ORIGINAL ARTICLE

Prevalence of Diabetes among Men and Women in China

Wenying Yang, M.D., Juming Lu, M.D., Jianping Weng, M.D., Weiping Jia, M.D., Linong Ji, M.D., Jianzhong Xiao, M.D., Ph.D., Zhongyan Shan, M.D., Jie Liu, M.D., Haoming Tian, M.D., Qiuhe Ji, M.D., Dalong Zhu, M.D., Jiapu Ge, M.D., Lixiang Lin, M.D., Li Chen, M.D., Xiaohui Guo, M.D., Zhigang Zhao, M.D., Qiang Li, M.D., Zhiguang Zhou, M.D., Guangliang Shan, M.D., Ph.D., and Jiang He, M.D., Ph.D., for the China National Diabetes and Metabolic Disorders Study Group*

ABSTRACT

BACKGROUND

Because of the rapid change in lifestyle in China, there is concern that diabetes may become epidemic. We conducted a national study from June 2007 through May 2008 to estimate the prevalence of diabetes among Chinese adults.

METHODS

A nationally representative sample of 46,239 adults, 20 years of age or older, from 14 provinces and municipalities participated in the study. After an overnight fast, participants underwent an oral glucose-tolerance test, and fasting and 2-hour glucose levels were measured to identify undiagnosed diabetes and prediabetes (i.e., impaired fasting glucose or impaired glucose tolerance). Previously diagnosed diabetes was determined on the basis of self-report.

RESULTS

The age-standardized prevalences of total diabetes (which included both previously diagnosed diabetes and previously undiagnosed diabetes) and prediabetes were 9.7% (10.6% among men and 8.8% among women) and 15.5% (16.1% among men and 14.9% among women), respectively, accounting for 92.4 million adults with diabetes (50.2 million men and 42.2 million women) and 148.2 million adults with prediabetes (76.1 million men and 72.1 million women). The prevalence of diabetes increased with increasing age (3.2%, 11.5%, and 20.4% among persons who were 20 to 39, 40 to 59, and ≥60 years of age, respectively) and with increasing weight (4.5%, 7.6%, 12.8%, and 18.5% among persons with a body-mass index [the weight in kilograms divided by the square of the height in meters] of <18.5, 18.5 to 24.9, 25.0 to 29.9, and ≥30.0, respectively). The prevalence of diabetes was higher among urban residents than among rural residents (11.4% vs. 8.2%). The prevalence of isolated impaired glucose tolerance was higher than that of isolated impaired fasting glucose (11.0% vs. 3.2% among men and 10.9% vs. 2.2% among women).

CONCLUSIONS

These results indicate that diabetes has become a major public health problem in China and that strategies aimed at the prevention and treatment of diabetes are needed.

From China–Japan Friendship Hospital, Beijing (W.Y., J.X.); Chinese People's Liberation Army General Hospital, Beijing (J. Lu); Sun Yat-sen University Third Hospital, Guangzhou (J.W.); Shanghai Jiaotong University Affiliated Sixth People's Hospital, Shanghai (W.J.); Peking University People's Hospital, Beijing (L.J.); First Affiliated Hospital, Chinese Medical University, Liaoling (Z.S.); Shanxi Province People's Hospital, Taiyuan, Shaanxi (J. Liu); West China Hospital, Sichuan University, Chengdu, Sichuan (H.T.); Xijing Hospital, Fourth Military Medical University, Xi'an, Shaanxi (Q.J.); Affiliated Drum Tower Hospital of Nanjing University Medical School, Nanjing, Jiangsu (D.Z.); Xinjiang Uygur Autonomous Region's Hospital, Urmqi, Xinjiang (J.G.); Fujian Provincial Hospital, Fuzhou, Fujiang (L.L.); Qilu Hospital, Qilu Hospital of Shandong University, Jinan, Shandong (L.C.); Peking University First Hospital, Beijing (X.G.); Henan Province People's Hospital, Zhengzhou, Henan (Z. Zhao); Second Affiliated Hospital of Harbin Medical University, Harbin, Heilongjiang (Q.L.); Xiangya Second Hospital, Changsha, Hunan (Z. Zhou); and Peking Union Medical College, Beijing (G.S.) — all in China; and Tulane University School of Public Health and Tropical Medicine, New Orleans (J.H.). Address reprint requests to Dr. Yang at the Department of Endocrinology, China–Japan Friendship Hospital, Beijing 100029, China, or at ywy_1010@yahoo.com.cn.

*The members of the China National Diabetes and Metabolic Disorders Study group are listed in the Supplementary Appendix, available with the full text of this article at NEJM.org.

N Engl J Med 2010;362:1090-101.

Cardiovascular disease has become the leading cause of death in China, a development that has followed rapid economic growth, an increase in life expectancy, and changes in lifestyle.[1] Diabetes is a major risk factor for cardiovascular disease, and the prevalence of diabetes is high and is increasing in China.[2-4] A national survey conducted in 1994, involving 224,251 Chinese residents, 25 to 64 years of age, from 19 provinces, showed that the prevalences of diabetes and impaired glucose tolerance were 2.5% and 3.2%, respectively.[2] These estimates were higher by a factor of approximately 3 than those reported in 1980.[3] In a cross-sectional study in 2000–2001 involving a nationally representative sample of 15,540 adults, 35 to 74 years of age, the prevalences of diabetes and impaired fasting glucose were 5.5% and 7.3%, respectively.[4] Although these studies have documented a marked increase in the prevalence of diabetes in China, they cannot be compared directly, owing to methodologic differences in sampling and to differences in the criteria used to define diabetes.[2-4] Furthermore, the prevalences of diabetes and prediabetes were probably underestimated in these studies because 2-hour oral glucose-tolerance tests were not performed in all participants. It has been suggested that isolated hyperglycemia 2 hours after glucose loading is common among Asian patients with diabetes.[5] For example, in the Shanghai Diabetes Study, 48.6% of patients with newly diagnosed diabetes had isolated hyperglycemia 2 hours after glucose loading, and 75.0% of those with prediabetes had isolated impaired glucose tolerance.[6]

The China National Diabetes and Metabolic Disorders Study, conducted from June 2007 through May 2008, was a cross-sectional study designed to provide current and reliable data on the prevalences of diabetes and associated metabolic risk factors in the adult population in China.

