested (4,14). For the published clinical model, two cutoffs were randomly selected that correspond approximately to the points on the ROC curve for all ages at which the cost-benefit ratios were 1:2 and 1:4 (13). A cost-benefit ratio of 1:4 means a false-negative result is four times worse than a false-positive result, because the opportunity to prevent a serious disease (diabetes) using a low-risk intervention (lifestyle) was missed. We also used the clinical model cutoff where the number of subjects above this cutoff equaled the number of subjects with IGT so the performance characteristics of these two tests could be directly compared.

RESULTS — Subjects ranged in age from 34 to 75 years. BMI ranged from 16.6 to 36.9 kg/m^2. The incidence of diabetes was 11% at 5 years and 18% at 10 years (Table 1). Comparison of baseline characteristics between subjects in whom diabetes did and did not develop is shown in Table 1. The 5- to 6-year and 10-year incidences of diabetes were 23 and 64%, respectively, for subjects with IFG; 25 and 38%, respectively, for subjects with IGT; and 1.8 and 4.5%, respectively, for subjects without IFG or IGT. At baseline, 20

Table 1—*Baseline characteristics of study subjects by type 2 diabetes status at follow-up at 5–6 and 10 years*

	Diabetes status at 5- to 6-year follow-up			Diabetes status at 10-year follow-up		
Baseline variable	Diabetic (n = 50)	Nondiabetic (n = 415)	P value	Diabetic (n = 74)	Nondiabetic (n = 338)	P value
Age (years)	58.9 ± 1.5 (62.6)	51.3 ± 0.6 (52.5)	<0.001	57.5 ± 1.3 (60.9)	50.6 ± 0.6 (49.0)	<0.001
Female sex	26 (52.0)	196 (47.2)	0.523	30 (40.5)	167 (49.4)	0.167
Family history*	30 (60.0)	175 (42.2)	0.016	46 (62.2)	135 (39.9)	<0.001
BMI (kg/m^2)	24.9 ± 0.5 (25.1)	24.0 ± 0.2 (23.7)	0.100	25.1 ± 0.4 (25.0)	23.9 ± 0.2 (23.6)	0.007
Systolic blood pressure (mmHg)	139 ± 2 (138.5)	128 ± 1 (125)	<0.001	137 ± 3 (134)	127 ± 1 (124)	<0.001
Diastolic blood pressure (mmHg)	80 ± 1 (80)	76 ± 1 (76)	0.021	80 ± 1 (80.5)	76 ± 1 (76)	<0.001
FPG (mmol/l)	5.5 ± 0.1 (5.6)	5.1 ± 0.0 (5.1)	<0.001	5.6 ± 0.1 (5.6)	5.1 ± 0.0 (5.0)	<0.001
IFG	7 (14.0)	23 (5.5)	0.021	18 (24.3)	10 (3.0)	<0.001
2-h glucose (mmol/l)	9.0 ± 0.2 (8.6)	7.1 ± 0.1 (7.0)	<0.001	8.8 ± 0.2 (8.7)	6.9 ± 0.1 (6.9)	<0.001
IGT	45 (90.0)	133 (32.1)	<0.001	59 (79.7)	98 (29.0)	<0.001
Cholesterol (mmol/l)	6.10 ± 0.15 (6.15)	5.80 ± 0.05 (5.70)	0.037	6.10 ± 0.15 (5.90)	5.75 ± 0.05 (5.65)	0.021
HDL cholesterol (mmol/l)	1.45 ± 0.05 (1.35)	1.50 ± 0.00 (1.45)	0.599	1.40 ± 0.05 (1.30)	1.55 ± 0.00 (1.45)	0.007
LDL cholesterol (mmol/l)	3.80 ± 0.15 (3.75)	3.60 ± 0.05 (3.55)	0.211	3.85 ± 0.10 (3.85)	3.60 ± 0.05 (3.55)	0.049
Triglycerides (mmol/l)	2.02 ± 0.34 (1.40)	1.52 ± 0.06 (1.24)	0.333	1.96 ± 0.18 (1.44)	1.46 ± 0.06 (1.18)	0.002

Data are means ± SE (medians) or n (column %). *Parent or sibling with type 2 diabetes.

subjects had both IFG and IGT and 277 subjects had normal FPG and normal glucose tolerance.

