

# Hemoglobin A<sub>1c</sub> as a Diagnostic Tool for Diabetes Screening and New-Onset Diabetes Prediction

A 6-year community-based prospective study

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**OBJECTIVE**—Various cutoff levels of hemoglobin A<sub>1c</sub> (A1C) have been suggested to screen for diabetes, although more consensus about the best level, especially for different ethnicities, is required. We evaluated the usefulness of A1C levels when screening for undiagnosed diabetes and as a predictor of 6-year incident diabetes in a prospective, population-based cohort study.

**RESEARCH DESIGN AND METHODS**—A total 10,038 participants were recruited from the Ansong-Ansan cohort study. All subjects underwent a 75-g oral glucose tolerance test at baseline and at each biennial follow-up. Excluding subjects with a previous history of diabetes ( $n = 572$ ), the receiver operating characteristic curve was used to evaluate the diagnostic accuracy of the A1C cutoff. The Cox proportional hazards model was used to predict diabetes at 6 years.

**RESULTS**—At baseline, 635 participants (6.8%) had previously undiagnosed diabetes. An A1C cutoff of 5.9% produced the highest sum of sensitivity (68%) and specificity (91%). At 6 years, 895 (10.2%) subjects had developed incident diabetes. An A1C cutoff of 5.6% had the highest sum of sensitivity (59%) and specificity (77%) for the identification of subsequent 6-year incident diabetes. After multivariate adjustment, men with baseline A1C  $\geq 5.6\%$  had a 2.4-fold increased risk and women had a 3.1-fold increased risk of new-onset diabetes.

**CONCLUSIONS**—A1C is an effective and convenient method for diabetes screening. An A1C cutoff of 5.9% may identify subjects with undiagnosed diabetes. Individuals with A1C  $\geq 5.6\%$  have an increased risk for future diabetes.

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The prevalence of type 2 diabetes is increasing rapidly. In the U.S., >13% of adults have been diagnosed with type 2 diabetes (1), and a similar prevalence has been reported in Asia (2). Up to 25% of newly diagnosed diabetic patients already had microvascular complications, which suggests that there is a 6- to 7-year time lag between the onset and the diagnosis of type 2 diabetes (3).

When considering the clinical implications of diabetes and its complications,

it is important to identify individuals with undiagnosed diabetes or those who are prone to diabetes in the near future. The American Diabetes Association (ADA) recommends screening asymptomatic people at 3-year intervals using a fasting plasma glucose (FPG) test or 2-h oral glucose tolerance test (OGTT) (4). However, it is not easy to perform the OGTT in primary practice, and it is debatable whether the FPG concentration alone provides an accurate diagnosis of diabetes, as

indicated by the estimated 40% of people who have undiagnosed diabetes (1).

The hemoglobin A<sub>1c</sub> (A1C) level is measured in a standardized test that produces data consistent with those of the international A1C-derived average glucose and the Diabetes Control and Complications Trial (5,6). The A1C level provides a reliable measure of chronic glycemic control without the need for a fasting or timed sample, and it correlates well with the risk of long-term diabetes complications and mortality (7,8). Several population-based studies have investigated the utility of the A1C level for detecting undiagnosed diabetes and the potential to use the A1C level as a good screening tool for type 2 diabetes (9,10). However, the recent ADA redefinition of the diagnosis of diabetes using an A1C level  $\geq 6.5\%$ , which considers many aspects of diagnostic testing and the economic burden, raises concerns about the possible delay in diagnosing diabetes (11,12). Thus, there is widespread debate about the appropriate A1C cutoff value for diagnosing diabetes.

To evaluate the predictive value of the A1C level and to find the appropriate A1C cutoff for identifying undiagnosed diabetes and new-onset diabetes over a 6-year follow-up, we analyzed the data from a large-scale, prospective cohort study of people from a homogeneous ethnic background.