METHODS

STUDY PARTICIPANTS

We used a multistage, stratified sampling method to select a nationally representative sample of persons 20 years of age or older in the general population. The sampling process was stratified according to geographic region (northeast, north, east, south central, northwest, and southwest China), degree of urbanization (large cities [Beijing, Shanghai, and provincial capitals], midsize cities, county seats, and rural townships), and economic development status (as assessed on the basis of the gross domestic product [GDP] for each province). The first two stages of sampling, in which provinces were selected from geographic regions and cities and counties were selected from provinces, were not random. In the next two stages (the stage in which city districts were selected from cities and rural townships from counties and the stage in which street districts were selected from city districts and rural villages from townships), the sampling was random (see Fig. 1 in the Supplementary Appendix, available with the full text of this article at NEJM.org). This multistage, stratified sampling process resulted in an oversampling of urban residents. In total, 152 urban street districts and 112 rural villages were selected. In the final stage of sampling, the sample was stratified according to the sex and age distribution in China, on the basis of Chinese population data from 2006.[7] Only persons who had lived in their current residence for 5 years or longer were eligible to participate.

A total of 54,240 people were selected and invited to participate in the study; 47,325 persons (18,976 men and 28,349 women) completed the study. The overall response rate was 87.3%: 81.0% for men and 92.0% for women; 88.1% of those who lived in urban areas and 82.7% of those who lived in rural areas responded. After the exclusion of 538 persons for whom demographic information was missing and 548 for whom data on fasting or 2-hour plasma glucose levels were missing, 46,239 adults were included in the final analysis.

The institutional review board or ethics committee at each participating institution approved the study protocol. Written informed consent was obtained from each participant before data collection.

DATA COLLECTION

A standard questionnaire was administered by trained staff to obtain information on demographic characteristics, personal and family medical history, and lifestyle risk factors.[8] The interview included questions related to the diagnosis and treatment of diabetes, hypertension, dyslipidemia, and cardiovascular events. Cigarette smoking was defined as having smoked at least 100 cigarettes in one's lifetime. Information was obtained on the amount and type of alcohol that was consumed during the previous year, and alcohol drinking was defined as the consumption of at least 30 g of alcohol per week for 1 year or more. Regular lei-

Table 1. Characteristics of Study Participants According to Plasma Glucose Categories and Sex.*

Characteristic	Normal Glucose Tolerance	Isolated Impaired Fasting Glucose	Isolated Impaired Glucose Tolerance	Combined Impaired Fasting Glucose and Impaired Glucose Tolerance	Previously Undiagnosed Diabetes	Previously Diagnosed Diabetes
			Men (N=18,419)			
Participants — no. (%)	13,426 (73.3)	686 (3.2)	1691 (11.0)	395 (1.9)	1327 (6.5)	894 (4.1)
Mean fasting plasma glucose (95% CI) — mg/dl	87.3 (87.0–87.7)	114.9 (114.4–115.5)	93.1 (92.3–93.9)	116.2 (115.5–117.0)	135.7 (132.0–139.4)	158.6 (151.8–165.4)
Mean 2-hr plasma glucose in oral glucose-tolerance test (95% CI) — mg/dl†	99.1 (98.4–99.7)	110.6 (107.9–113.3)	160.9 (159.7–162.1)	164.6 (161.8–167.4)	243.5 (236.4–250.7)	265.9 (252.8–278.9)
Mean age (95% CI) — yr	42.5 (42.1–43.0)	48.5 (46.4–50.6)	50.2 (49.0–51.5)	50.2 (47.8–52.6)	52.1 (50.8–53.4)	55.8 (54.2–57.4)
Family history of diabetes (95% CI) — %	12.9 (11.8–14.1)	12.8 (9.3–17.3)	14.6 (12.0–17.6)	23.5 (17.3–31.0)	23.3 (19.1–28.1)	42.6 (36.6–48.9)
College or higher level of education (95% CI) — %	25.3 (24.1–26.5)	19.2 (14.7–24.8)	18.7 (16.1–21.6)	22.6 (17.3–28.9)	16.8 (14.2–19.7)	16.4 (13.0–20.5)
Cigarette smoking (95% CI) — %‡	57.5 (56.2–59.1)	56.8 (50.2–63.1)	58.6 (54.6–62.5)	60.1 (52.2–67.5)	59.4 (54.9–63.8)	50.5 (44.6–56.3)
Consumption of alcohol (95% CI) — %§	44.3 (42.8–45.7)	41.7 (35.6–48.2)	39.5 (35.7–43.3)	51.6 (43.6–59.4)	40.5 (36.3–44.8)	35.2 (29.9–40.8)
Regular leisure-time physical activity (95% CI) — %¶	33.3 (32.0–34.7)	31.6 (25.5–38.4)	36.2 (32.5–40.0)	39.2 (31.6–47.4)	30.3 (26.5–34.3)	49.7 (43.9–55.5)
Mean body-mass index (95% CI)‖	23.6 (23.5–23.7)	24.5 (24.1–25.0)	24.8 (24.5–25.2)	26.6 (26.0–27.2)	25.8 (25.4–26.3)	25.2 (24.9–25.6)
Mean waist circumference (95% CI) — cm	82.1 (81.8–82.4)	86.7 (85.0–88.3)	85.5 (84.5–86.5)	90.7 (89.2–92.1)	89.1 (88.1–90.0)	88.7 (87.7–89.7)
Mean systolic blood pressure (95% CI) — mm Hg	121.0 (120.5–121.5)	127.4 (124.8–130.0)	129.2 (127.2–131.1)	132.1 (129.3–135.0)	133.2 (131.4–134.9)	132.0 (129.6–134.3)
Mean heart rate (95% CI) — beats/min	72.4 (72.1–72.8)	73.4 (72.1–74.6)	74.2 (73.3–75.1)	75.1 (73.2–77.1)	76.4 (75.4–77.5)	76.6 (75.2–78.0)
Mean HDL cholesterol (95% CI) — mg/dl	48.5 (48.1–48.9)	47.1 (45.3–49.0)	48.9 (47.9–49.9)	45.6 (44.0–47.3)	48.1 (46.9–49.3)	44.5 (42.9–46.0)
Mean LDL cholesterol (95% CI) — mg/dl	101.2 (100.2–102.3)	108.5 (103.2–113.7)	108.5 (105.2–111.9)	112.5 (106.4–118.6)	112.1 (108.3–115.8)	109.7 (105.3–114.0)
Mean triglycerides (95% CI) — mg/dl	141.7 (138.6–144.7)	176.5 (160.9–192.2)	169.5 (160.8–178.1)	204.3 (180.9–227.7)	198.6 (186.0–211.3)	172.4 (159.0–185.7)
			Women (N=27,820)			
Participants — no. (%)	20,867 (76.4)	783 (2.2)	2880 (10.9)	562 (1.7)	1581 (5.2)	1147 (3.5)
Mean fasting plasma glucose (95% CI) — mg/dl	86.9 (86.6–87.2)	114.7 (114.2–115.2)	93.7 (93.0–94.4)	115.5 (114.7–116.4)	135.3 (131.2–139.4)	165.2 (147.1–183.3)
Mean 2-hr plasma glucose in oral glucose-tolerance test (95% CI) — mg/dl†	102.1 (101.5–102.6)	111.6 (109.4–113.7)	159.6 (158.5–160.6)	165.8 (163.7–167.9)	259.2 (250.9–267.6)	285.8 (263.5–308.1)
Mean age (95% CI) — yr	42.1 (41.6–42.5)	46.6 (44.8–48.4)	51.9 (50.5–53.4)	53.9 (51.8–56.0)	54.8 (53.4–56.2)	59.3 (57.9–60.8)
Family history of diabetes (95% CI) — %	13.9 (13.0–14.8)	12.2 (9.2–16.1)	17.5 (13.4–22.7)	15.3 (10.5–21.8)	23.4 (19.0–28.6)	44.3 (36.3–52.6)
College or higher level of education (95% CI) — %	20.3 (19.4–21.3)	11.1 (8.4–14.5)	9.6 (7.7–12.0)	11.0 (8.0–14.8)	6.3 (5.0–7.9)	4.6 (3.4–6.3)
Cigarette smoking (95% CI) — %‡	3.0 (2.7–3.5)	2.3 (1.3–4.0)	4.4 (3.1–6.2)	3.7 (1.6–8.7)	4.6 (2.9–7.2)	4.2 (2.4–7.3)
Consumption of alcohol (95% CI) — %§	4.1 (3.7–4.6)	4.3 (2.4–7.4)	3.8 (2.7–5.4)	4.0 (2.2–6.9)	4.7 (3.0–7.2)	3.4 (1.9–6.0)
Regular leisure-time physical activity (95% CI) — %¶	30.9 (29.8–32.0)	22.9 (18.1–28.6)	34.6 (30.0–39.6)	30.9 (24.9–37.6)	35.5 (31.2–40.1)	49.2 (42.7–55.7)
Mean body-mass index (95% CI)‖	22.9 (22.8–23.0)	24.2 (23.8–24.7)	25.8 (25.2–26.4)	25.9 (25.5–26.3)	24.8 (24.5–25.1)	24.6 (24.2–25.1)
Mean waist circumference (95% CI) — cm	76.3 (76.0–76.6)	80.8 (79.5–82.1)	82.0 (81.2–82.8)	86.3 (84.5–88.0)	85.6 (84.8–86.4)	84.4 (83.3–85.4)
Mean systolic blood pressure (95% CI) — mm Hg	116.4 (115.9–117.0)	123.6 (120.7–126.4)	128.6 (127.0–130.2)	134.2 (131.6–136.9)	134.9 (132.9–137.0)	136.1 (133.5–138.8)

