Age- and Sex-Specific Prevalence of Diabetes and Impaired Glucose Regulation in 11 Asian Cohorts

THE DECODA STUDY GROUP

OBJECTIVE — To report the age- and sex-specific prevalence of diabetes and impaired glucose regulation (IGR) according to revised World Health Organization criteria for diabetes in Asian populations.

RESEARCH DESIGN AND METHODS — We performed 11 studies of 4 countries, comprising 24,335 subjects (10,851 men and 13,484 women) aged 30–89 years who attended the 2-h oral glucose tolerance test and met the inclusion criteria for data analysis.

RESULTS — The prevalence of diabetes increased with age and reached the peak at 70–89 years of age in Chinese and Japanese subjects but peaked at 60–69 years of age followed by a decline at the 70 years of age in Indian subjects. At 30–79 years of age, the 10-year age-specific prevalence of diabetes was higher in Indian than in Chinese and Japanese subjects. Indian subjects also had a higher prevalence of IGR in the younger age-groups (30–49 years) compared with that for Chinese and Japanese subjects. Impaired glucose tolerance was more prevalent than impaired fasting glycemia in all Asian populations studied for all age-groups.

CONCLUSIONS — Indians had the highest prevalence of diabetes among Asian countries. The age at which the peak prevalence of diabetes was reached was ~10 years younger in Indian compared with Chinese and Japanese subjects. Diabetes and IGR will be underestimated in Asians based on the fasting glucose testing alone.

Diabetes Care 26:1770–1780, 2003

Epidemiological studies on diabetes have had a significant impact on diabetes research, care, and prevention in the last century. The Asia-Pacific region has been considered to be the major site of a rapidly emerging epidemic of diabetes (1,2), and with its large populations it is of prime importance for the epidemiology of diabetes. It has been estimated that among the 10 leading countries in terms of the number of people with diabetes in the year 2025, 5 are in Asia (1).

According to earlier findings, the prevalence of type 2 diabetes and impaired glucose tolerance (IGT) varies markedly throughout Asia (3,4), according to race, lifestyle, level of affluence, mechanization, and urbanization. Apart from the increasing prevalence rates in the Asian-Pacific region, the ages at which the disease develops are becoming younger. In developed countries with predominantly Caucasian populations, most people with diabetes are older than 65 years. In developing countries, however, the majority are between the ages of 45 and 64 years (4). Age- and sex-specific prevalences of diabetes and impaired glucose regulation (IGR), according to the recently revised diagnosed criteria (5), have been reported among only a few Asian populations and not in a fully comparable fashion. We have previously reported (6,7) the discrepancies in classification of individuals with diabetes between the previous World Health Organization (WHO) criteria (8,9) and the revised diagnostic criteria (5,10) in the Asian populations participating in the DECODA (Diabetes Epidemiology: Collaborative analysis of Diagnostic criteria in Asia) study. In this article, age- and sex-specific prevalence of diabetes and IGR, as well as the age- and sex-specific prevalence of isolated fasting or isolated 2-h hyperglycemia, is reported for the 11 DECODA surveys.

Study populations

The study populations and the methods used to recruit the participants in the DECODA study have been previously reported (6,7). In the current data analysis, 11 population-based studies from four Asian countries were included (11–19). Among these, two studies were newly recruited, one from China, the Qingdao Diabetes Survey, and another from India, the National Urban Diabetes Study (NUDS) (19). Briefly, information on previous history of diabetes, data on glucose measurements at fasting and 2-h after a standard 75-g oral glucose tolerance test (OGTT) were sent to the Diabetes and Genetic Epidemiology Unit of the National Public Health Institute in Helsinki, Finland, where collaborative data analysis was carried out. The inclusion criteria for the current study are as follows: pure population-based studies (1); studies performed after 1980 (2); studies including

From the Department of Epidemiology and Health Promotion, National Public Health Institute, Helsinki, Finland.

Address correspondence and reprint requests to Dr. Qing Qiao, Diabetes and Genetic Epidemiology Unit, Department of Epidemiology and Health Promotion, National Public Health Institute, Mannerheimintie 166, FIN-00300, Helsinki, Finland. E-mail: qing.qiao@ktl.fi.

Received for publication 6 May 2002 and accepted in revised form 14 March 2003.

Members of the DECODA Group are listed in the APPENDIX.

Additional information for this article can be found in a data supplement at http://care.diabetesjournals.org.

Abbreviations: 2hPG, 2-h plasma glucose; DECODA, Diabetes Epidemiology: Collaborative Analysis of Diagnostic Criteria in Asia; FPG, fasting plasma glucose; IFG, impaired fasting glucose; IGT, impaired glucose tolerance; IGR, impaired glucose regulation; OGTT, oral glucose tolerance test; PDD, previously diagnosed diabetes; WHO, World Health Organization.

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

Table 1—Demographic data of the study population and the OGTT among those who had no previous history of diabetes

Study cohort	Mean age	Men (%)	Subjects with OGTT (*n*)	OGTT participation rate (%)	Fasting time (h)	Time of blood sampling (h)	Year of screening	Ethnic group	Study location
Shunyi, China	54 (40–79)	40.9	646	98	12	8:00 to 11:00	1997–1998	Chinese	Rural
Beijing, China	58 (40–89)	38.9	1,429	98	10–12	8:00 to 10:00	1997	Chinese	Urban
Qingdao, China	54 (30–74)	37.2	1,808	92	Overnight	7:00 to 9:30	2002	Chinese	Urban
Ojika, Japan	59 (35–89)	40.6	1,318	45	Overnight	9:00 to 11:00	1991	Japanese	Rural
Funagata, Japan	59 (40–87)	44.0	2,507	75	Overnight	7:00 to 11:00	1990–1992	Japanese	Rural
Hisayama, Japan	57 (40–79)	42.0	2,289	77	>12	8:00 to 10:30	1988	Japanese	Urban
Dombivli, India	48 (31–79)	54.0	520	76	Overnight	8:00 to 12:00	1998–1999	Indian	Urban
Chennai97, India	47 (30–78)	40.5	765	86	>10	7:00 to 10:30	1996–1998	Indian	Urban
Chennai94, India	44 (30–79)	52.6	1,105	72	>10	7:00 to 11:00	1993–1995	Indian	Urban
NUDS, India	46 (30–89)	46.3	7,458	90	Overnight	Morning	2000	Indian	Urban
Singapore	43 (30–69)	46.9	2,326	100	10	8:00 to 1:00	1992	Chinese, Malay, Indian	Urban
Total	51 (30–89)	44.2	22,171						

Data are range (years) unless otherwise indicated.

both men and women (3); at least 20 years of age range (4); and a standard 2-h 75-g OGTT in the morning after an over night fast for at least 10 h (5), according to WHO recommendations (8,9).