## RESEARCH DESIGN AND METHODS

The design and baseline characteristics of the Ansong-Ansan cohort study have been published by our group (13). Briefly, it is an ongoing prospective, community-based cohort study that is part of the Korean Health and Genome Study, a community-based epidemiological survey to investigate the trends in diabetes and associated risk factors. The baseline examination was performed in 2001–2002, and biennial follow-up examinations will continue through 2010. The eligibility criteria included an age of 40–69 years, residence within the borders

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of the survey area for at least 6 months before testing, and sufficient mental and physical ability to participate.

Participants were recruited from the residents of two Korean communities within 60 km of Seoul. Ansung is a representative rural farming community that had a population of 132,906 in 2000 (14). Of 7,192 eligible individuals in Ansung, 5,018 were surveyed (70% response rate) using a cluster-sampling method stratified by age, sex, and residential district. Ansan is a representative urban community that had a population of 554,998 in 2000 (14). We successfully recruited 5,020 subjects from 124,775 eligible subjects (4.0%) using a random-sampling method of the local telephone directory.

At baseline, we excluded 572 (5.7%) individuals with known type 2 diabetes and 91 who had an unknown glucose status. Among 9,375 (4,415 men and 4,960 women) participants without a previous history of diabetes, 635 (6.8%) were newly diagnosed with type 2 diabetes at the baseline examination. Of 8,740 remaining nondiabetic subjects, 5,945 (3,022 from Ansung and 2,923 from Ansan) were included and underwent repeated examinations during the 6-year follow-up period. The recall rate was 85.7% at the 2-year follow-up examination, 74.9% at year 4, and 66.7% at year 6. To deal with the bias arising from missing data, we used a data-deletion method and found that there was no significant bias caused by loss to follow-up.

Informed written consent was obtained from all participants. The study protocol was approved by the ethics committee of the Korean Center for Disease Control and the Ajou University School of Medicine Institutional Review Board.

Throughout the study, the same trained researchers and instruments were used to collect the data. Anthropometric parameters and blood pressure were measured by standard methods. The fasting plasma concentrations of glucose, insulin, total cholesterol, triglycerides, HDL cholesterol, and high-sensitivity C-reactive protein (hsCRP) were measured in a central laboratory.

After an 8- to 14-h overnight fast, all subjects underwent a 2-h 75-g OGTT at inclusion and biennially. A1C level was measured using high-performance liquid chromatography (Variant II; BioRad Laboratories, Hercules, CA). Pancreatic  $\beta$ -cell function and insulin resistance were calculated by the homeostasis model

assessment (HOMA- $\beta$  and HOMA-IR, respectively).

### Definition

For both baseline and during follow-up, the definition of diabetes was based on plasma glucose results during the 75-g OGTT, defined according to the 1997 ADA criteria: FPG concentration  $\geq 7.0$  mmol/L (126 mg/dL) or 2-h plasma glucose  $\geq 11.1$  mmol/L (200 mg/dL) or current treatment by oral antidiabetes drugs or insulin (15). A family history of diabetes was coded if there was at least one diabetic first-degree relative. Hypertension was defined as systolic blood pressure  $\geq 140$  mmHg or diastolic blood pressure  $\geq 90$  mmHg or taking antihypertensive medication.

### Statistical analysis

The data are presented as means  $\pm$  SD, as numbers and percentages, or as a relative risk (RR) with 95% CIs. Fasting insulin, triglycerides, and hsCRP concentrations and HOMA- $\beta$  and HOMA-IR were normalized by logarithmic transformation. The means were compared by Student *t* tests or by ANCOVA. For qualitative variables, the results are expressed as percentages and were compared by  $\chi^2$  or by logistic regression. Pearson correlation analysis was used to determine the relationships between A1C level and plasma glucose concentration. The diagnostic properties of the specific threshold levels of A1C were evaluated by calculating the sensitivity, specificity, and positive and negative predictive value by the receiver operating characteristic (ROC) curve. To decide optimal-cutoff A1C, we were referencing the Youden-Index ( $J = \max_c \{sensitivity(c) + specificity(c) - 1\}$ , for all possible cutoff values *c*) (16).