Mean heart rate (95% CI) — beats/min	74.3 (74.0–74.6)	74.7 (73.6–75.8)	76.5 (75.6–77.4)	78.5 (76.6–80.4)	78.0 (77.2–78.9)	77.2 (76.2–78.3)
Mean HDL cholesterol (95% CI) — mg/dl	52.4 (52.0–52.7)	51.4 (50.0–52.9)	52.0 (51.2–52.8)	50.6 (48.3–52.9)	51.4 (50.4–52.3)	51.4 (48.9–53.8)
Mean LDL cholesterol (95% CI) — mg/dl	99.8 (98.7–100.8)	113.0 (108.2–117.9)	112.0 (108.6–115.4)	117.4 (111.3–123.5)	113.8 (110.5–117.1)	115.8 (110.5–121.1)
Mean triglycerides (95% CI) — mg/dl	113.6 (111.9–115.4)	140.9 (130.4–151.5)	154.6 (147.6–161.6)	166.2 (155.7–176.7)	172.9 (165.1–180.6)	174.6 (158.6–190.6)

* All data, including percentages and mean values, were weighted to represent the total population of Chinese adults (20 years of age or older) on the basis of Chinese population data from 2006. Plasma glucose level was categorized as follows: normal glucose tolerance (fasting plasma glucose, <110 mg per deciliter, and 2-hour plasma glucose in a glucose-tolerance test, <140 mg per deciliter); isolated impaired fasting glucose (fasting glucose, ≥110 and <126 mg per deciliter, and 2-hour plasma glucose in a glucose-tolerance test, <140 mg per deciliter); isolated impaired glucose tolerance (fasting glucose, <110 mg per deciliter, and 2-hour plasma glucose in a glucose-tolerance test, ≥140 mg and <200 mg per deciliter); combined impaired fasting glucose and impaired glucose tolerance (fasting glucose, ≥110 and <126 mg per deciliter, and 2-hour plasma glucose in a glucose-tolerance test, ≥140 and <200 mg per deciliter); and undiagnosed diabetes (fasting glucose, ≥126 mg per deciliter, 2-hour plasma glucose in a glucose-tolerance test, ≥200 mg per deciliter, or both). To convert the values for glucose to millimoles per liter, multiply by 0.05551. To convert the values for cholesterol to millimoles per liter, multiply by 0.02586. To convert the values for triglycerides to millimoles per liter, multiply by 0.01129. HDL denotes high-density lipoprotein, and LDL low-density lipoprotein.

† For safety reasons, participants with a self-reported history of diabetes were given a steamed bun that contained approximately 80 g of complex carbohydrates.

‡ Cigarette smoking was defined as having smoked at least 100 cigarettes in one's lifetime.

§ Alcohol drinking was defined as consumption of at least 30 g of alcohol per week for 1 year or more.

¶ Regular leisure-time physical activity was defined as participation in 30 or more minutes of moderate or vigorous activity per day at least 3 days per week.