A total of 22,171 subjects (9,806 men and 12,365 women) who had no previous history of diabetes and 2,164 subjects (1,045 men and 1,119 women) who had a previous history of diabetes from four countries in Asia met the inclusion criteria for the current data analysis. The age range was 30–89 years. The demographic characteristics and information on the OGTT is shown in Table 1 for each study cohort, and more detailed information is shown in the APPENDIX. The proportion of female participants was slightly higher in 9 of the 11 studies. The participation rate for the 2-h OGTT varied from 72 to ~100% in most of the studies. Plasma glucose was determined in 10 and capillary whole blood glucose in 1 of the studies. Before data analysis, the capillary whole blood glucose was converted to the plasma glucose according to the conversion factors described before (20).

Classification of glucose abnormality

Subjects who reported a previous history of diabetes were classified as previously diagnosed diabetic. Those who were not diagnosed as diabetic before screening were classified according to the 1999 WHO recommendations for the diagnosis of diabetes (5). The classification of undiagnosed diabetes, IGT, and normal glucose tolerance was made according to 2-h plasma glucose (2hPG) concentrations ≥11.1, 7.8–11.0, and <7.8 mmol/l, respectively. Fasting plasma glucose (FPG) concentrations ≥7.0, 6.1–6.9, and <6.1 mmol/l, respectively, classified subjects into diabetes, impaired fasting glucose (IFG), and normal fasting glucose. Subjects with IGT and/or IFG were defined as having impaired glucose regulation according to the WHO 1999 recommendations (5).

Statistical analysis

Mean fasting and 2hPG concentrations were calculated for the Chinese, Japanese, and Indian subjects, excluding patients with previously diagnosed diabetes (PDD). The cohorts with the same ethnic origin were combined as one population. Age- and sex-specific prevalences of diabetes were calculated for six 10-year age

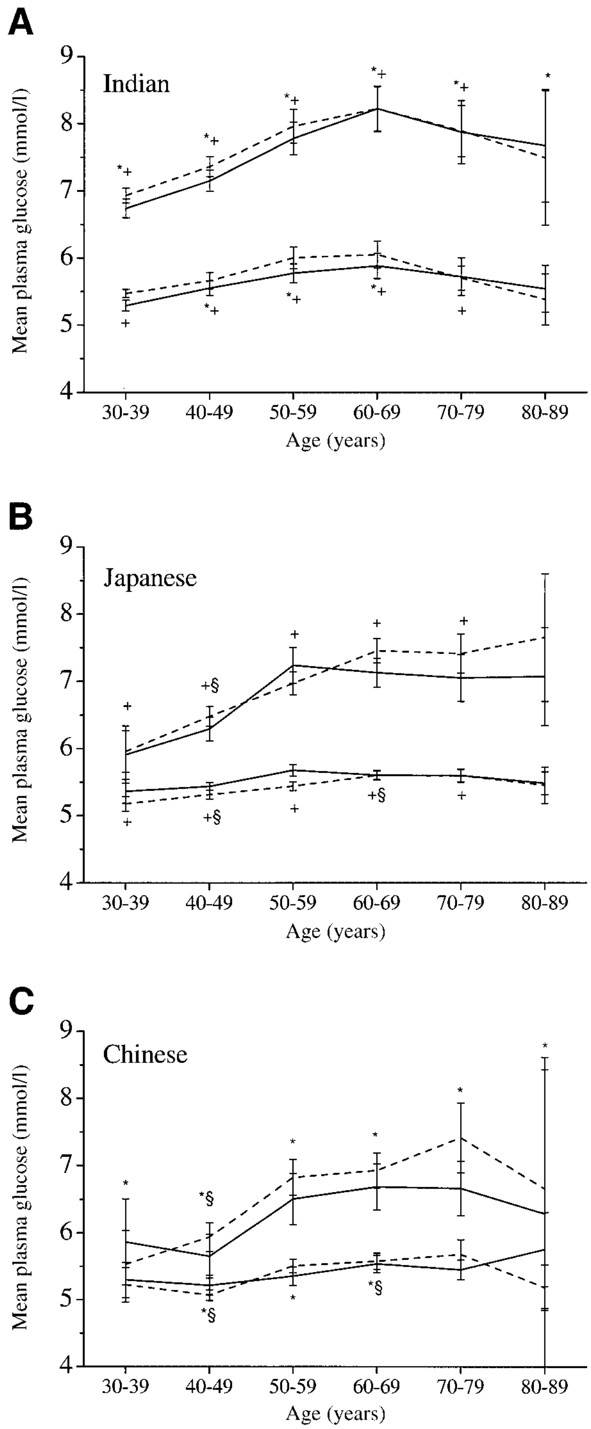

Figure 1—*Mean fasting (two lower lines on each panel) and 2hPG (two upper lines on each panel) concentrations and their 95% CIs (vertical bars) for the three populations of Indian (*A*), Japanese (*B*), and Chinese (*C*) subjects. The cohorts of the same country were combined as one population. —, men; - - -, women. *Indian vs. Chinese, +Indian vs. Japanese, §Japanese vs. Chinese, all for* P *< 0.05 for both sexes combined.*

intervals, from 30 to 89 years, separately for people with and without a previous history of diabetes. The prevalence of PDD was calculated by dividing the number of diagnosed cases by the total number of subjects who had responded to the questions on the previous history of diabetes. Because there were some nonparticipants in the OGTTs, the prevalence of undiagnosed diabetes [(undiagnosed cases identified by the OGTTs/the number of individuals who attended the OGTT) × (1 − PDD)]. The same rule was applied for calculating the prevalence of IGR, IGT, and IFG. Because the prevalence pattern for Chinese and Japanese subjects was similar and differed markedly from that for Indian subjects, the data for Chinese and Japanese subjects were combined in the pooled analysis; similarly, the data for all Indian cohorts were combined. We further divided the Chinese and Japanese populations into urban and rural populations in order to make comparisons with the urban Indian population. A χ^2 test was used to measure the differences in the prevalence between men and women and between different age-groups.

RESULTS

Age- and sex-specific plasma glucose concentration

Both FPG and 2hPG concentrations increased with age and reached a peak at 60–69 years of age then started to decline in Indian subjects and continued to increase after 70 years of age in Chinese and Japanese subjects (Fig. 1). At each age-group, the mean 2hPG was significantly higher for Indians than for Chinese and Japanese subjects (all $P < 0.05$), this was also true for FPG at most of the age-groups (Fig. 1). The increase is steeper for 2hPG than for FPG. The mean FPG and 2hPG concentrations did not differ between Chinese and Japanese subjects, except at 40–49 years of age where the glucose values were higher in Japanese than in Chinese subjects. There was no significant difference in mean glucose levels between men and women.