Risk of new-onset diabetes according to the A1C cutoff was modeled using the Cox proportional hazards model, after adjusting for age, and using those variables with  $P \leq 0.25$  in the age-adjusted comparison between the diabetic and nondiabetic groups. We first examined the age-adjusted effects of the A1C cutoff on the 6-year incidence of diabetes (model A). Model B comprised model A with additional adjustment for anthropometric and social parameters. Model C was the adjusted model B plus triglyceride, HDL cholesterol, and hsCRP concentrations and HOMA- $\beta$  and HOMA-IR. The final Cox models fulfilled the proportional hazards assumption.

We compared the predictive performance of A1C level and FPG concentration

as continuous variables using the ROC curves and by calculating the area under the curves. For detecting undiagnosed diabetes at baseline by ROC curve analysis, we used the baseline data of participants without a previous history of diabetes. For incident diabetes after the 6-year follow-up, we used the 6-year follow-up data of participants who were nondiabetic at baseline and who had completed the 6-year follow-up. MedCalc software was used to calculate the ROC curves; the significance of differences between areas under these curves was calculated as shown elsewhere (17). All other analyses were performed using SPSS software (version 12.0; SPSS, Chicago, IL). Significance was defined as  $P < 0.05$  for two-sided tests.

## RESULTS

### Baseline characteristics

Of 9,375 participants without a previous history of diabetes, 635 (6.8%) subjects revealed previously undiagnosed diabetes at the baseline 75-g OGTT test (Table 1). The clinical characteristics of participants with and without undiagnosed diabetes at baseline are shown in Supplementary Table 1. At baseline, the Pearson correlation coefficients were 0.759 between A1C level and FPG and 0.673 between A1C level and 2-h plasma glucose (all  $P < 0.001$ ).

Table 1 showed the different characteristics between diabetic converters versus nondiabetic subjects. Over 6 years, 895 (10.2%) subjects developed new type 2 diabetes, and the mean follow-up periods were  $5.68 \pm 0.99$  years. After adjusting for age, BMI, waist circumference, blood pressure, FPG, and 2-h plasma glucose, A1C level, fasting insulin, HOMA-IR, total cholesterol, triglycerides, and hsCRP concentrations were higher in those who developed diabetes. In both sexes, a family history of diabetes, hypertension, and urban residence (Ansan) were more frequent in the incident diabetic group.

### A1C cutoff for detecting undiagnosed diabetes and predicting progression to diabetes

Table 2 shows the sensitivity, specificity, and positive and negative predictive values of A1C level for detecting undiagnosed diabetes and predicting 6-year incident diabetes at A1C cutoff values of 5.0–6.6%. For detecting undiagnosed diabetes, an A1C cutoff of 5.9% produced the maximum sum of sensitivity (68%)

Table 1—Baseline characteristics of men and women who developed or did not develop diabetes at 6 years