‖ The body-mass index is the weight in kilograms divided by the square of the height in meters.

sure-time physical activity was defined as participation in moderate or vigorous activity for 30 minutes or more per day at least 3 days a week. Socioeconomic status, educational level, occupation, and income were also recorded. The economic development of provinces or municipalities was defined on the basis of the GDP per capita in 2006. Blood pressure, body weight, height, and waist circumference were measured with the use of standard methods, as described previously.[2]

All study investigators and staff members successfully completed a training program that familiarized them with both the aims of the study and the specific tools and methods used. At the training sessions, interviewers were given detailed instructions concerning the administration of the study questionnaire. Clinical staff members were trained to measure blood pressure and obtain anthropometric measurements and blood specimens according to a standard protocol.[8]

ORAL GLUCOSE-TOLERANCE TEST

Participants were instructed to maintain their usual physical activity and diet for at least 3 days before the oral glucose-tolerance test. After at least 10 hours of overnight fasting, a venous blood specimen was collected in a vacuum tube containing sodium fluoride, for the measurement of plasma glucose. Participants with no history of diabetes were given a standard 75-g glucose solution, whereas for safety reasons, participants with a self-reported history of diabetes were given a steamed bun that contained approximately 80 g of complex carbohydrates. Blood samples were drawn at 0, 30, and 120 minutes after the glucose or carbohydrate load to measure glucose concentrations. Plasma glucose was measured with the use of a hexokinase enzymatic method, and serum cholesterol and triglyceride levels were assessed enzymatically with the use of commercially available reagents, at the clinical biochemical laboratories in each province. All the study laboratories successfully completed a standardization and certification program.

STUDY-OUTCOME DEFINITIONS

The 1999 World Health Organization diagnostic criteria were used to diagnose diabetes.[9] Results of plasma glucose testing were categorized as follows: isolated impaired fasting glucose (fasting glucose level, ≥110 mg per deciliter [6.1 mmol per liter] and <126 mg per deciliter [7.0 mmol per liter),

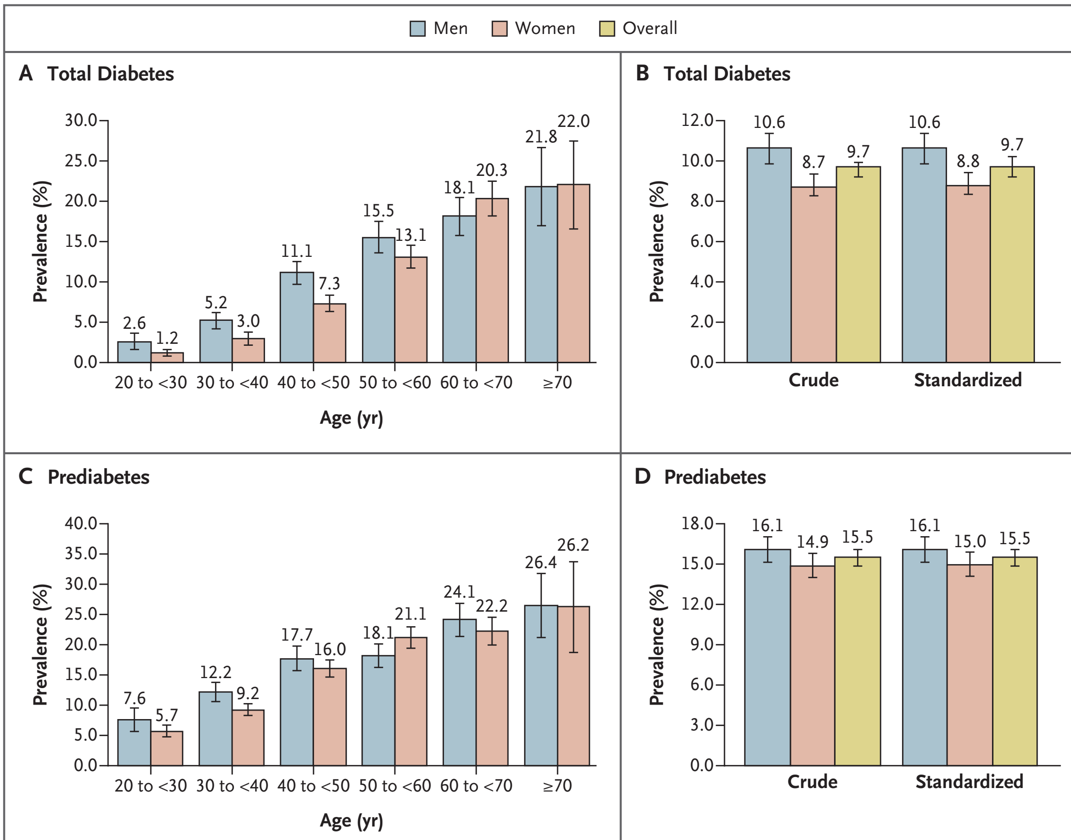

Figure 1. Age-Specific Prevalences of Diabetes and Prediabetes among Chinese Adults 20 Years of Age or Older.

The prevalences of total diabetes (Panel A) and prediabetes (Panel C) among men and women are shown, according to age. The crude and age-standardized prevalences of total diabetes and prediabetes among men and women are shown in Panels B and D, respectively. Total diabetes includes both previously diagnosed diabetes and previously undiagnosed diabetes. Prediabetes was defined as impaired fasting glucose or impaired glucose tolerance. I bars indicate 95% confidence intervals.

and 2-hour glucose level in the glucose-tolerance test, <140 mg per deciliter [7.8 mmol per liter]), isolated impaired glucose tolerance (fasting glucose level, <110 mg per deciliter, and 2-hour glucose level, ≥140 and <200 mg per deciliter [11.1 mmol per liter]), combined impaired fasting glucose and impaired glucose tolerance (fasting glucose level, ≥110 and <126 mg per deciliter, and 2-hour glucose level, ≥140 and <200 mg per deciliter), and undiagnosed diabetes (fasting glucose level, ≥126 mg per deciliter, 2-hour glucose level, ≥200 mg per deciliter, or both). Previously diagnosed diabetes was identified by a positive response from the participant to the question, "Has a doctor ever told you that you have diabetes?" Among participants with previously diagnosed diabetes, 81.2% were using insulin or oral hypoglycemic agents and 14.9% were using lifestyle intervention alone (diet, regular exercise, or both). Total diabetes included both previously diagnosed diabetes and previously undiagnosed diabetes. Prediabetes was defined as either impaired fasting glucose or impaired glucose tolerance.

STATISTICAL ANALYSIS

Our study was designed to provide accurate estimates of the prevalence of diabetes according to age, sex, urban or rural residence, and level of economic development in the general Chinese population of persons 20 years of age or older. Sample sizes were estimated to meet generally recommended requirements for precision in a complex survey design.[10] All calculations were weighted to represent the total population of Chinese adults (20 years of age or older) on the basis of Chinese population data from 2006 and the study sampling scheme, and were corrected for several features of the survey, including oversampling for female and urban residents, nonresponse, highly developed economic regions, and other demographic or geographic differences between the sample and the total population.