Additional independent variables and interactions

Adding the following variables individually to the clinical model did not improve the fit of the model for predicting 5- to 6-year incidence of diabetes: ln triglycerides (P = 0.32), diastolic blood pressure (P = 0.53), waist circumference (P = 0.11), or fasting insulin (P = 0.13). Each of the following interaction terms significantly improved the fit of the clinical model using study data for predicting diabetes at 5–6 years: age × BMI (P = 0.011), age × sex (P = 0.004), and age × HDL cholesterol (P < 0.0001). No significant interaction was found for age × family history of diabetes (P = 0.67), age × systolic blood pressure (P = 0.12), age × FPG (P = 0.07), or sex × HDL cholesterol (P = 0.63).

Model comparisons

The areas under the ROC curves for the various models tested are shown in Table 2. Because the clinical model does not account for differences in the association between incident diabetes and several independent variables with age, the results are also stratified by age. The age stratification demonstrates that the clinical model was significantly better than FPG, and comparable to the clinical model using study data and 2-h glucose, for predicting 5- to 6-year incidence of diabetes in subjects aged ≤55 years. In older subjects, 2-h glucose was significantly better than the clinical model or FPG for predicting 5-year incidence of diabetes. The clinical model using study data was significantly better than the published clinical model and fasting glucose in older subjects.

Sensitivity, specificity, and likelihood ratios are shown in Table 3. It should be noted that only 30 subjects had IFG, 20 of whom also had IGT. An especially striking result was the finding that the LR– was low for 2-h glucose in both age groups, indicating that a negative result for IGT was useful for identifying subjects of all ages in whom diabetes did not develop.

CONCLUSIONS — We have demonstrated that a clinical model using risk factor information and FPG was significantly better than FPG alone and was not significantly different than 2-h glucose for predicting incident diabetes at 5–6 years in Japanese Americans aged ≤55 years. However, the clinical model was significantly less accurate than 2-h glucose and was not significantly better than FPG alone for predicting 5- to 6-year incidence of diabetes in older subjects. Our findings differ from those of Stern et al. (5), who did not find evidence of significant interactions between the diabetes risk associated with independent variables in the clinical model and age. In the San Antonio Heart Study, subjects ranged in age from 25–64 years (mean 42.6–44.8), whereas our study included older subjects (range 34–75 years, mean 52.1). The inclusion of elderly subjects likely improved our ability to discern the effect of age on the accuracy of the clinical model for determining diabetes risk.

We previously reported a significant age-BMI interaction with diabetes risk in Japanese Americans, such that BMI is a strong risk factor for diabetes in subjects aged ≤55 years, but BMI was not associated with incident diabetes in older subjects (15). In the Third National Health and Nutrition Examination Survey (NHANES III) the association between BMI and diabetes was also found to be greater for subjects younger than 55 years than for older subjects (16). Although models typically perform better in the datasets used to develop them than in independent datasets, we found the clinical model using study data was significantly better than the published clinical model only among older subjects. These findings suggest that the published clinical model does not improve prediction of diabetes beyond that of FPG in older Japanese Americans because it fails to take into account the interactions between age and several variables in the model with diabetes risk.