	Men			Women		
	Not diabetic at follow-up	Diabetic at follow-up	Age-adjusted P	Not diabetic at follow-up	Diabetic at follow-up	Age-adjusted P
n	2,328	478		2,722	417	
Age (years)	51.1 ± 8.4	52.5 ± 8.7		51.6 ± 8.7	54.1 ± 8.8	
BMI (kg/m <sup>2</sup> )	24.1 ± 2.8	24.8 ± 3.1	<0.001	24.6 ± 3.1	26.0 ± 3.3	<0.001
Waist circumference (cm)	83 ± 7	85 ± 8	<0.001	81 ± 9	85 ± 10	<0.001
Systolic blood pressure (mmHg)	116 ± 16	121 ± 17	<0.001	115 ± 18	123 ± 20	<0.001
Diastolic blood pressure (mmHg)	76 ± 11	78 ± 11	<0.001	73 ± 11	77 ± 12	<0.001
FPG (mmol/L)	4.7 ± 0.5	5.1 ± 0.6	<0.001	4.6 ± 0.4	4.9 ± 0.6	<0.001
2-h glucose (mmol/L)	6.1 ± 1.6	8.0 ± 1.9	<0.001	6.6 ± 1.5	8.4 ± 1.6	<0.001
A1C (%)	5.3 ± 0.3	5.6 ± 0.5	<0.001	5.3 ± 0.3	5.8 ± 0.5	<0.001
Fasting insulin (pmol/L)	35.8 ×/÷ 25.4	38.3 ×/÷ 28.1	0.016	41.1 ×/÷ 30.6	46.1 ×/÷ 27.2	<0.001
HOMA-IR	1.2 ×/÷ 0.9	1.4 ×/÷ 1.1	<0.001	1.4 ×/÷ 1.1	1.7 ×/÷ 1.0	<0.001
HOMA-β	105.3 ×/÷ 123.4	84.5 ×/÷ 223.2	<0.001	139.6 ×/÷ 142.2	120.9 ×/÷ 150.0	<0.001
Total cholesterol (mmol/L)	5.0 ± 0.9	5.1 ± 1.0	<0.001	4.9 ± 0.9	5.2 ± 0.9	<0.001
HDL cholesterol (mmol/L)	1.2 ± 0.3	1.1 ± 0.3	0.026	1.2 ± 0.3	1.2 ± 0.3	<0.001
Triglycerides (mmol/L)	1.6 ×/÷ 1.2	1.9 ×/÷ 1.2	<0.001	1.3 ×/÷ 0.8	1.8 ×/÷ 1.1	<0.001
hsCRP (mg/dL)	0.12 ×/÷ 0.57	0.14 ×/÷ 0.42	0.005	0.10 ×/÷ 0.60	0.15 ×/÷ 0.25	<0.001
Serum creatinine (mg/dL)	1.0 ± 0.2	1.0 ± 0.2	0.072	0.73 ± 0.16	0.73 ± 0.13	0.898
Hypertension (%)	8.6	14.9	<0.001	10.9	25.2	<0.001
Family history of diabetes (%)	9.2	14.0	<0.001	10.9	17.5	<0.001
Smoker (%)	46.1	48.2	0.319	2.4	5.6	0.001
Living in urban area (Ansan) (%)	50.1	61.7	<0.001	45.2	51.3	<0.001
Sporting activity (≥1 per week) (%)	39.2	38.7	0.929	32.9	34.3	0.150
Alcohol intake (≥60 Kcal per day) (%)	45.2	49.3	0.053	2.8	4.1	0.042
Child with birth weight >4 kg (%)	—	—	—	11.2	12.3	0.338

Data are means ± SD, geometric mean ×/÷ SD, or column percentage. Comparisons are adjusted for age.

and specificity (91%) by ROC analysis. The positive and negative predictive values of this cut point were 34 and 98%, respectively.

For predicting incident diabetes at 6 years, an A1C level of 5.6% was the optimal cutoff; the sensitivity, specificity, and positive and negative predictive values of this cut point were 59, 77, 31, and 91%, respectively.

To test the A1C cut points to predict future diabetes, we tested reliability by randomly dividing our cohort into the two groups. Half of the cohort was used to define the cut point and the other half to test reliability by calculating the incidence and adjusted RRs. The incidences and RRs were 31.7, 37.6, 46.5, 53.3, 58.9, 67.6, and 89.7% and 4.9, 5.9, 8, 9.4, 10.8, 13.8, and 51.5 at the A1C cutoff of 5.6, 5.7, 5.8, 5.9, 6, 6.2, and 6.6%, respectively.

#### A1C level and prediction of new-onset diabetes

The RR of new-onset diabetes in subjects whose A1C levels were above or below 5.6% was assessed using the Cox proportional hazards model (Table 3). In the age-adjusted model (model A), an A1C

cutoff ≥5.6% predicted incident diabetes in both men and women with a RR of 3.4 (95% CI 2.9–4.1) in men and 4.6 (3.7–5.7) in women (both  $P < 0.001$ ). This increased risk remained after additional adjusting for other confounding factors (model C).