Mean values for lifestyle and metabolic factors were determined according to sex and plasma glucose categories. Prevalence estimates for diabetes and prediabetes were calculated for the overall population and for subgroups according to age, sex, and other variables. Age- and sex-standardized prevalences were calculated by the direct method with the use of data on the population distribution in China in 2006.[7] Estimated numbers of persons with diabetes and prediabetes were calculated from subgroup-specific prevalences according to age, sex, geographic region, urban or rural residence, and level of economic development and from data on the size of the population in China in 2006. A multinomial logit analysis was used to examine the association of demographic, lifestyle, and metabolic factors with the odds of diabetes and prediabetes. With the use of backward elimination, only covariables that were significant ($P<0.05$) were retained in the final model. Standard errors were calculated with the use of a technique that was appropriate to the complex survey design. All P values are two-tailed and have not been adjusted for multiple testing. All statistical analyses were conducted with the use of SUDAAN software, version 10 (Research Triangle Institute).

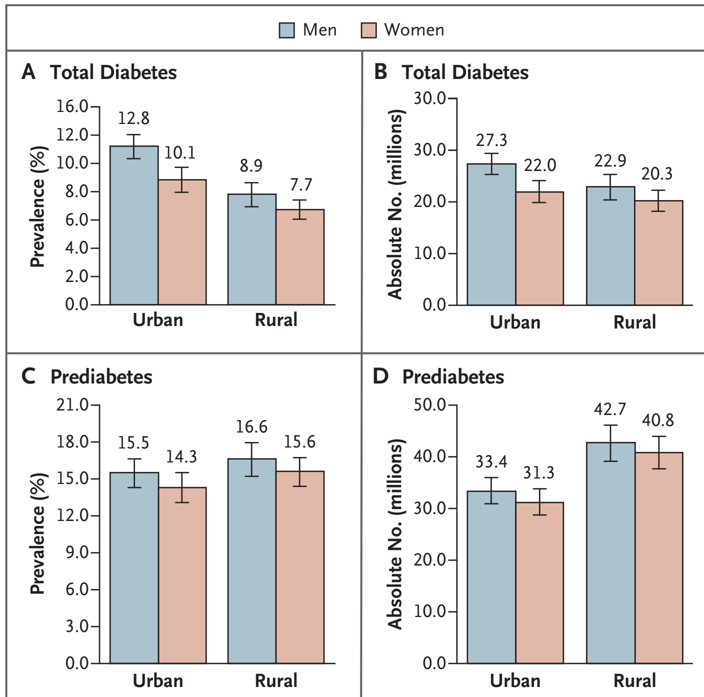

Figure 2. Prevalences of Diabetes and Prediabetes and Absolute Numbers of Cases among Chinese Adults 20 Years of Age or Older, According to Urban or Rural Residence.

The prevalences of total diabetes (Panel A) and prediabetes (Panel C) and the estimated numbers of cases of total diabetes (Panel B) and prediabetes (Panel D) among men and women are shown, according to rural or urban residence in China. Total diabetes includes both previously diagnosed and previously undiagnosed diabetes. Prediabetes was defined as impaired fasting glucose or impaired glucose tolerance. I bars indicate 95% confidence intervals.

RESULTS

PREVALENCES OF DIABETES AND PREDIABETES

The prevalences of isolated impaired fasting glucose, isolated impaired glucose tolerance, combined impaired fasting glucose and impaired glucose tolerance, previously undiagnosed diabetes, and previously diagnosed diabetes were 3.2%, 11.0%, 1.9%, 6.5%, and 4.1% among men and 2.2%, 10.9%, 1.7%, 5.2%, and 3.5% among women, respectively (Table 1). The prevalence of undiagnosed diabetes in which the 2-hour plasma glucose level in an oral glucose-tolerance test was 200 mg per deciliter or more but the fasting glucose level was less than 126 mg per deciliter was 2.9% among men and 2.6% among women. In other words, 46.6% of the participants with undiagnosed diabetes (44.1% of the men and 50.2% of the women) had isolated increased 2-hour plasma glucose levels after an oral glucose-tolerance test. In the case of approximately 61.3% of the men with diabetes and 59.8% of the women with diabetes, the diabetes had not previously been diagnosed. In general, patients with previously diagnosed diabetes had higher fasting plasma glucose levels and higher 2-hour plasma glucose levels in an oral glucose-tolerance test than did those with undiagnosed diabetes. In addition, patients with previously diagnosed diabetes, as compared with those with undiagnosed diabetes, were older, more likely to have a family history of diabetes, more likely to participate in leisure-time physical activity, less likely to smoke cigarettes, and less likely to be obese. A total of 70.7% of the participants with prediabetes (68.3% of the men and 73.6% of the women) had isolated impaired glucose tolerance, and participants with isolated

Table 2. Age- and Sex-Standardized Prevalences of Diabetes and Prediabetes and Mean Values of Metabolic Risk Factors in the Overall Cohort and in Subgroups.*

