Use of the 1997 American Diabetes Association Diagnostic Criteria for Diabetes in a Hong Kong Chinese Population

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OBJECTIVE — Recently, the American Diabetes Association (ADA) has proposed revised diagnostic criteria for diabetes. Lowering of the fasting plasma glucose (FPG) cutoff value is intended to reduce the discrepancy with the 2-h plasma glucose (PG) cutoff value and to encourage the use of FPG. We have applied these new criteria to data collected from a population-based prevalence survey in Hong Kong Chinese subjects of working age.

RESEARCH DESIGN AND METHODS — The results of 1,513 oral glucose tolerance tests (OGTTs) from a previously published prevalence survey of glucose intolerance and cardiovascular risk factors in a Hong Kong Chinese working population were reexamined using the new criteria. Of the 1,513 subjects, 27 had a known history of diabetes. Of the remaining 1,486 subjects, 228 were also selected randomly for a second OGTT without prior knowledge of the result of the first test.

RESULTS — After exclusion of the 27 subjects with a known history of diabetes, the crude prevalence of diabetes was 2.83% (n = 42) when the World Health Organization's (WHO) criteria were applied. When the criterion of FPG ≥7.0 mmol/l was used, as recommended by the ADA, the prevalence of diabetes was 1.41% (n = 21). Twenty-nine subjects (1.95%) with FPG <7.0 mmol/l had a 2-h PG ≥11.1 mmol/l. Eight subjects (0.53%), previously without a diagnosis of diabetes according to the WHO criteria (FPG <7.8 mmol/l and 2-h PG <11.1 mmol/l), had FPG between 7.0 and 7.8 mmol/l and were classified as having diabetes by the ADA criteria. This classification gave a net change of −1.42% in the prevalence of diabetes between the use of FPG ≥7.0 mmol/l alone and the use of WHO criteria. Among the 1,486 subjects with no known history of diabetes, those classified as having diabetes according to the ADA FPG criterion alone had higher HbA_{1c} and fructosamine levels than diabetic subjects defined by the WHO criteria. Of the 228 subjects for whom two FPG measurements were available, those who had consistent definitions (diabetes, impaired fasting glucose, normal fasting glucose) on both occasions were considered to have reproducible tests, giving an overall reproducibility of 90.8% (207 of 228).

CONCLUSIONS — Compared with the WHO criteria, the use of FPG to diagnose diabetes, as recommended by the ADA, was a more reproducible test and identified those subjects who had a greater degree of hyperglycemia. Although lowering of the cutoff value from 7.8 to 7.0 mmol/l increased the number of diagnoses among subjects with low FPG, the omission of the 2-h PG would lead to fewer subjects having their diabetes diagnosed.

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Abbreviations: ADA, American Diabetes Association; CV, coefficient of variation; FPG, fasting plasma glucose; IFG, impaired fasting glucose; IGT, impaired glucose tolerance; NFG, normal fasting glucose; OGTT, oral glucose tolerance test; PG, plasma glucose; WHO, World Health Organization; WHR, waist-to-hip ratio.

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

The 75-g oral glucose tolerance test (OGTT) is generally regarded as the gold standard and final reference for the diagnosis of diabetes. In 1985, the World Health Organization (WHO) recommended a fasting plasma glucose (FPG) concentration ≥7.8 mmol/l and/or a 2-h post–glucose loading plasma glucose (PG) ≥11.1 mmol/l for the diagnosis of diabetes (1). However, the validity of the diagnostic FPG value of 7.8 mmol/l has been challenged because of its low sensitivity (2–5). Studies have suggested that the FPG value corresponding to a 2-h post–glucose loading PG concentration of 11.1 mmol/l lies between 5.3 and 7.1 mmol/l (2,6). In Hong Kong Chinese subjects, this value lies between 5.6 and 5.8 mmol/l (5,7). Furthermore, nondiabetic Chinese subjects with FPG values between 5.7 and 7.8 mmol/l have been reported to show increased obesity, hypertension, dyslipidemia, microalbuminuria, and hyperinsulinemia compared with subjects with a value <5.7 mmol/l, despite adjustment for age (5).