Age- and sex-specific prevalence of diabetes

The prevalence of diabetes varied markedly among Asian populations studied. It increased with age up to 70–89 years of age in Chinese and Japanese subjects but up to 60–69 years of age and then declined thereafter in Indian subjects (Table 2 and Fig. 2). Age- and sex-specific prevalence, especially the peak prevalence of diabetes, was higher in cohorts of India and Singapore than in most of the Chinese and Japanese cohorts. In Chinese and Japanese subjects, the prevalence was <10% at 30–49 years of age; the peak prevalence was <20% in most of the cohorts, and none of the cohorts had a prevalence exceeding 30%. In contrast, in India and Singapore, the prevalence was >10% among those aged 40–49 years and over 30% among those aged 50–69 years for most of the cohorts. The urban Chinese and Japanese subjects had significantly higher prevalences of diabetes

Table 2—*Prevalences of previously diagnosed and undiagnosed diabetes defined by 2hPG and FPG criteria (mmol/l) in men (M) and women (F) in the DECODA cohorts*

Cohort	Age (years)	Undiagnosed diabetes: 2hPG ≥11.1 and FPG <7.0		Undiagnosed diabetes: 2hPG <11.1 and FPG ≥7.0		Undiagnosed diabetes: 2hPG ≥11.1 and FPG ≥7.0		Diagnosed diabetes		Total diabetes	
		M	F	M	F	M	F	M	F	M	F
Shunyi, China	40–49	0	1.9	0	0.6	1.2	1.9	1.2	1.9	2.4	6.2
	50–59	3.1	1.9	0	0.9	2.1	4.7	1.0	2.8	6.2	10.3
	60–69	1.6	4.6	3.2	0	1.6	1.1	3.2	5.7	9.5	11.4
	70–79	0	2.6	0	0	0	2.6	0	5.1	0	10.3
Beijing, China	40–49	0.6	1.8	1.3	2.1	3.8	1.1	2.5	2.1	8.2	7.1
	50–59	5.2	5.4	0.8	0.5	3.7	5.4	4.5	4.9	14.2	16.1
	60–69	4.0	1.6	1.7	1.3	1.2	3.8	6.9	11.4	13.8	18.0
	70–79	2.6	3.9	2.6	2.3	3.5	7.0	11.4	15.6	20.2	28.9
	80–89	0	10.5	0	0	8.3	0	8.3	15.8	16.7	26.3
Qingdao, China	30–39	0	0	1.2	2.3	4.7	3.1	2.1	0.7	8.0	6.1
	40–49	3.6	1.0	1.4	1.0	2.2	2.3	2.0	2.2	9.2	6.5
	50–59	2.3	3.6	2.3	2.6	7.0	4.4	8.7	4.8	20.3	15.4
	60–69	3.1	3.4	2.7	2.4	7.5	5.1	5.4	7.1	18.7	18.0
	70–74	2.2	0	6.6	9.7	0	4.1	6.1	4.8	14.9	18.6
Ojika, Japan	35–39	0	0	2.9	0	0	0	0	0	2.9	0
	40–49	1.8	2.4	1.8	1.6	0.9	0	0.9	1.6	5.5	5.7
	50–59	5.1	1.9	2.5	1.9	1.7	1.9	0.9	0.5	10.2	6.2
	60–69	4.3	3.4	1.1	0.3	2.2	0.3	2.7	2.0	10.3	6.1
	70–79	4.8	2.8	0	1.9	2.4	0	4.8	0.9	11.9	5.7
	80–89	14.3	0	0	0	0	14.3	0	0	14.3	14.3
Funagata, Japan	40–49	0.4	0.4	0.4	0	0	0.4	1.3	1.6	2.1	2.4
	50–59	2.5	2.2	0.4	0	0.7	1.5	0.7	1.9	4.3	5.6
	60–69	4.2	3.6	1.0	1.7	2.0	2.5	4.5	3.7	11.7	11.5
	70–79	2.8	4.9	1.1	0.9	1.1	0.9	6.6	7.7	11.6	14.4
	80–89	3.7	7.4	0	0	0	0	8.5	15.8	12.1	23.2
Hisayama, Japan	40–49	2.8	1.2	1.2	0.5	1.9	0.7	5.6	2.7	11.6	5.1
	50–59	5.1	2.8	2.1	1.4	3.9	1.1	13.2	5.3	24.3	10.7
	60–69	3.5	3.0	1.7	1.6	2.1	1.6	13.4	11.4	20.7	17.6
	70–79	2.1	2.8	2.1	1.5	1.4	1.9	11.7	8.3	17.3	14.5
Dombivli, India	30–39	0	1.4	1.4	2.6	2.9	2.6	0	2.6	4.3	9.2
	40–49	0	1.3	2.0	2.5	3.1	1.3	3.1	10.1	8.2	15.1
	50–59	1.4	0	1.4	2.1	4.4	8.5	10.3	8.5	17.6	19.1
	60–69	7.1	2.6	9.5	7.7	9.5	10.2	0	10.3	26.1	30.8
	70–79	0	0	0	0	0	5.1	0	11.8	0	16.9
Chennai97, India	30–39	0.9	1.3	0	0	0	1.3	2.4	1.1	3.3	3.7
	40–49	4.5	1.4	0	0	2.7	2.1	10.2	5.4	17.4	8.9
	50–59	9.0	1.1	0	0	4.6	6.7	17.1	12.4	30.7	20.2
	60–69	2.6	6.0	0	4.5	5.2	7.5	29.8	17.6	37.6	35.7
	70–79	0	5.0	0	2.6	3.5	5.0	16.0	11.9	19.5	24.5
Chennai94, India	30–39	2.0	1.0	0	2.1	2.0	1.5	2.3	1.9	6.2	6.4
	40–49	2.8	5.5	2.4	2.9	3.0	4.7	8.3	11.3	16.5	24.4
	50–59	3.1	8.9	1.2	2.2	6.1	9.9	19.7	14.0	30.1	35.0
	60–69	3.1	2.8	0.0	0	6.3	11.1	27.3	22.4	36.8	36.3
	70–79	0	0	4.9	0	0	5.4	13.0	14.7	17.9	20.1
NUDS, India	30–39	2.1	2.1	4.0	5.9	2.5	2.2	4.8	4.3	13.3	14.4
	40–49	2.6	2.5	5.2	5.2	3.7	4.2	13.3	12.6	24.8	24.5
	50–59	5.2	3.1	5.2	5.1	5.8	5.7	18.9	20.6	35.0	34.5
	60–69	3.4	3.1	6.4	4.2	6.8	5.8	25.8	21.6	42.4	34.7
	70–79	3.2	5.4	4.6	6.3	7.3	4.1	22.4	20.7	37.4	36.5
	80–89	4.4	3.2	4.4	6.5	6.7	3.3	13.3	6.5	28.9	19.4