Diabetes may also be more strongly associated with 2-h glucose than FPG in older subjects compared with younger subjects (17,18). Our findings are consistent with this observation, in that 2-h glucose was more predictive of diabetes risk than the clinical model or FPG in older subjects but not in younger subjects at the 5- to 6-year follow-up period. The effect

Table 2—*Areas under the ROC curve for various tests used to predict diabetes incidence*

	Diabetes incidence after 5–6 years			Diabetes incidence after 10 years		
		P value compared to:			*P* value compared to:	
	ROC area (95% CI)	Model 1	Model 4	ROC area (95% CI)	Model 1	Model 4
All ages						
Model 1: clinical model (as published)*	0.755 (0.700–0.810)			0.790 (0.735–0.845)		
Model 2: clinical model (study data)†	0.789 (0.731–0.846)	0.157	0.022	0.807 (0.752–0.861)	0.181	0.020
Model 3: 2-h glucose	0.829 (0.782–0.876)	0.027	0.006	0.820 (0.769–0.871)	0.387	0.125
Model 4: FPG	0.716 (0.647–0.785)	0.113		0.765 (0.710–0.821)	0.201	
Age ≤55 years						
Model 1: clinical model (as published)*	0.896 (0.848–0.945)			0.807 (0.713–0.901)		
Model 2: clinical model (study data)†	0.897 (0.848–0.946)	0.947	0.018	0.827 (0.743–0.911)	0.277	0.033
Model 3: 2-h glucose	0.851 (0.779–0.923)	0.341	0.324	0.829 (0.741–0.917)	0.704	0.180
Model 4: FPG	0.776 (0.658–0.893)	0.008		0.740 (0.644–0.836)	0.097	
Age >55 years						
Model 1: clinical model (as published)*	0.599 (0.502–0.696)			0.729 (0.645–0.812)		
Model 2: clinical model (study data)†	0.772 (0.687–0.858)	0.002	0.010	0.804 (0.736–0.872)	0.020	0.019
Model 3: 2-h glucose	0.792 (0.723–0.861)	<0.001	0.004	0.793 (0.724–0.863)	0.224	0.245
Model 4: FPG	0.627 (0.532–0.723)	0.467		0.737 (0.661–0.812)	0.796	

*Model 1 uses published coefficients for age, sex, ethnicity, FPG, systolic blood pressure, HDL cholesterol, BMI, and family history of diabetes; †Model 2 is the same as model 1 except coefficients are calculated using study data.

of age on diabetes risk associated with FPG or 2-h glucose may also explain conflicting results of other studies regarding the prognostic value of IFG compared with IGT. In our study, subjects with IFG had a similar incidence of diabetes compared with subjects with IGT, although few subjects had only IFG. The incidence of diabetes was also similar in subjects with IFG compared with subjects with IGT in the Hoorn Study of Dutch men and women aged 50–75 years (19). However, Pima Indians older than 15 years with IFG reportedly have a higher incidence of diabetes than those with IGT (14), possibly because this population includes a large proportion of younger adults.

Identifying individuals at low risk for diabetes is also of interest. Absence of IGT was a useful test for identifying Japanese Americans at low risk for developing diabetes in this study, although the LR– for a clinical model cutoff ≥0.1265 was lower than that for IGT among subjects aged ≤55 years for predicting 5- to 6-year incidence of diabetes. Gabir et al. (14) suggested that lowering the cutoff for IFG may improve the performance of IFG as a prognostic test for future diabetes. We found that even if a cutoff of ≥5.6 mmol/l (100 mg/dl) for FPG is used, IGT still had a lower LR– than FPG. However, absence of IGT may not be as useful for identifying individuals at low risk for diabetes in other populations. The LR– for IGT was 0.55 in the San Antonio Heart Study (5) and 0.60 in the Mauritius study (20) compared with 0.15–0.30 in this study.