The performance of OGTT is labor intensive and inconvenient, and the results are poorly reproducible (8–11). In Hong Kong Chinese, the overall reproducibility of OGTT using the WHO criteria is only 65.6% (12). This percentage applies even to high-risk subjects, such as those with high HbA_{1c}, BMI, or waist-to-hip ratio (WHR) (12).

Recently, a committee of the American Diabetes Association (ADA) has proposed a revision of the diagnostic criteria for diabetes that lowers the FPG cutoff value. A joint working group of the WHO and the International Diabetes Federation is considering a similar proposal (G. Alberti, P. Zimmet, as yet unpublished). The ADA report recommends the use of FPG ≥7.0 mmol/l (126 mg/dl) instead of ≥7.8 mmol/l to diagnose diabetes (13). Subjects with FPG values between 6.1 and 7.0 mmol/l (110 and 126 mg/dl) are considered to have an intermediate form of the disease, which has been designated as impaired fasting glucose (IFG). FPG values below 6.1 mmol/l (110 mg/dl) are considered to be normal.

Table 1—*Categorization of glycemic status using the 75-g OGTT in 1,513 Hong Kong Chinese based on the WHO criteria*

OGTT categories	Subjects without known diabetes	Total subjects studied
Normal	1,334 (89.77)	1,334 (88.17)
IGT	110 (7.40)	110 (7.27)
Diabetes	42 (2.83)	69 (4.56)
Total	1,486 (100)	1,513 (100)

Data are *n* (%).

In this analysis, we have applied the proposed ADA diagnostic criteria to data collected from a previously published population-based prevalence survey for glucose intolerance and cardiovascular risk factors in Hong Kong Chinese subjects (14,15). We have also examined the reproducibility of categorization of glycemic status using the 1997 ADA criteria in a subgroup of 228 subjects in whom two FPG values were obtained.

RESEARCH DESIGN AND METHODS

— The results of 1,513 OGTTs from a prevalence survey for glucose intolerance and cardiovascular risk factors in a Hong Kong Chinese working population were reexamined. The subjects included 910 men and 603 women. The mean age (±SD) was 37.5 ± 9.2 years (36.7 ± 9.2 for men and 38.6 ± 9.1 for women; range, 18–66). The methodology has been described in detail previously (14,15). In brief, all employees from a public utility company and a regional hospital were invited to participate. On the day of the study, subjects were in attendance at their workplaces after overnight (12-h) fasting. Demographic data were documented, and height and weight were measured to the nearest 0.1 kg with the subject in light clothing and without shoes. BMI was calculated as the weight (expressed in kilograms) divided by the square of the height (expressed in meters). Waist circumference, measured to the nearest 0.5 cm, was taken as the minimum circumference between the umbilicus and the xiphoid process. Hip circumference, measured to the nearest 0.5 cm, was taken as the maximum circumference around the buttocks posteriorly and the symphysis pubis anteriorly. WHR was then calculated. A blood sample was taken for measurement of FPG, HbA_{1c}, and fructosamine. All subjects then underwent a 75-g OGTT for measurement of 2-h PG.

PG was measured by a glucose oxidase method (Diagnostic Chemicals reagent kit, Canada). Intra- and interassay coefficients of variation (CVs) for glucose were 2% at 6.6 mmol/l. HbA_{1c} (normal range, 5.1–6.4%) was measured by an automated ion-exchange chromatographic method (Bio-Rad, Hercules, CA). The intra- and interassay CV for HbA_{1c} was ≤3.1% at values <8.5%. Fructosamine was measured using a commercial reagent kit (Roche, Basel) with a centrifugal analyzer (Cobas Bio; Hoffman-La Roche, Basel). The interassay CV was 8.4% at low plasma fructosamine concentration (mean ± SD, 153 ± 12.9 μmol/l) and 4.2% at high plasma fructosamine concentration (313 ± 13.0 μmol/l). The intra-assay CV was <5%.