Continued on following page

Table 2—*Continued*

Cohort	Age (years)	Undiagnosed diabetes: 2hPG ≥11.1 and FPG <7.0		Undiagnosed diabetes: 2hPG <11.1 and FPG ≥7.0		Undiagnosed diabetes: 2hPG ≥11.1 and FPG ≥7.0		Diagnosed diabetes		Total diabetes	
		M	F	M	F	M	F	M	F	M	F
Singapore	30–39	1.6	0.5	0.8	0.7	2.8	1.3	2.1	1.4	7.3	3.9
	40–49	3.3	5.0	3.3	0.5	3.6	6.3	4.7	4.7	15.0	16.4
	50–59	2.9	3.4	1.4	1.7	4.8	5.2	15.1	9.6	24.3	20.0
	60–69	2.1	8.3	2.7	0	8.2	8.3	20.0	16.5	33.0	33.0
Chinese and Japanese, total	30–39	0	0	1.7	1.7	3.3	2.3	1.5	0.5	6.5	4.5
	40–49	1.7	1.3	1.0	0.9	1.6	1.1	3.1	2.1	7.4*	5.4
	50–59	3.8	3.0	1.4	1.3	3.3	2.8	6.2†	3.7	14.8‡	10.7
	60–69	3.7	3.1	1.6	1.4	2.8	2.5	6.7	7.1	14.9	14.2
	70–79	2.7	3.3	1.9	2.2	1.7	2.4	9.2	8.1	15.5	16.0
	80–89	5.4	6.5	0	0	1.8	2.6	10.7	16.9	17.9	26.0
Indian, total	30–39	1.9	1.9	3.2*	4.9	2.3	2.1	4.0	3.6	11.4	12.5
	40–49	2.6	2.8	4.2	4.4	3.5	3.9	11.5	11.6	21.8	22.7
	50–59	4.9*	3.3	4.0	4.4	5.7	6.3	18.4	18.7	33.0	32.6
	60–69	3.6	3.3	5.9	4.2	6.9	6.4	24.7	20.7	41.0†	34.6
	70–79	2.6	4.8	4.1	5.1	6.0	4.5	19.9	18.6	32.6	33.0
	80–89	3.6	2.7	3.6	5.3	7.2	2.7	9.8	7.1	24.2	17.7

Data are %. *$P < 0.05$, †$P < 0.01$, ‡$P < 0.001$ for the difference between men and women.

than their rural counterparts at 40–69 years of age for men and at 50–79 years of age for women (Fig. 2).

In all populations, the prevalence of isolated fasting hyperglycemia (FPG ≥7.0 mmol/l and 2hPG <11.1 mmol/l) did not increase with age (Fig. 2 and Table 2). The prevalence of isolated 2-h hyperglycemia (2hPG ≥11.1 mmol/l and FPG <7.0 mmol/l) tended to increase with age in Chinese and Japanese but not in Indian subjects.

Age- and sex-specific prevalence of IGR

The prevalence of IGR increased with age up to 70–89 years of age in most of the study cohorts (Table 3 and Fig. 3). The increase was graded with aging in Chinese, Japanese, and Singaporean populations but not in the Indian population, where the prevalence of IGR did not change much with age. The peak prevalences of IGR were not different among various populations, but the age-specific prevalence of IGR was higher in Indian than in Chinese and Japanese subjects at 30–49 years of age for both men and women. In the urban populations the prevalence was higher than in the rural population aged 40–69 years in men and 50–59 years in women (Fig. 3). In most of the study cohorts the age- and sex-specific prevalence of IGT was higher than the prevalence of IFG (Table 3 and Fig. 3). The concordance of the two was very poor.

Sex difference in prevalence of diabetes, IFG, and IGT

The age-specific prevalence of diabetes did not differ between men and women except in a few age-groups where men had higher prevalences of diabetes than women (Table 2). The prevalence of IFG seemed to be higher in men than in women in Chinese and Japanese populations, whereas it was higher in women than in men in the Indian population (Table 3). The prevalence of IGT tended to be higher in women than in men in Chinese and Japanese subjects, but the difference was significant only at 40–49 years of age. There was no sex difference in the prevalence of IGT in Indian populations except at 30–39 years of age where women had higher prevalence of IGT than men.

Proportion of previously undiagnosed diabetes

The proportions of previously undiagnosed diabetes varied with age, with the highest in the youngest age-group and the lowest in the elderly. The declining trend with age was similar in Chinese, Japanese, and Indian subjects, with only one exception in the very old Indian population where the proportion increased again at 80–89 years of age. The proportion of undiagnosed diabetes was slightly higher in women than in men at younger age-groups. They were, in Chinese and Japanese men (women) combined, 0.77 (0.89), 0.59 (0.61), 0.58 (0.65), 0.55 (0.50), 0.40 (0.50), and 0.40 (0.35) and in all Indian men (women) combined 0.65 (0.71), 0.47 (0.49), 0.44 (0.43), 0.40 (0.40), 0.39 (0.44), and 0.60 (0.60), respectively, at 30–39, 40–49, 50–59, 60–69, 70–79, and 80–89 years of age.

Figure 2— *Age- and sex-specific prevalence of diabetes for Chinese and Japanese studies combined and for all Indian studies combined for the men (A) and women (B). DMF (■): diabetes determined by FPG ≥7.0 mmol/l and 2hPG <11.1 mmol/l; DMP (▤): diabetes determined by 2hPG ≥11.1 mmol/l and FPG <7.0 mmol/l; DMF and DMP (□): diabetes determined by FPG ≥7.0 mmol/l and 2hPG ≥11.1 mmol/l. ▨, PDD. *P < 0.05, **P < 0.01, ***P < 0.001, for the difference between urban and rural Chinese and Japanese; +P < 0.05, +++P < 0.001, for the difference between Chinese and Japanese combined and Indian combined.*

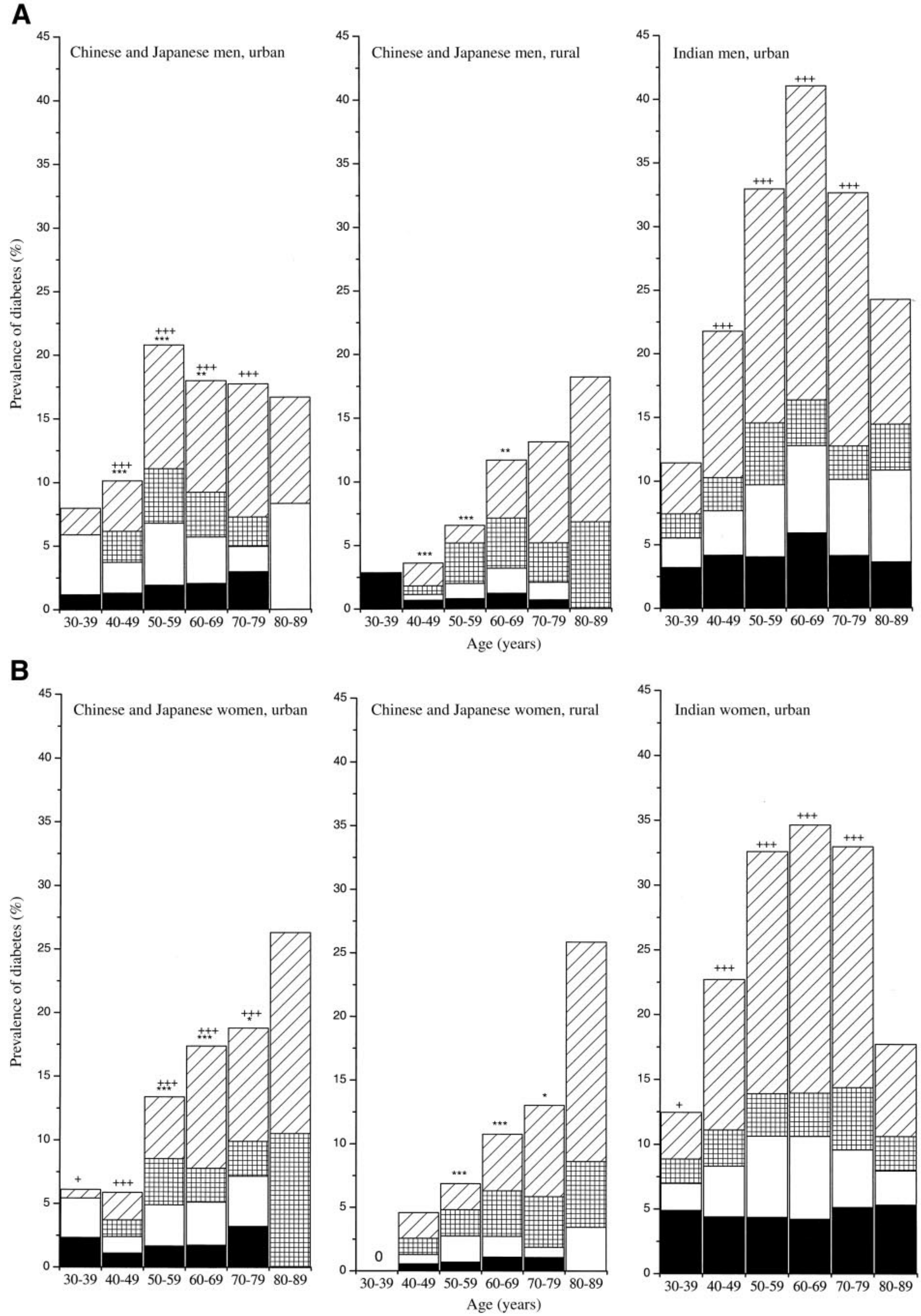
A
Chinese and Japanese men, urban
Chinese and Japanese men, rural
Indian men, urban
Prevalence of diabetes (%)
Age (years)
30-39 40-49 50-59 60-69 70-79 80-89
B
Chinese and Japanese women, urban
Chinese and Japanese women, rural
Indian women, urban
Prevalence of diabetes (%)
Age (years)
30-39 40-49 50-59 60-69 70-79 80-89