Cohort	Total Diabetes	Prediabetes	Mean Fasting Glucose	Mean 2-Hour Glucose in Oral Glucose-Tolerance Test
	% (95% CI)		mg/dl (95% CI)	
Overall	9.7 (9.2–10.1)	15.5 (14.9–16.1)	94.8 (94.2–95.3)	124.0 (122.9–125.1)
Sex				
Male	10.6 (9.9–11.3)	16.1 (15.2–17.0)	95.4 (94.8–96.1)	123.6 (122.2–125.0)
Female	8.8 (8.2–9.4)	14.9 (14.1–15.8)	94.1 (93.2–95.0)	124.4 (122.9–125.9)
P value for difference	<0.001	0.07	0.01	0.47
Age				
20–39 yr	3.2 (2.8–3.6)	9.0 (8.3–9.7)	88.9 (88.5–89.4)	105.8 (104.8–106.7)
40–59 yr	11.5 (10.8–12.2)	18.1 (17.2–19.0)	97.0 (96.4–97.6)	129.7 (128.4–131.1)
≥60 yr	20.4 (18.6–22.3)	24.5 (22.3–26.9)	103.0 (100.5–105.6)	152.9 (148.5–157.3)
P value for difference	<0.001	<0.001	<0.001	<0.001
Body-mass index				
<18.5	4.5 (3.1–6.5)	11.2 (8.6–14.5)	86.4 (85.1–87.8)	110.4 (107.1–113.8)
18.5–24.9	7.6 (7.1–8.3)	13.1 (12.3–13.9)	92.9 (92.0–93.7)	118.6 (117.1–120.0)
25.0–29.9	12.8 (11.9–13.7)	19.9 (18.7–21.0)	98.8 (98.0–99.5)	133.8 (132.1–135.4)
≥30.0	18.5 (16.2–21.2)	26.7 (24.0–29.7)	102.7 (101.1–104.2)	147.5 (143.4–151.6)
P value for difference	<0.001	<0.001	<0.001	<0.001
Level of economic development†				
Developed				
Rural	12.0 (11.0–13.2)	16.6 (15.4–17.8)	98.6 (97.6–99.6)	131.2 (128.9–133.5)
Urban	12.0 (11.2–12.9)	13.6 (12.7–14.5)	97.2 (96.5–97.9)	128.8 (127.1–130.4)
P value for difference	1.00	<0.001	0.02	0.09
Intermediately developed				
Rural	6.7 (5.7–7.8)	15.6 (13.9–17.6)	88.8 (87.8–89.7)	120.1 (117.9–122.3)
Urban	11.3 (9.9–12.8)	20.0 (18.2–22.0)	97.7 (96.7–98.7)	130.3 (127.3–133.3)
P value for difference	<0.001	0.001	<0.001	<0.001
Underdeveloped				
Rural	5.8 (4.9–6.8)	15.9 (14.3–17.6)	93.2 (92.4–94.1)	111.0 (109.2–112.9)
Urban	10.4 (8.9–12.1)	12.9 (11.2–14.9)	93.8 (90.2–97.3)	124.2 (119.3–129.1)
P value for difference	<0.001	0.02	0.77	<0.001

* Total diabetes includes previously diagnosed and previously undiagnosed diabetes, as indicated by the fasting glucose level or the 2-hour glucose level in an oral glucose-tolerance test. Prediabetes was defined as impaired fasting glucose or impaired glucose tolerance. To convert the values for glucose to millimoles per liter, multiply by 0.05551. To convert the values for high-density lipoprotein (HDL) cholesterol to millimoles per liter, multiply by 0.02586. To convert the values for triglycerides to millimoles per liter, multiply by 0.01129.

† The level of economic development of provinces or municipalities was defined on the basis of the gross domestic product per capita in 2006, in thirds: developed, 23,663 to 65,473 Chinese yuan; intermediately developed, 13,123 to 19,363 Chinese yuan; and underdeveloped, 6,742 to 12,843 Chinese yuan. (In July 2006, 7.9732 yuan equaled U.S. $1.00.)

impaired glucose tolerance were slightly older than those who had isolated impaired fasting glucose. In addition, women with isolated impaired glucose tolerance had a higher body-mass index, higher systolic blood pressure, and higher serum triglyceride levels than did women with isolated impaired fasting glucose.

The overall prevalences of total diabetes (pre-

Mean HDL Cholesterol	Mean Triglycerides	Mean Body-Mass Index	Mean Waist Circumference	Mean Systolic Blood Pressure
	mg/dl (95% CI)		*cm (95% CI)*	*mm Hg (95% CI)*
50.2 (50.0–50.5)	138.3 (136.6–139.9)	23.7 (23.7–23.8)	80.7 (80.5–80.9)	121.7 (121.4–122.0)
48.2 (47.9–48.6)	151.9 (149.2–154.6)	24.0 (23.9–24.1)	83.5 (83.2–83.7)	123.5 (123.1–124.0)
52.2 (51.9–52.5)	125.1 (123.4–126.8)	23.4 (23.3–23.5)	78.0 (77.8–78.2)	120.0 (119.6–120.4)
<0.001	<0.001	<0.001	<0.001	<0.001
49.6 (49.3–49.9)	125.1 (122.6–127.6)	23.0 (22.9–23.1)	77.7 (77.4–78.0)	113.9 (113.5–114.2)
50.4 (50.0–50.7)	149.6 (147.2–152.0)	24.3 (24.3–24.4)	82.4 (82.2–82.7)	123.8 (123.4–124.2)
51.4 (50.8–52.0)	143.4 (139.3–147.5)	24.0 (23.8–24.2)	83.8 (83.3–84.3)	134.9 (133.9–136.0)
<0.001	<0.001	<0.001	<0.001	<0.001
53.7 (52.5–55.0)	100.2 (93.4–107.1)	17.6 (17.5–17.6)	68.0 (67.4–68.5)	111.2 (109.7–112.6)
51.2 (50.9–51.5)	123.2 (121.3–125.1)	22.1 (22.0–22.1)	77.0 (76.8–77.2)	118.8 (118.5–119.2)
48.2 (47.9–48.6)	168.2 (164.9–171.5)	26.9 (26.9–27.0)	88.1 (87.9–88.3)	127.5 (127.0–128.0)
47.2 (46.4–47.9)	188.5 (181.8–195.2)	32.2 (32.0–32.3)	97.6 (97.0–98.1)	132.4 (131.3–133.5)
<0.001	<0.001	<0.001	<0.001	<0.001
52.6 (52.1–53.0)	149.4 (145.4–153.3)	24.1 (24.0–24.2)	82.2 (81.9–82.6)	124.7 (124.2–125.3)
50.1 (49.8–50.4)	142.2 (139.6–144.8)	24.2 (24.1–24.3)	82.4 (82.2–82.7)	124.5 (124.0–124.9)
<0.001	0.003	0.24	0.33	0.45
49.3 (48.7–49.9)	125.2 (120.7–129.6)	23.3 (23.1–23.4)	77.9 (77.4–78.4)	120.3 (119.4–121.2)
49.3 (48.8–49.8)	145.8 (141.2–150.5)	24.1 (23.9–24.2)	80.8 (80.4–81.2)	122.6 (122.0–123.3)
0.98	<0.001	<0.001	<0.001	<0.001
49.4 (48.8–50.1)	130.5 (126.9–134.1)	23.0 (22.9–23.2)	79.6 (79.2–80.0)	117.6 (116.8–118.4)
50.8 (50.3–51.4)	139.7 (135.8–143.5)	23.6 (23.5–23.7)	81.1 (80.7–81.5)	119.4 (118.7–120.2)
<0.001	<0.001	<0.001	<0.001	0.001

viously diagnosed plus previously undiagnosed diabetes) and prediabetes were 9.7% and 15.5%, respectively. The age-specific prevalences of diabetes and prediabetes increased significantly with increasing age (P<0.001 for both comparisons) (Fig. 1). The age-standardized prevalence of diabetes was significantly higher among men than among women (P<0.001), but the age-standardized prevalence of prediabetes did not differ significantly according to sex (P=0.08). The age-standardized prevalence of diabetes was significantly higher among urban residents than among rural residents (11.4% vs. 8.2%, P<0.001) (Fig. 2); however, the age-standardized prevalence of prediabetes was slightly lower among urban residents than among rural residents (14.9% vs. 16.0%, P=0.06).