Of the 1,513 subjects, 27 had a known history of diabetes. The remaining 1,486 subjects, all of whom were asymptomatic and had no significant medical history, underwent an OGTT. Of these subjects, 228 were also randomly selected for a second OGTT without prior knowledge of the result of the first test.

Statistical analysis

Statistical analysis was performed using the SPSS (version 6.0) software on an IBM-compatible computer. All results are expressed as percentages, and Student's *t* test was used for between-group comparisons. *P* values <0.05 (two-tailed) were considered to be statistically significant.

RESULTS — Based on the 1985 WHO criteria, diabetes was diagnosed in 69 (4.56%) of the 1,513 subjects. After exclusion of the 27 subjects with a known history of diabetes, the crude prevalence of diabetes according to the 1985 WHO criteria was 2.83% (diabetes was diagnosed in 42 of the remaining 1,486 subjects) (Table 1). Of these 1,486 subjects, 21 (1.41%) had FPG ≥7.0 mmol/l (Table 2). Twenty-nine subjects (1.95%) with FPG <7.0 mmol/l had 2-h PG ≥11.1 mmol/l. Eight (0.54%) subjects in whom diabetes was not previously diagnosed by the WHO criteria (FPG <7.8 mmol/l and 2-h PG <11.1 mmol/l) had FPG values between 7.0 and 7.8 mmol/l and were therefore classified as having diabetes by the ADA criteria (Table 2). This result gave a net change of −1.42% in the prevalence of diabetes when the FPG

Table 2—*Categorization of glycemic status using FPG in 1,513 Hong Kong Chinese based on the 1997 ADA diagnostic criteria*

1997 ADA diagnostic criteria	FPG (mmol/l)	2-h PG (mmol/l)	Subjects without known diabetes	Total subjects studied
NFG			1,427 (96.03)	1,427 (94.32)
	<6.1	<7.8	1,313 (88.36)	1,313 (86.78)
		7.8–11.1	93 (6.26)	93 (6.15)
		≥11.1	21 (1.41)	21 (1.39)
IFG			38 (2.56)	38 (2.51)
	6.1–7.0	<7.8	14 (0.94)	14 (0.92)
		7.8–11.1	16 (1.08)	16 (1.06)
		≥11.1	8 (0.54)	8 (0.53)
Diabetes			21 (1.41)	48 (3.17)
	7.0–7.8	<7.8	7 (0.47)	—
		7.8–11.1	1 (0.07)	—
		≥11.1	3 (0.20)	—
	≥7.8	<7.8	2 (0.13)	—
		7.8–11.1	0	—
		≥11.1	8 (0.54)	—
Total			1,486 (100)	1,513 (100)

Data are *n* (%) unless otherwise indicated.

Table 3—*HbA_{1c}, fructosamine concentrations, and simple anthropometric indices in Hong Kong Chinese with different glycemic status categorized by either the WHO or 1997 ADA criteria*

		Diabetes		Normal		Nondiabetes	
Diagnostic criteria	Total	ADA	WHO	ADA (NFG)	WHO (normal OGTT)	ADA (NFG or IFG) but 2 h PG ≥11.1 mmol/l	WHO (IGT or normal OGTT) but FPG ≥7.0 mmol/l
n	1,486	21	42	1,427	1,334	29	8
HbA_{1c} (%)	4.68 ± 1.02	6.18 ± 1.59	5.79 ± 1.60	4.64 ± 0.98	4.63 ± 0.96	5.36 ± 1.38	5.24 ± 0.81
Fructosamine (μmol/l)	226.2 ± 39.6	276.8 ± 85.5	272.1 ± 61.8	225.2 ± 37.9	223.9 ± 37.5	256.2 ± 40.7	226.6 ± 62.4
BMI (kg/m²)	23.3 ± 3.2	26.0 ± 2.7	25.8 ± 4.0	23.2 ± 3.2	23.1 ± 3.1	25.4 ± 4.5	25.1 ± 2.6
WHR	0.84 ± 0.07	0.89 ± 0.08	0.90 ± 0.06	0.84 ± 0.07	0.84 ± 0.07	0.90 ± 0.05	0.88 ± 0.09
WC (cm)	78.3 ± 8.5	85.4 ± 8.1	85.8 ± 8.7	78.0 ± 8.4	77.6 ± 8.1	85.1 ± 9.3	82.4 ± 8.7