Table 3—*Prevalences of IGT, IFG, and IGR defined according to 2hPG and FPG criteria (mmol/l) in men (M) and women (F) in the DECODA cohorts*

Cohort	Age (years)	Isolated IGT 2hPG 7.8–11.0 and FPG <6.1		Isolated IFG 2hPG <7.8 and FPG 6.1–6.9		IGT and IFG 2hPG 7.8–11.0 and FPG 6.1–6.9		IGR IGT and/or IFG	
		M	F	M	F	M	F	M	F
Shunyi, China	40–49	4.7	10.6	1.2	0	0	0	5.9	10.6
	50–59	11.3	8.4	2.1	3.7	1.0	0	14.4	12.2
	60–69	11.1	10.2	1.6	2.3	1.6	2.3	14.3	14.8
	70–79	33.3	19.5	0	0	0	0	33.3	19.5
Beijing, China	40–49	5.7	6.8	3.8	0.7	0.6	0.7	10.1	8.2
	50–59	6.7	7.3	6.0	2.4	2.2	3.4	14.9	13.2
	60–69	9.2	9.2	5.8	2.9	4.0	3.8	19.0	15.8
	70–79	11.4	14.8	7.9	3.9	2.6	1.6	21.9	20.3
	80–89	8.3	10.5	8.3	0	0	5.3	16.7	15.8
Qingdao, China	30–39	1.2	0	7.1	0.8	3.5	0.8	11.8	1.6
	40–49	5.8	6.3	3.6	6.9	3.6	1.3	13.0	14.5
	50–59	6.9	7.0	8.8	12.2	1.4	1.6	17.1	20.8
	60–69	8.4	10.5	9.7	6.4	3.5	5.7	21.7	22.6
	70–74	15.3	12.4	6.6	13.8	2.2	2.8	24.0	29.0
Ojika, Japan	35–39	5.7	0	0	0	5.7	0	11.4	0
	40–49	10.9	12.2	5.5	3.3	0.9	1.6	17.3	17.1
	50–59	10.2	14.8	5.9	2.9	0.9	1.0	17.0	18.7
	60–69	16.2	18.0	4.3	5.4	9.2	4.8	29.7	28.1
	70–79	17.9	13.2	0	4.7	2.4	4.7	20.2	22.6
	80–89	21.4	28.6	7.1	0	0	0	28.6	28.6
Funagata, Japan	40–49	4.1	10.4	2.5	1.6	2.5	1.2	9.0	13.2
	50–59	7.1	10.0	2.1	0.7	1.8	1.0	10.9	11.7
	60–69	10.6	16.0	2.5	3.1	3.0	2.5	16.0	21.6
	70–79	11.4	18.3	2.8	3.1	2.8	3.1	17.0	24.6
	80–89	18.3	7.4	7.3	7.4	0	2.4	25.6	17.3
Hisayama, Japan	40–49	9.1	10.8	7.5	3.4	3.8	2.4	20.3	16.6
	50–59	11.6	13.3	7.3	5.1	4.3	3.5	23.1	21.9
	60–69	15.4	16.8	6.3	5.9	6.7	3.0	28.4	25.8
	70–79	13.9	17.2	10.4	6.2	4.2	7.2	28.5	30.7
Dombivli, India	30–39	2.9	0	10.1	4.0	5.8	2.6	18.8	6.6
	40–49	3.1	2.5	11.3	5.0	1.1	2.5	15.5	10.1
	50–59	1.4	2.1	7.4	8.5	4.4	4.3	13.2	14.9
	60–69	4.8	5.1	4.8	10.2	4.8	5.1	14.4	20.5
	70–79	7.1	5.1	7.1	10.4	7.1	0	21.3	15.5
Chennai97, India	30–39	3.6	6.4	1.9	0	0	0.6	5.5	7.0
	40–49	11.7	6.2	0.9	1.4	0	0.7	12.6	8.3
	50–59	7.5	8.9	1.5	0	3.0	1.1	12.0	10.0
	60–69	5.2	3.0	0	4.5	2.6	1.5	7.8	9.0
	70–79	7.0	12.6	0	0	3.5	0	10.5	12.6
Chennai94, India	30–39	3.3	7.6	1.4	1.0	1.4	0	6.1	8.5
	40–49	9.2	9.8	2.0	2.9	1.7	3.4	12.9	16.1
	50–59	5.5	11.0	3.1	6.6	1.9	3.3	10.4	20.9
	60–69	9.5	8.3	9.5	0	0	0	18.9	8.3
	70–79	0	16.0	0	0	0	0	0	16.0
NUDS, India	30–39	11.7	14.3	6.6	9.7	3.7	4.6	22.1	28.6
	40–49	13.5	11.2	6.3	7.8	4.9	5.2	24.7	24.1
	50–59	10.9	10.3	6.5	7.3	4.9	5.4	22.4	23.0
	60–69	13.8	12.7	3.0	6.9	4.0	5.5	20.8	25.0
	70–79	13.7	12.2	4.1	6.3	6.9	8.1	24.7	26.6