METABOLIC RISK FACTORS

The age-adjusted mean fasting glucose level, body-mass index, waist circumference, serum triglyceride level, and systolic blood pressure were sig-

Table 3. Multivariable-Adjusted Odds Ratios for Diabetes and Prediabetes.*

Variable	Total Diabetes		Prediabetes	
	Odds Ratio (95% CI)	P Value	Odds Ratio (95% CI)	P Value
Male sex	1.26 (1.12–1.43)	<0.001	1.06 (0.95–1.17)	0.30
Age, per 10-yr increment	1.68 (1.60–1.77)	<0.001	1.37 (1.31–1.45)	<0.001
Family history of diabetes	3.14 (2.68–3.68)	<0.001	1.32 (1.12–1.56)	0.001
Less than college education	1.57 (1.34–1.84)	<0.001	1.17 (1.03–1.33)	0.02
Overweight†	1.43 (1.22–1.67)	<0.001	1.42 (1.25–1.62)	<0.001
Obesity‡	2.17 (1.68–2.81)	<0.001	2.05 (1.66–2.54)	<0.001
Central obesity§	1.39 (1.18–1.63)	<0.001	1.22 (1.06–1.40)	0.006
Heart rate, per increase of 10 beats/min	1.29 (1.21–1.36)	<0.001	1.15 (1.09–1.21)	<0.001
Systolic blood pressure, per increase of 10 mm Hg	1.17 (1.13–1.20)	<0.001	1.12 (1.09–1.15)	<0.001
Triglycerides, per increase of 50 mg/dl (0.56 mmol/liter)	1.28 (1.22–1.33)	<0.001	1.20 (1.16–1.25)	<0.001
Urban residence	1.22 (1.08–1.38)	0.002	0.90 (0.81–0.99)	0.04

* Odds ratios were calculated with the use of multinomial logit models. All covariables listed were included in the model simultaneously. Status with respect to cigarette smoking and alcohol consumption, level of leisure-time physical activity, serum cholesterol levels, and level of economic development were not significantly associated with the risk of diabetes and were not included in the final model. Total diabetes includes previously diagnosed and previously undiagnosed diabetes, as detected on the basis of the fasting glucose level or 2-hour glucose level in an oral glucose-tolerance test. Prediabetes was defined as impaired fasting glucose or impaired glucose tolerance.

† Overweight was defined as a body-mass index between 25.0 and 29.9.

‡ Obesity was defined as a body-mass index of 30.0 or more.

§ Central obesity was defined as a waist circumference of 90 cm or more in men and as 80 cm or more in women.

nificantly higher in men than in women, whereas the high-density lipoprotein (HDL) cholesterol level was lower in men than in women (Table 2). The sex-adjusted fasting glucose level, 2-hour glucose level in an oral glucose-tolerance test, body-mass index, waist circumference, HDL cholesterol level, triglyceride level, and systolic blood pressure all increased significantly with increasing age. The age- and sex-adjusted prevalences of diabetes and prediabetes, as well as the mean fasting glucose level, 2-hour glucose level in the oral glucose-tolerance test, waist circumference, serum triglyceride level, and systolic blood pressure, increased significantly, whereas the HDL cholesterol level decreased, with increasing body-mass index.

ECONOMIC DEVELOPMENT AND URBANIZATION

In the economically developed regions, the age- and sex-adjusted prevalence of diabetes did not differ significantly between urban and rural residents, whereas the prevalence of prediabetes was higher among rural residents. In the intermediately developed and underdeveloped regions, the prevalence of diabetes and levels of metabolic risk factors were higher among urban residents than among rural residents.

In 2007–2008, it was estimated that among adults 20 years of age or older in China, there were 92.4 million persons with diabetes (50.2 million men and 42.2 million women) and 148.2 million persons with prediabetes (76.1 million men and 72.1 million women). An estimated 49.3 million persons with diabetes lived in urban areas, and 43.1 million in rural areas (Fig. 2); an estimated 64.7 million persons with prediabetes lived in urban areas, and 83.5 million in rural areas.

MULTIVARIABLE RISK ASSESSMENT

In the multivariable, multinomial, logit models, male sex, older age, a family history of diabetes, overweight, obesity, central obesity, increased heart rate, elevated systolic blood pressure, elevated serum triglyceride level, educational level below college, and urban residence were all significantly associated with an increased risk of diabetes (Table 3). In addition, older age, a family history of diabetes, overweight, obesity, central obesity, increased heart rate, elevated systolic blood pressure, elevated serum triglyceride level, and educational level below college were significantly associated with an increased risk of prediabetes, whereas there was a marginally significant association between urban residence and a decreased risk of prediabetes.

DISCUSSION

Our results indicate that diabetes has reached epidemic proportions in the general adult population in China. Overall, 92.4 million adults 20 years of age or older (9.7% of the adult population) have diabetes, and in 60.7% of these cases, the diabetes is undiagnosed. In addition, 148.2 million adults (15.5%) have prediabetes, which is an important risk factor for the development of overt diabetes and cardiovascular disease.[11,12] These findings, which are based on a large population-based study involving a nationally representative sample of Chinese adults, should provide an accurate estimate of the diabetes and prediabetes burden in China. In addition, the diagnosis of diabetes was established on the basis of both fasting plasma glucose levels and 2-hour plasma glucose levels in an oral glucose-tolerance test, and these measurements were obtained with the use of stringent quality-control procedures.

Diabetes increases the risk of microvascular and macrovascular complications and premature death in the general population and results in a huge economic burden for society.[13-17] Randomized clinical trials have shown that interventions involving diet and exercise reduce the risk of diabetes among people with prediabetes.[18-20] Public health measures should be undertaken to mitigate the consequences of new cases of diabetes.