Data are means ± SD. WC, waist circumference.

cutoff value of 7.0 mmol/l was used alone. When categorization of all 1,513 subjects was based only on an FPG value of ≥7.0 mmol/l, the prevalence of diabetes was 3.17%, compared with 4.56% based on the WHO criteria (Tables 1 and 2).

Among the 1,486 subjects with no known history of diabetes, those classified as having diabetes according to the ADA's proposed FPG criterion had higher HbA_{1c} and fructosamine levels than those of diabetic subjects defined by the WHO criteria (Table 3). These indices were similar, however, between nondiabetic subjects defined by the ADA criteria and nondiabetic subjects defined by the WHO criteria. Subjects with discordant definitions by the proposed ADA and WHO criteria also had similar glycemic indices (Table 3). The BMI, WHR, and waist circumferences were similar between the two groups defined as diabetic by the ADA or WHO criteria (Table 3).

Table 4 summarizes the reproducibility of the FPG as a diagnostic test, using the new ADA recommendation, in the 228 subjects in whom two FPG measurements were available. The rates of diabetes using the ADA criteria were 5.7 and 4.8%, respectively, according to the first and second test results. The respective rates of IFG were 9.6 and 10.5%. Subjects who had consistent definitions (diabetes, IFG, or normal fasting glucose [NFG]) on both occasions (207 of 228 subjects) were considered to have reproducible tests, giving an overall reproducibility of 90.8% (Table 4).

CONCLUSIONS — The proposed ADA revised diagnostic criteria for glucose intolerance are intended to reduce the discrepancy between the FPG and 2-h PG cutoff values and to encourage the use of FPG, rather than OGTT, to diagnose diabetes (13). However, if the 2-h PG is omitted, fewer people will be diagnosed with diabetes. In the present analysis of Hong Kong Chinese subjects, the prevalence of diabetes was reduced by half, from 2.83% based on the WHO criteria to 1.41% using the 1997 ADA criterion of FPG alone. This finding reflects the fact that the diagnosis of diabetes in a significant proportion of subjects was based on 2-h PG ≥11.1 mmol/l (WHO criterion) when FPG was <7.0 mmol/l. In earlier studies of the glucose tolerance test in Chinese (5,7), our group reported similar findings. In Chinese subjects, the range of FPG values corresponding "statistically" to a 2-h PG value of 11.1 mmol/l is 5.7–5.8 mmol/l. The results of the two studies taken together indicate that 20% of subjects with 2-h PG ≥11.1 mmol/l also have FPG ≥7.8 mmol/l and that 28% have FPG ≥7.0 mmol/l (5,15).

As shown in Table 2, there is also difficulty with assignment of intermediate states when the different criteria are compared. Of the 110 subjects identified as having impaired glucose tolerance (IGT) using the WHO criteria, 93 (85%) had FPG <6.1 mmol/l. Conversely, 38 subjects would be categorized as having IFG according to the new criteria. Among these 38 subjects, the 2-h PG values are highly variable: 16 subjects (42%) have 2-h PG that is coincident with IGT, 14 subjects (36%) have normal 2-h PG, and 8 subjects (21%) have a 2-h value in the diabetic range (Table 2).