Continued on following page

Table 3—*Continued*

Cohort	Age (years)	Isolated IGT 2hPG 7.8–11.0 and FPG <6.1		Isolated IFG 2hPG <7.8 and FPG 6.1–6.9		IGT and IFG 2hPG 7.8–11.0 and FPG 6.1–6.9		IGR IGT and or IFG	
		M	F	M	F	M	F	M	F
	0–89	15.6	9.7	11.1	3.2	6.7	6.5	33.3	19.4
Singapore	30–39	8.7	10.8	3.4	2.2	2.8	2.0	15.0	14.9
	40–49	11.0	14.1	7.0	1.8	5.6	4.5	23.5	20.4
	50–59	15.1	13.0	7.8	4.3	6.4	9.1	29.3	26.5
	60–69	17.3	15.8	6.2	7.5	7.6	6.8	31.1	30.1
Chinese and Japanese, total	30–39	2.5	0	5.0*	0.6	4.2*	0.6	11.7‡	1.1
	40–49	6.8*	9.2	4.5*	2.9	2.4	1.4	13.7	13.5
	50–59	8.9	10.3	5.6	5.0	2.3	2.0	16.8	17.2
	60–69	11.9	14.1	5.1	4.4	4.8	3.6	21.8	22.2
	70–79	13.7	16.3	5.4	5.1	2.9	4.0	21.9	25.4
	80–89	16.1	11.7	7.1	3.9	0	2.6	23.2	18.2
Indian, total	30–39	10.0*	12.5	5.9*	7.8	3.3	3.7	19.3‡	24.0
	40–49	12.0	10.2	5.5	6.5	3.8	4.5	21.3	21.2
	50–59	9.3	9.9	5.8	6.7	4.3	4.8	19.4	21.4
	60–69	12.5	11.3	3.3†	6.5	3.7	4.9	19.5	22.6
	70–79	12.4	11.6	3.7	5.5	6.4	6.2	22.5	23.3
	80–89	12.6	13.3	9.0	2.7	5.4	5.3	27.1	21.2

Data are %. *$P < 0.05$, †$P < 0.01$, ‡$P < 0.001$ for the difference between men and women.

CONCLUSIONS — We found that the prevalence of diabetes increased with age in all of our studies, but the peak prevalence of diabetes differed between different ethnic groups. The prevalence of diabetes reached its peak in the oldest age-group (>70 years) in Chinese and Japanese cohorts and at 60–69 years of age, followed by a decline at 70–79 years of age in Indian cohorts. Among people aged 30–79 years, the 10-year age-specific prevalence of diabetes was higher in Indian than in Chinese and Japanese subjects of the same age or even older. A younger age at onset of the disease has been previously reported in Asian Indian subjects (15,19). Asian Indian subjects have been identified as the ethnic group with one of the highest prevalences of diabetes (3,21). Also, the familial aggregation of type 2 diabetes is high among Indians, suggesting a strong genetic component for risk of the disease (22,23). Studies in Singapore (14) revealed that Asian Indian subjects were more centrally obese and insulin resistant and had low HDL and higher incidence of myocardial infarction than Chinese and Malay subjects living in Singapore. It is possible that the earlier onset of diabetes with a high prevalence and a high incidence of myocardial infarction resulted in a greater premature mortality in diabetic individuals, and that this contributed to the decline in the prevalence of diabetes after 70 years of age in Indian subjects.

In addition, we found that IGT was more prevalent than IFG in almost all age-groups in Asian subjects. The prevalence of IFG did not increase with age, but IGT increased more in the elderly, which is consistent with data in European populations (20). It is clear that a 2-h OGTT is an important part of a diabetes and IGR detection program in Asian populations. Without an OGTT the majority of the people with hyperglycemia would remain unidentified, and without intervention, this may prevent worsening from IGT to diabetes, as demonstrated by the Da Qing study (24).

Compared with the European populations included in the DECODE Study (20), the age-specific prevalence of diabetes in Urban Chinese and Japanese subjects was slightly higher than that in European subjects at 30–69 years of age, which is all lower than that in Indian subjects. The peak prevalence in the elderly population, however, was higher only in a few European populations, such as in Maltese, Finnish women in Oulu, and Spanish women living in the Canary Islands, than in Indian subjects. The age at which the peak prevalence of diabetes was reached was similar for European, Chinese, and Japanese subjects (over 70 years), whereas Indian subjects had their highest prevalence at 60–69 years of age. The prevalence of IGR increased gradually with age in Chinese and Japanese subjects, which was similar to that of European subjects but different from that of Indian subjects. In Indian subjects, the prevalence of IGR reached a high level already at 30 years of age and did not increase further with age. The difference in the prevalence of diabetes and IGR in different ethnic groups may not be completely explained by living environments and geographic locations, suggesting that genetic background play an important role.

The ratio of IGT to diabetes has been reported to decrease as prevalence of diabetes increases (3) and may have some predictive value in determining the stage of a glucose intolerance epidemic within a population (25). When the ratio is high but the prevalence of diabetes is low, the early stage of a diabetes epidemic may occur (3). The age- and sex-specific ratios of IGR to diabetes according to the newly