Because the A1C level displayed a significant interaction with sex and FPG concentration, we stratified by sex and performed subgroup analysis in the subjects with impaired fasting glucose (IFG) (Table 3; Supplementary Table 2). A total of 457 participants had IFG at baseline, and 138 subjects developed incident diabetes during the 6 years. In IFG group at baseline, an A1C level of 5.8% produced the highest sum of sensitivity and specificity for predicting new-onset diabetes at 6 years (Supplementary Table 3). After multivariate adjustment, those with an A1C level ≥5.8% had a 3.5-fold increased risk of incident diabetes in men and 5.2-fold increased risk in women. The RR of incident diabetes increased as baseline A1C level increased in both the group with normal glucose tolerance and with IFG, respectively (Supplementary Table 2).

#### ROC curves

Figure 1 shows the ROC curves representing the sensitivity and specificity of the A1C levels in detecting undiagnosed diabetes (Fig. 1A) and predicting new-onset diabetes (Fig. 1B) at each possible A1C cutoff level. The analysis indicated a high predictive value for A1C level in screening for undiagnosed diabetes and in predicting future diabetes.

For the identification of undiagnosed diabetes in the entire study population of 9,375 subjects, the areas under the curve for A1C level were similar with that for FPG concentration (0.85 [95% CI 0.84–0.87] vs. 0.88 [0.86–0.89];  $P = 0.14$ ). The optimal FPG cutoff for predicting undiagnosed diabetes was 5.5 mmol/L (99 mg/dL), with 70% sensitivity and 94% specificity (Fig. 1A, dotted line).

For predicting new-onset diabetes after the 6-year follow-up, the area under the curve for A1C level was significantly greater than that for FPG concentration (0.74 [95% CI 0.72–0.76] vs. 0.69 [0.67–0.71];  $P < 0.001$ ). For FPG concentrations, the cutoff value of 4.8 mmol/L (87 mg/dL) yielded the maximum sum of sensitivity (62%) and specificity (67%) in

**Table 2—Sensitivity, specificity, and positive and negative predictive value of increasing A1C cutoff levels for detecting undiagnosed diabetes and for predicting the incidence of type 2 diabetes at the 6-year follow-up**

A1C cutoff (%)	Baseline undiagnosed diabetes				Incident diabetes after 6 years of follow-up			
	Predictive value				Predictive value			
	Sensitivity	Specificity	Positive	Negative	Sensitivity	Specificity	Positive	Negative
5.0 (−1.00 SDs above normal mean)	0.972	0.115	0.074	0.982	0.962	0.121	0.162	0.947
5.1 (−0.75 SDs above normal mean)	0.956	0.185	0.079	0.98	0.935	0.198	0.171	0.945
5.2 (−0.50 SDs above normal mean)	0.945	0.279	0.087	0.986	0.886	0.302	0.184	0.937
5.3 (−0.25 SDs above normal mean)	0.915	0.390	0.098	0.984	0.827	0.419	0.201	0.932
5.4 (0.00 SDs above normal mean)	0.887	0.506	0.115	0.984	0.768	0.547	0.231	0.930
5.5 (0.25 SDs above normal mean)	0.866	0.616	0.141	0.984	0.682	0.665	0.265	0.922
<b>5.6 (0.50 SDs above normal mean)</b>	<b>0.822</b>	<b>0.717</b>	<b>0.174</b>	<b>0.982</b>	<b>0.594</b>	<b>0.769</b>	<b>0.313</b>	<b>0.914</b>
5.7 (0.75 SDs above normal mean)	0.770	0.797	0.216	0.979	0.508	0.847	0.370	0.907
5.8 (1.00 SDs above normal mean)	0.720	0.862	0.274	0.977	0.420	0.908	0.448	0.898
<b>5.9 (1.25 SDs above normal mean)</b>	<b>0.676</b>	<b>0.907</b>	<b>0.344</b>	<b>0.975</b>	0.333	0.947	0.527	0.889
6.0 (1.50 SDs above normal mean)	0.619	0.935	0.411	0.971	0.263	0.967	0.586	0.881
6.2 (2.00 SDs above normal mean)	0.523	0.968	0.544	0.965	0.152	0.987	0.677	0.868
6.6 (3.00 SDs above normal mean)	0.372	0.992	0.771	0.956	0.051	0.999	0.885	0.856

predicting new-onset diabetes (Fig. 1B, dotted line).