There are several limitations to this study. The sample size was small, particularly after stratification by age, which can result in a type II statistical error. This may have resulted in the failure to detect a significant advantage of the clinical model for predicting 5- to 6-year incidence of diabetes compared with 2-h glucose in younger subjects or FPG in older subjects. The sample size at the 10-year examination was even smaller and may have resulted in failure to detect an advantage of the clinical model over 2-h glucose or fasting glucose in both age groups. Because of the small number of subjects from a single ethnic group, this study is not well suited for proposing new models of diabetes risk in older subjects. Therefore, the results are useful for demonstrating the limitations of the clinical model in older Japanese Americans, but a larger study population would be needed to develop more refined models. Another limitation is that only one OGTT was performed at each visit in this study, and 2-h glucose has lower reproducibility than FPG (21,22). To minimize this problem, we evaluated diabetes risk at 10 years, independent of the findings at the 5- to 6-year visit. The area under the ROC curve was larger for 2-h glucose than for the clinical model or FPG in older subjects at the 5- to 6-year follow-up period, and in both age groups at the 10-year examination. Therefore, it is unlikely that variability in diabetes outcomes based on 2-h glucose accounts for failure to detect an advantage of the published clinical model over 2-h glucose in Japanese Americans. However, variability in diabetes outcomes based on 2-h glucose might account for the discrepancy in the level of significance for the comparisons of 2-h glucose to the clinical model at the 5- to 6-year and 10-year follow-up periods.

In summary, this study demonstrates that a recently published clinical model was significantly better than FPG alone, but not 2-h glucose, for predicting 5- to

Table 3—*Sensitivity, specificity, and likelihood ratios for a clinical model, 2-h glucose, and FPG as tests for predicting diabetes incidence at 5–6 and 10 years*

	Diabetes incidence after 5–6 years					Diabetes incidence after 10 years				
Test (cutoff)	Diabetes/total (*n*)	Sensitivity %	Specificity %	LR+	LR−	Diabetes/total (*n*)	Sensitivity %	Specificity %	LR+	LR−
All ages	50/465					74/412				
Clinical model (≥0.40)*	17/78	34.0	85.3	2.31	0.77	30/62	40.5	90.5	4.28	0.66
Clinical model (≥0.26)*	30/141	60.0	73.3	2.24	0.55	48/121	64.9	78.4	3.00	0.45
Clinical model (=IGT prevalence)*	36/178	72.0	65.8	2.10	0.43	54/157	73.0	69.5	2.39	0.39
2-h glucose (≥7.8 mmol/l)†	45/178	90.0	68.0	2.81	0.15	59/157	79.7	71.0	2.75	0.29
FPG (≥6.1 mmol/l)‡	7/30	14.0	94.5	2.53	0.91	18/28	24.3	97.0	8.22	0.78
FPG (≥5.6 mmol/l)§	27/125	54.0	76.4	2.29	0.60	39/103	52.7	81.1	2.78	0.58
Age ≤55 years	16/240					23/217				
Clinical model (≥0.40)*	6/17	37.5	95.1	7.64	0.66	5/14	21.7	95.4	4.67	0.82
Clinical model (≥0.26)*	10/36	62.5	88.4	5.38	0.42	13/32	56.5	90.2	5.77	0.48
Clinical model (=IGT prevalence)*	15/70	93.8	75.5	3.82	0.08	16/65	69.6	74.7	2.75	0.41
2-h glucose (≥7.8 mmol/l)†	14/70	87.5	75.0	3.50	0.17	18/65	78.3	75.8	3.23	0.29
FPG (≥6.1 mmol/l)‡	1/5	6.3	98.2	3.50	0.95	3/4	13.0	99.5	25.3	0.87
FPG (≥5.6 mmol/l)§	8/37	50.0	87.1	3.86	0.57	7/32	30.4	87.1	2.36	0.80
Age >55 years	34/225					51/195				
Clinical model (≥0.40)*	11/61	32.4	73.8	1.24	0.92	25/48	49.0	84.0	3.07	0.61
Clinical model (≥0.26)*	20/105	58.8	55.5	1.32	0.74	35/89	68.6	62.5	1.83	0.50
Clinical model (=IGT prevalence)*	20/108	58.8	53.9	1.28	0.76	36/92	70.6	61.1	1.82	0.48
2-h glucose (≥7.8 mmol/l)†	31/108	91.2	59.7	2.26	0.15	41/92	80.4	64.6	2.27	0.30
FPG (≥6.1 mmol/l)‡	6/25	17.7	90.1	1.77	0.91	15/24	29.4	93.8	4.71	0.75
FPG (≥5.6 mmol/l)§	19/88	55.9	63.9	1.55	0.69	32/71	62.7	72.9	2.32	0.51