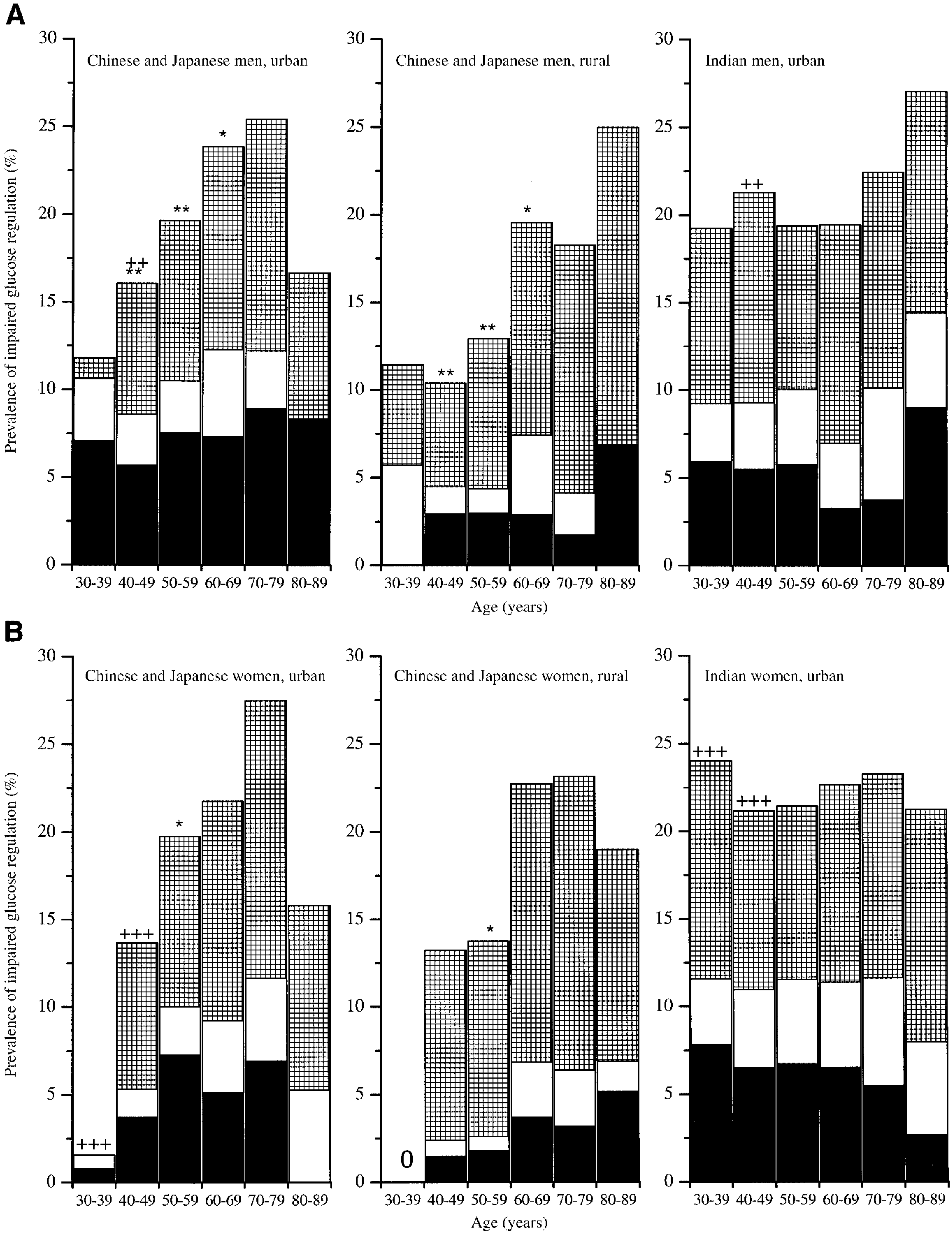

Figure 3— *Age- and sex-specific prevalence of IGR for Chinese and Japanese studies combined and for all Indian studies combined for the men* (A) *and women* (B). *Isolated IFG* (■): *FPG 6.1–6.9 mmol/l and 2hPG <7.8 mmol/l; isolated IGT* (▦): *2hPG 7.8–11.0 mmol/l and FPG <6.1 mmol/l; IFG and IGT* (□): *FPG 6.1–6.9 mmol/l and 2hPG 7.8–11.0 mmol/l.* *$P < 0.05$, **$P < 0.01$, *for the difference between urban and rural Chinese and Japanese;* ++$P < 0.01$, +++$P < 0.001$, *for the difference between Chinese and Japanese combined and Indian combined.*

revised diagnostic criteria for diabetes (5) were calculated for Asian and European populations (see data supplement at http://care.diabetesjournals.org). The ratio of IGR to diabetes seemed to decline when the prevalence of diabetes increased in both Asian and European populations, but the trend was not clear. It has been estimated that there will be a 57% increase in the prevalence of diabetes in Asia and a 24% increase in Europe from the year 2000 to the year 2010 (26). According to this, a higher ratio of IGR to diabetes will be expected in Asia than in Europe given the same age and same prevalence of diabetes. This was, however, not observed. Despite the low ratio of IGT to diabetes in India, a recent study showed that both the prevalence of diabetes and IGT are still increasing nation-wide in India (19).

In conclusion, the age- and sex-specific prevalence of diabetes was higher in Indian than in Chinese and Japanese subjects, but the prevalence of IGR was not, except in very young populations. The prevalence of diabetes increased with age, reaching its peak at 70–89 years of age in Chinese and Japanese subjects, and at 60–69 years of age followed by a decline at 70 years of age in Indian subjects. IGT was more prevalent than IFG in all age-groups in Asians. We strongly recommended retaining the 2-h OGTT when determining impaired glucose regulation in Asian populations.

Acknowledgments— The DECODA Study was initially funded by Novo Nordisk, Bagsvaerd, Denmark. This analysis has been carried out with the help of grants from Novartis Pharma, Basel, Switzerland, and from the Finnish Academy (Grants 46558, 76502, and 77618). The Japan Diabetes Foundation and Japan Arteriosclerosis Prevention Fund (Japanese Ministry of Health, Welfare and Labor) and Shiseikai Overseas Research Foundation (Tokyo Women's Medical University) supported a fellowship for Tomoko Nakagami.

APPENDIX

Organization

The DECODA (Diabetes Epidemiology: Collaborative Analysis Of Diagnostic Criteria in Asia) study was initiated in 1998 and carried out under the supervision of the International Diabetes Epidemiology Group. (Jaakko Tuomilehto, National Public Health Institute, Helsinki, Finland; Knut Borch-Johnsen, Steno Diabetes Center, Gentofte, Denmark; Naoko Tajima, Jikei University School of Medicine, Tokyo, Japan; and Clive S. Cockram, Department of Medicine, the Chinese University of Hong Kong, Prince of Wales Hospital, Hong Kong, China).

Steering committee

Qing Qiao, Jaakko Tuomilehto, Department of Epidemiology and Health Promotion, National Public Health Institute, Helsinki, Finland; Tomoko Nakagami, Knut Borch-Johnsen, Steno Diabetes Center, Gentofte, Denmark; and Takeshi Kuzuya, JA Shioya General Hospital, Tochigi, Japan.

Data analysis

Qing Qiao, Gang Hu, Department of Epidemiology and Health Promotion, National Public Health Institute, Helsinki, Finland.

Writing committee

Qing Qiao,[1] Gang Hu,[1] Jaakko Tuomilehto,[1] Tomoko Nakagami,[2] Beverley Balkau,[3] Knut Borch-Johnsen,[4] A. Ramachandran,[5,15] V. Mohan,[6] S. Ramnathan Iyer,[7] Makoto Tominaga,[8] Yutaka Kiyohara,[9] Isao Kato,[9] Ken Okubo,[9] Masaki Nagai,[10] Satomi Shibazaki,[10] Ze Yang,[11,12] Zhifu Tong,[11] Qinying Fan,[11] Binzhi Wang,[12] Suok Kai Chew,[13] Bee Yian Tan,[13] Derrick Heng,[13] Shanta Emmanuel,[13] Naoko Tajima,[14] Yasuhiko Iwamoto,[2] C. Snehalatha,[15] V. Vijay,[15] A. Kapur,[15] Yanhu Dong,[16] Hairong Nan,[16] Weiguo Gao,[16] Haiyan Shi,[16] Fangming Fu[16].

From the [1]Diabetes and Genetic Epidemiology Unit, Department of Epidemiology and Health Promotion, National Public Health Institute, Helsinki, Finland; the [2]Diabetes Center, Tokyo Women's Medical University, Tokyo, Japan; [3]INSERM U258, Paris, France, the [4]Steno Diabetes Center, Gentofte, Denmark; the [5]Chennai 94 Study: Diabetes Research Center, Chennai, India; the [6]Chennai 97 Study: Madras Diabetes Research foundation, Chennai, India; the [7]Dombivli Study: Ambika Clinic and Research Center, Dombivli (East), District Thane, Maharashtra, India; [8]Funagata Diabetes Studies: Department of Laboratory Medicine, Yamagata University, Yamagata, Japan; the [9]Hisayama Study: the Department of Medicine and Clinical Science, Graduate School of Medical Science, Kyushu University, Fukuoka, Japan; [10]Ojika Surveys: Department of Public Health, Saitama Medical School, Saitama, Japan; the [11]Beijing Study: Institute of Geriatrics and Beijing Hospital and Chinese-Japanese Friendship Hospital, Ministry of Health, Beijing, China; the [12]Shunyi Study: Shunyi Country People's Hospital, Shunyi, China; the [13]National Health Survey: Epidemiology and Disease Control, Ministry of Health, Singapore; the [14]Jikei University School of Medicine, Tokyo, Japan; [15]The National Urban Diabetes Survey (NUDS), India; and the [16]Qingdao Endocrinology and Diabetes Institute, Hiserve Medical Group, Qingdao, China.