**CONCLUSIONS**—The main finding of this study is that the A1C assay was useful as a screening test for type 2 diabetes and as a predictor of future diabetes. In our population, an A1C cutoff of 5.9% was able to identify people with undiagnosed diabetes, and individuals with an A1C  $\geq$ 5.6% had an increased risk for progression to type 2 diabetes independent of other confounding factors.

This was a large, prospective cohort study that used stringent criteria to diagnose diabetes and to evaluate the usefulness of A1C level in diabetes screening and in the prediction of new-onset diabetes. In this homogeneous population-based study, we applied the OGTT to all

participants and used the same instruments and personnel for all clinical and biochemical assessments during the 6 years.

Use of the A1C level in the diagnosis of or screening for diabetes has been debated for many years. Most A1C assays, such as the National Glycohemoglobin Standardization Program (18), are standardized, and recent expert committee reports suggest an A1C cutoff of 6.5% for diagnosing diabetes (11). For screening a general population, the A1C level has several advantages over the currently used FPG concentration or 2-h glucose concentration after an OGTT. The A1C assay does not need a fasting or timed sample. It is a better indicator of chronic glycemic level, has less preanalytic instability (19), and has a more consistent relationship

with diabetic microvascular complications than does FPG concentration (20,21). However, concerns remain about the risk of underdiagnosing people with overt diabetes when using an A1C cutoff of 6.5% (12).

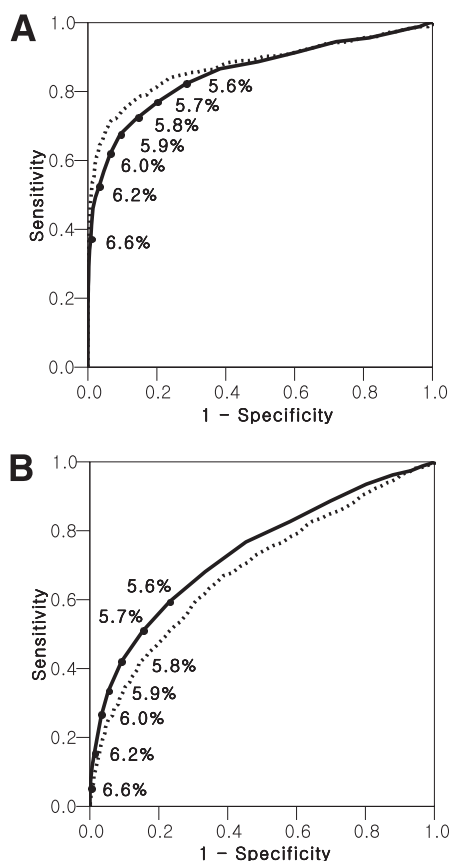
Several cross-sectional studies have evaluated the accuracy of the A1C cutoffs in screening for diabetes. In analysis of the National Health and Nutrition Examination Survey data, Buell et al. (9) reported that an A1C level of 5.8% showed the highest sensitivity (86%) and specificity (92%) in identifying undiagnosed diabetes when using FPG concentration as the diagnostic test for type 2 diabetes. In the current study, the definition of diabetes was based on plasma glucose results from the 75-g OGTT, and the A1C value of 5.9% was appropriate for detecting undiagnosed type 2 diabetes in this Korean cohort population. In a Japanese study of OGTT results in 1,904 people, an A1C cut point of 5.6% identified undiagnosed type 2 diabetes, and this value is used as a supplementary diagnostic criterion by the Japanese Diabetes Society (10).