Data for diabetes/total are number of subjects above the cutoff who developed type 2 diabetes/total number of subjects with value above the cutoff. *Probability of diabetes from a published clinical model using age, sex, ethnicity, systolic blood pressure, HDL cholesterol, BMI, and family history of diabetes. Probability cutoffs where the prevalence = IGT prevalence are ≥0.2011 (5 years, all ages), ≥0.1917 (10 years, all ages), ≥0.1265 (5 years, age ≤55 years), ≥0.1340 (10 years, age ≤55 years), ≥0.2587 (5 years, age >55 years), and ≥0.2563 (10 years, age >55 years); †cutoff corresponds to IGT (2-h glucose ≥140 mg/dl); ‡cutoff corresponds to IFG (FPG ≥110 mg/dl); §FPG ≥100 mg/dl.

6-year incidence of diabetes in Japanese Americans aged ≤55 years. However, the model was significantly worse than 2-h glucose and was no better than FPG alone in older subjects. The sensitivity of IFG for predicting future diabetes was poor (6–29%). Furthermore, absence of IGT seems to be more useful for identifying Japanese Americans at low risk of developing diabetes than is absence of IFG. Our findings indicate that despite the limitations of the OGTT, the 2-h glucose is a useful test for predicting future diabetes in middle-aged and elderly Japanese Americans. If mathematical models of diabetes risk are to be used as an alternative to the OGTT for defining diabetes risk in clinical practice, then further refinements that take into account the differential effects of age are needed. Further research is also needed to determine whether these findings apply to other Asian and non-Asian groups in the U.S. and in other countries.

Acknowledgments— This research was supported by National Institutes of Health Grants DK-02654, DK-31170, and HL-49292. Facility support was provided by the Clinical Nutrition Research Unit (DK-35816), the Diabetes Endocrinology Research Center (DK-17047), the General Clinical Research Center (RR-00037) at the University of Washington, and the Medical Research Service of the Department of Veterans Affairs.

References

1. Tuomilehto J, Lindstrom J, Eriksson JG, Valle TT, Hamalainen H, Ilanne-Parikka P, Keinanen-Kiukaanniemi S, Laakso M, Louheranta A, Rastas M, Salminen V, Uusitupa M: Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *N Engl J Med* 344:1343–1350, 2001
2. The Diabetes Prevention Program Research Group: Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med* 346:393–403, 2002
3. Chiasson JL, Josse RG, Gomis R, Hanefeld M, Karasik A, Laakso M: Acarbose for prevention of type 2 diabetes mellitus: the STOP-NIDDM randomised trial. *Lancet* 359:2072–2077, 2002
4. American Diabetes Association, National Institutes of Diabetes Digestive Diseases and Kidney Diseases: The prevention or delay of type 2 diabetes. *Diabetes Care* 25: 742–749, 2002
5. Stern MP, Williams K, Haffner SM: Iden-