References

1. King H, Aubert RE, Herman WH: Global burden of diabetes, 1995–2025: prevalence, numerical estimates, and projections. *Diabetes Care* 21:1414–1431, 1998
2. Amos AF, McCarty DJ, Zimmet P: The rising global burden of diabetes and its complications: estimates and projections to the year 2010. *Diabet Med* 14 (Suppl.):7S–5S, 1997
3. King H, Rewers M, WHO Ad Hoc Diabetes Reporting Group: Global estimates for prevalence of diabetes mellitus and impaired glucose tolerance in adults. *Diabetes Care* 16:157–177, 1993
4. Cockram C, Chan J: The epidemiology of diabetes in the Western Pacific Region (excluding Japan). In *Diabetes in the New Millennium*. Turle J, Kaneko T, Osato S, Eds. Sydney, Pot Still Press, 1999, p. 11–22
5. WHO Consultation: *Definition, Diagnosis and Classification of Diabetes Mellitus and Its Complications: Part 1. Diagnosis and Classification of Diabetes Mellitus*. Geneva, World Health Org., 1999 (Report no. 99.2)
6. Qiao Q, Nakagami T, Tuomilehto J, Borch-Johnsen K, Balkau B, Iwamoto Y, Tajima N: Comparison of the fasting and the 2-hour glucose criteria for diabetes in different Asian cohorts. *Diabetologia* 43: 1470–1475, 2000
7. Nakagami T, Qiao Q, Tuomilehto J, Balkau B, Carstensen B, Tajima N, Iwamoto Y: The fasting plasma glucose cut-point predicting a diabetic 2-h OGTT glucose level depends on the phenotype. *Diabetes Res Clin Pract* 55:35–43, 2002
8. World Health Organization Expert Committee on Diabetes Mellitus: *Report of the WHO Expert Committee on Diabetes Mellitus: Second Report*. Geneva, World Health

Org., 1980 (Tech. Rep. Ser., no. 646)
9. World Health Organization: *Diabetes Mellitus: Report of a WHO Study Group*. Geneva, World Health Org., 1985 (Tech. Rep. Ser., no. 727)
10. Expert Committee on the Diagnosis and Classification of Diabetes Mellitus: *Report of the Expert Committee on the Diagnosis and Classification of Diabetes Mellitus*. *Diabetes Care* 20:1183–1197, 1997
11. Nagai M, Sakata K, Yanagawa H, Sueta H, Tanaka T, Shirahama S: The prevalence of diabetes mellitus and impaired glucose tolerance studies by 75-gram oral glucose tolerance test in a rural island population. *Nippon Koshu Eisei Zasshi* 39:907–912, 1992
12. Sekikawa A, Tominaga M, Takahashi K, Eguchi H, Igarashi M, Ohnuma H, Sugiyama K, Manaka H, Sasaki H, Fukuyama H, Miyazawa K: Prevalence of diabetes and impaired glucose tolerance in Funagata area, Japan. *Diabetes Care* 16:570–574, 1993
13. Ohmura T, Ueda K, Kiyohara Y, Kato I, Iwamoto H, Nakayama K, Nomiyama K, Ohmori S, Yoshitake T, Shinkawu A, et al: Prevalence of type 2 (non-insulin-dependent) diabetes mellitus and impaired glucose tolerance in the Japanese general population: the Hisayama Study. *Diabetologia* 36:1198–1203, 1993
14. Tan CE, Emmanuel SC, Tan BY, Jacob E: Prevalence of diabetes and ethnic differences in cardiovascular risk factors: the 1992 Singapore National Health Survey. *Diabetes Care* 22:241–247, 1999
15. Ramachandran A, Snehalatha C, Latha E, Vijay V, Viswanathan M: Rising prevalence of NIDDM in an urban population in India. *Diabetologia* 40:232–237, 1997
16. Iyer SR, Iyer RR, Upasani SV, Baitule MN: Diabetes mellitus in Dombivli–an urban population study. *J Assoc Physicians India* 49:713–716, 2001
17. Mohan V, Ravikumar R, Shanthi Rani S, Deepa R: Intimal medial thickness of the carotid artery in South Indian diabetic and non-diabetic subjects: the Chennai Urban Population Study (CUPS). *Diabetologia* 43:494–499, 2000
18. Yang Z, Zheng H, Tong Z: Prevalence of diabetes and IGT in elderly population of Beijing in 1997. *Chin J Geriatr* 20:290–293, 2001
19. Ramachandran A, Snehalatha C, Kapur A, Vijay V, Mohan V, Das AK, Rao PV, Yajnik CS, Kumar KMP, Nair JD: High prevalence of diabetes and impaired glucose tolerance in India: National Urban Diabetes Survey. *Diabetologia* 44:1094–1101, 2001
20. The DECODE Study Group: Age- and sex-specific prevalences of diabetes and impaired glucose regulation in 13 European cohorts. *Diabetes Care* 26:61–69, 2003
21. Ramachandran A, Snehalatha C, Dharmaraj D, Viswanathan M: Prevalence of glucose intolerance in Asian Indians: urban-rural difference and significance of upper body adiposity. *Diabetes Care* 15:1348–1355, 1992
22. UK Prospective Diabetes Study X: Difference between Asian, Afro-Caribbean and white Caucasian type 2 diabetic patients at diagnosis of diabetes. *Diabet Med* 11:670–677, 1994
23. Viswanathan M, McCarthy M, Snehalatha C, Hitman G, Ramachandran A: Familial aggregation of type 2 (non-insulin-dependent) diabetes mellitus in south India: absence of excess maternal transmission. *Diabet Med* 13:232–237, 1996
24. Pan X, Li G, Hu Y, Wang J, Yang W, An Z, Hu Z, Lin J, Xiao J, Cao H, Liu P, Jiang X, Jiang Y, Wang J, Zheng H, Zhang H, Bennett P, Howard B: Effects of diet and exercise in preventing NIDDM in people with impaired glucose tolerance: the Da Qing IGT and Diabetes Study. *Diabetes Care* 20:537–544, 1997
25. Dowse GK, Zimmet PZ, King H: Relationship between prevalence of impaired glucose tolerance and NIDDM in a population. *Diabetes Care* 14:968–974, 1991
26. Zimmet P, Alberti KG, Shaw J: Global and societal implications of the diabetes epidemic. *Nature* 414:782–787, 2001