Only a few studies have investigated the utility of A1C level in predicting new-onset diabetes. Recent Japanese and French cohort studies reported that A1C level is effective in predicting type 2 diabetes (22,23) but was less sensitive and specific than FPG concentration for predicting FPG-defined diabetes (22). This might be because many people with an abnormal 2-h glucose concentration after an OGTT have a normal FPG concentration (24). We used OGTT to

**Table 3—The RR of incident type 2 diabetes at the 6-year follow-up in Cox proportional hazards models based on A1C status at baseline**

	Men		Women	
	RR (95% CI)	P	RR (95% CI)	P
A1C $\geq$ 5.6% (vs. <5.6%) in the entire study population				
Model A*	3.44 (2.87–4.13)	<0.001	4.60 (3.75–5.66)	<0.001
Model B†	3.17 (2.62–3.84)	<0.001	4.00 (3.24–4.95)	<0.001
Model C‡	2.41 (1.98–2.93)	<0.001	3.06 (2.46–3.81)	<0.001
A1C $\geq$ 5.8% (vs. <5.8%) in subjects with IFG				
Model A*	3.15 (2.13–4.64)	<0.001	6.29 (3.03–13.05)	<0.001
Model B†	3.57 (2.36–5.41)	<0.001	5.99 (2.83–12.66)	<0.001
Model C‡	3.47 (2.27–5.29)	<0.001	5.15 (2.39–11.11)	<0.001

There was significant interaction between A1C and sex. The interaction between A1C and FPG also was significant. \*Age adjusted. †Model A and waist circumference, family history of diabetes, living in urban area, hypertension, smoking, and alcohol intake were adjusted. ‡Model B and triglycerides (log), HDL cholesterol, HOMA-IR (log), HOMA- $\beta$  (log), and hsCRP (log) were adjusted.



**Figure 1**—ROC curves for undiagnosed diabetes at baseline (A) and incident diabetes after 6 years of follow-up (B). Solid line, A1C; dotted line, FPG.

define diabetes and found that A1C level was independently related to an increased risk of new-onset diabetes, even in those with IFG at baseline. The predictive value of the A1C level was greater than that of the FPG concentration.

Determining the optimal A1C cutoff for diabetes screening is somewhat arbitrary because the risk of diabetes is continuous over a range of glycemic measures. To maximize the diagnostic efficiency, the optimal A1C cutoff should be considered in balancing both sensitivity and specificity. Despite the A1C cutoff value of 5.6% for identifying individuals with increased risk of future diabetes, as was chosen by the Youden Index, it showed only 31% of the positive predictive value. However, we considered the clinical situation because diabetes is a common disease and the action for prevention is highly beneficial and does relatively little harm to healthy subjects.

Our study has some limitations. All participants were enrolled from Korean rural and urban communities of homogeneous ethnic background, and it is

debatable whether these results can be generalized. Although racial differences in A1C level have been suggested (25), the significance of any differences is not clear, and the use of different A1C values according to ethnicity is not currently recommended. However, after multivariate adjustment of confounders, A1C level remained as an independent predictor of incident diabetes. In addition, the stringency of our study method and prospective follow-up of a large community-based cohort for 6 years make our results stronger than those of other studies.

In conclusion, we found that A1C level was effective and convenient for diabetes screening. An A1C cutoff of 5.9% may identify a high proportion of people with undiagnosed type 2 diabetes. Individuals with A1C  $\geq$ 5.6% have an increased risk for future diabetes, and early preventive intervention could be helpful.

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S.H.C. wrote and edited the manuscript. T.H.K. performed the statistical analysis and wrote the manuscript. S.L. contributed to discussion and statistical analysis. K.S.P. and H.C.J. reviewed and edited the manuscript. N.H.C. was the principal investigator of the project, collected and researched data, designed and performed the cohort study, and wrote the manuscript.

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