tification of persons at high risk for type 2 diabetes mellitus: do we need the oral glucose tolerance test? *Ann Intern Med* 136: 575–581, 2002
6. Fujimoto WY, Leonetti DL, Kinyoun JL, Newell M-L, Shuman WP, Stolov WC, Wahl PW: Prevalence of diabetes mellitus and impaired glucose tolerance among second-generation Japanese-American men. *Diabetes* 36:721–729, 1987
7. The Expert Committee on the Diagnosis and Classification of Diabetes Mellitus: American Diabetes Association Report of the Expert Committee on the Diagnosis and Classification of Diabetes Mellitus. *Diabetes Care* 20:1183–1197, 1997
8. National Heart, Lung, and Blood Institute: National Cholesterol Education Program: Recommendations for improving cholesterol measurement: a report from the Laboratory Standardization Panel of the National Cholesterol Education Program. Washington, DC, US Govt. Printing Office, 1993 (NIH publ. no. 93–2964)
9. National Heart, Lung, and Blood Institute: National Cholesterol Education Program: Recommendations on lipoprotein measurement from the Working Group on Lipoprotein Measurement. Washington, DC, US Govt. Printing Office, 1995 (NIH publ. no. 95–3044)
10. Friedewald WT, Levy RI, Fredrickson DS: Estimation of the concentration of low density lipoprotein cholesterol in plasma without the use of the preparative centrifuge. *Clin Chem* 18:499–502, 1972
11. Hanley JA, McNeil BJ: A method of comparing the areas under receiver operating characteristic curves derived from the same cases. *Radiology* 148:839–843, 1983
12. DeLong ER, DeLong DM, Clarke-Pearson DL: Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. *Biometrics* 44:837–845, 1988
13. Sox HC, Blatt MA, Higgins MC, Marton KI: *Medical Decision Making*. Boston, MA, Butterworths, 1988, p. 130–145
14. Gabir MM, Hanson RL, Dabelea D, Imperatore G, Roumain J, Bennett PH, Knowler WC: The 1997 American Diabetes Association and 1999 World Health Organization criteria for hyperglycemia in the diagnosis and prediction of diabetes. *Diabetes Care* 23:1108–1112, 2000
15. McNeely MJ, Boyko EJ, Shofer JB, Newell-Morris L, Leonetti DL, Fujimoto WY: Standard definitions of overweight and central adiposity for determining diabetes risk in Japanese Americans. *Am J Clin Nutr* 74:101–107, 2001
16. Must A, Spadano J, Coakley EH, Field AE, Colditz G, Dietz WH: The disease burden associated with overweight and obesity. *JAMA* 282:1523–1529, 1999
17. Drzewoski J, Czupryniak L: Concordance between fasting and 2-h post-glucose challenge criteria for the diagnosis of diabetes mellitus and glucose intolerance in high risk individuals. *Diabet Med* 18:29–31, 2001
18. Hilton DJ, O'Rourke PK, Welborn TA, Reid CM: Diabetes detection in Australian general practice: a comparison of diagnostic criteria. *Med J Aust* 176:104–107, 2002
19. de Vegt F, Dekker JM, Jager A, Hienkens E, Kostense PJ, Stehouwer CD, Nijpels G, Bouter LM, Heine RJ: Relation of impaired fasting and postload glucose with incident type 2 diabetes in a Dutch population: the Hoorn Study. *JAMA* 285:2109–2113, 2001
20. Shaw JE, Zimmet PZ, de Courten M, Dowse GK, Chitson P, Gareeboo H, Hemraj F, Fareed D, Tuomilehto J, Alberti KG: Impaired fasting glucose or impaired glucose tolerance: what best predicts future diabetes in Mauritius? *Diabetes Care* 22: 399–402, 1999
21. Mooy JM, Grootenhuis PA, de Vries H, Kostense PJ, Popp-Snijders C, Bouter LM, Heine RJ: Intra-individual variation of glucose, specific insulin and proinsulin concentrations measured by two oral glucose tolerance tests in a general Caucasian population: the Hoorn Study. *Diabetologia* 39:298–305, 1996
22. Burke JP, Haffner SM, Gaskill SP, Williams KL, Stern MP: Reversion from type 2 diabetes to nondiabetic status: influence of the 1997 American Diabetes Association criteria. *Diabetes Care* 21:1266–1270, 1998