Thus, although the proposed new criteria are to be welcomed as an improvement on the old, they only partly rectify the problems associated with the old criteria, and they need to be applied with caution. In Chinese populations, this need for caution may be more apparent than in Western populations. Assuming that a 2-h PG of 11.1 mmol/l remains an appropriate cutoff value, then lowering of the FPG cutoff value from 7.8 to 7.0 mmol/l will increase the detection rate of diabetes, based on FPG alone, from 24% of the total to 42%. In addition, the introduction of the IFG category may add complexity to the diagnostic process. Further studies are urgently needed in Chinese populations to identify the most appropriate cutoff values based on clinical end points. The continuum of risk also needs to be considered. In Hong Kong Chinese, IGT (WHO classification) carries an increased risk of hypertension that is almost equal to diabetes (C.S.C., unpublished observations). Increased clustering of cardiovascular risk has also been shown for nondiabetic subjects with FPG values >5.7 mmol/l (5), and this finding is more strik-

Table 4—*Reproducibility of FPG in the diagnosis of diabetes based on the 1997 ADA diagnostic criteria*

First FPG*	Second FPG†	*n* (% in first FPG category)
NFG	NFG	184 (95.3)
	IFG	8 (4.2)
	Diabetes	1 (0.5)
IFG	NFG	7 (31.8)
	IFG	14 (63.7)
	Diabetes	1 (0.5)
Diabetes	NFG	2 (15.4)
	IFG	2 (15.4)
	Diabetes	9 (69.2)
Total		228 (100.0)

Reproducibility = (184 + 14 + 9)/228 = 90.8%. *First FPG results (*n* [%]): NFG, 193 (84.7); IFG, 22 (9.6); diabetes, 13 (5.7). †Second FPG results (*n* [%]): NFG, 193 (84.7); IFG, 24 (10.5); diabetes, 11 (4.8).

ing if the HbA_{1c} is also in the upper tertile of the normal range (16).

On the other hand, of the 1,486 asymptomatic subjects, 29 (1.95%) with an FPG <7.0 mmol/l had a 2-h PG ≥11.1 mmol/l, and 8 (0.54%) who were not classified as having diabetes by the WHO criteria were reclassified as having diabetes according to the new ADA recommendations. This reclassification produced an overall reduction of 1.42% in diabetes prevalence. This change is similar to the 2.0% reduction (from 6.4 to 4.4%) reported in a U.S. population study (17). However, with the WHO criteria used as the reference test, only 50% of the Chinese subjects were identified by the ADA's FPG criterion as having diabetes, compared with 69% in the U.S. population (17).

In this epidemiological study, although fewer subjects were classified as having diabetes by FPG alone (using the cutoff value of 7.0 mmol/l) than by the WHO criteria (using both FPG with a cutoff value of 7.8 mmol/l and 2-h PG with a cutoff value of 11.1 mmol/l), subjects in whom diabetes was diagnosed using the former criterion had higher glycemic indices, including HbA_{1c} and fructosamine, than those whose diabetes was diagnosed by the WHO criteria. These findings suggest that the new FPG criterion was better at identifying the more hyperglycemic subjects.

From a practical point of view, the administration of an OGTT is costly, labor intensive, and often causes inconvenience to subjects undergoing the test. The poor reproducibility of the test, reported to be as low as 50% in some studies (8–11), often adds confusion rather than clarification. In a subgroup analysis of the same study population, we have shown that the reproducibility of OGTT using the WHO criteria was only 65.6% (12). By contrast, the categorization of diabetes, IFG and NFG based on the new ADA criteria was more consistent, with an overall reproducibility of 90.8%. This reflects the lower intra-individual CV of the FPG compared with the 2-h PG (18).

In conclusion, compared with the WHO criteria, the use of an FPG cutoff value of 7.0 mmol/l alone to diagnose diabetes, as recommended by the ADA, was a more reproducible test and identified the more hyperglycemic subjects. Although the lowered cutoff value from 7.8 to 7.0 mmol/l increased the rate of diagnosis when based on FPG alone, the omission of 2-h PG would have led to fewer subjects being diagnosed and to a substantially lower overall prevalence rate. However, only long-term follow-up will show whether the subjects with FPG <7.0 mmol/l but a 2-h PG ≥11.1 mmol/l will turn out to be overtly diabetic. Also, only a long-term follow-up will prove whether and to what extent these subjects are prone to develop any diabetic complications.

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