Several previous national or regional studies have documented a rapid increase in the prevalence of diabetes in the Chinese adult population.[2-4,6,21] However, in those studies, oral glucose-tolerance tests were not performed in the entire study population or in a random sample[2-4]; therefore, the true prevalence of undiagnosed diabetes may have been underestimated. In the present study, 46.6% of the cases of undiagnosed diabetes and 70.7% of the cases of prediabetes met the criteria for elevated 2-hour plasma glucose levels in an oral glucose-tolerance test but not the criteria for elevated fasting glucose levels. Qiao and colleagues found that in a pooled analysis of Asian cohorts, more than half the subjects with diabetes had isolated hyperglycemia after glucose loading and three quarters of the subjects with prediabetes had isolated impaired glucose tolerance.[5] Even accounting for differences in diagnostic criteria, our study documents a large increase in the prevalences of previously diagnosed diabetes, previously undiagnosed diabetes, and prediabetes. The aging of the population, urbanization, nutritional changes, and decreasing levels of physical activity, with a consequent epidemic of obesity, have probably contributed to the rapid increase in the diabetes burden in the Chinese population.[21-23] Future studies are needed to examine the relative contributions of individual risk factors to the increased prevalence of diabetes in the Chinese population.

A higher prevalence of diabetes among urban residents than among rural residents has been observed in developing countries throughout the world.[2-4,16,17,24,25] Urbanization is associated with changes in lifestyle that lead to physical inactivity, an unhealthful diet, and obesity, all of which have been implicated as contributing factors in the development of diabetes.[26-28] In our study, both overall obesity and central obesity were strongly associated with increased prevalences of diabetes and prediabetes. In the analysis stratified according to the level of economic development, the prevalence of diabetes was similar between urban residents and rural residents in economically developed regions but differed between these groups in intermediately developed and underdeveloped regions. Our analysis suggests that the level of economic development and associated lifestyle and diet may explain the differences in the prevalence of diabetes between persons who live in urban settings and those who live in rural areas.

Like previous studies,[29,30] our study showed a significant inverse association between educational level and the prevalence of diabetes. Educational level is a good indicator of socioeconomic status, and a higher educational level has been associated with lower levels of cardiovascular risk factors, such as obesity, dyslipidemia, and hypertension.[31,32]

Our study has several limitations. First, women and urban residents were oversampled, and there was a lower response rate among men than among women. We took these issues into account when we calculated statistical weights. However, the response rate was higher than 80% among men, and potential selection bias due to nonresponse should be minimal. Second, dietary intake and work-related physical activity were not assessed in our study. Therefore, we were not able to determine the association between these factors and the prevalence of diabetes. Third, to ensure comparability across studies, we used the World Health Organization criteria to define diabetes and prediabetes in our study. The relationship of glucose categories to the risk of microvascular and macrovascular diseases, however, has not been extensively examined in the Chinese population.[20,33]

In summary, our results show that diabetes and prediabetes are highly prevalent in the general adult population in China. Given its large population, China may bear a higher diabetes-related burden than any other country.[16,17] More troublesome is the finding that the majority of cases of diabetes are undiagnosed. These results indicate that diabetes has become a major public health challenge in China and underscore the need for national strategies aimed at the prevention, detection, and treatment of diabetes in the general Chinese population.

Supported by grants from the Chinese Medical Association Foundation and Chinese Diabetes Society.

No potential conflict of interest relevant to this article was reported.

REFERENCES

1. He J, Gu D, Wu X, et al. Major causes of death among men and women in China. N Engl J Med 2005;353:1124-34.
2. Pan XR, Yang WY, Li GW, Liu J. Prevalence of diabetes and its risk factors in China, 1994. Diabetes Care 1997;20:1664-9.
3. National Diabetes Research Group. Diabetes mellitus survey of 300,000 in fourteen provinces and cities of China. Chin Med J 1981;20:678-81.
4. Gu D, Reynolds K, Duan X, et al. Prevalence of diabetes and impaired fasting glucose in the Chinese adult population: International Collaborative Study of Cardiovascular Disease in Asia (InterASIA). Diabetologia 2003;46:1190-8.
5. Qiao Q, Nakagami T, Tuomilehto J, et al. Comparison of the fasting and the 2-h glucose criteria for diabetes in different Asian cohorts. Diabetologia 2000;43:1470-5.
6. Jia WP, Pang C, Chen L, et al. Epidemiological characteristics of diabetes mellitus and impaired glucose regulation in a Chinese adult population: the Shanghai Diabetes Studies, a cross-sectional 3-year follow-up study in Shanghai urban communities. Diabetologia 2007;50:286-92.
7. National Bureau of Statistics of China. China statistical yearbook — 2006. Beijing: China Statistics Press, 2006. (Accessed February 26, 2010, at http://www.stats.gov.cn/tjsj/ndsj/2006/indexeh.htm.)
8. Luepker RV, Evans A, McKeigue P, Reddy KS. Cardiovascular survey methods. 3rd ed. Geneva: World Health Organization, 2004.
9. Department of Noncommunicable Disease Surveillance. Definition, diagnosis and classification of diabetes mellitus and its complications: report of a WHO consultation. Part 1. Diagnosis and classification of diabetes mellitus. Geneva: World Health Organization, 1999. (Accessed February 26, 2010, at http://www.staff.ncl.ac.uk/philip.home/who_dmg.pdf.)
10. Plan and operation of the Third National Health and Nutrition Examination Survey, 1988-94. Series 1: programs and collection procedures. Vital Health Stat 1 1994;32:1-407.
11. Schmidt MI, Duncan BB, Bang H, et al. Identifying individuals at high risk for diabetes: the Atherosclerosis Risk in Communities study. Diabetes Care 2005;28:2013-8.
12. Levitzky YS, Pencina MJ, D'Agostino RB, et al. Impact of impaired fasting glucose on cardiovascular disease: the Framingham Heart Study. J Am Coll Cardiol 2008;51:264-70.
13. Haffner SM, Lehto S, Ronnemaa T, Pyorala K, Laakso M. Mortality from coronary heart disease in subjects with type 2 diabetes and in nondiabetic subjects with and without prior myocardial infarction. N Engl J Med 1998;339:229-34.
14. Schramm TK, Gislason GH, Køber L, et al. Diabetes patients requiring glucose-lowering therapy and nondiabetics with a prior myocardial infarction carry the same cardiovascular risk: a population study of 3.3 million people. Circulation 2008;117:1945-54.
15. Brancati FL, Whelton PK, Randall BL, Neaton JD, Stamler J, Klag MJ. Risk of end-stage renal disease in diabetes mellitus: a prospective cohort study of men screened for MRFIT: Multiple Risk Factor Intervention Trial. JAMA 1997;278:2069-74.
16. Wild S, Roglic G, Green A, Sicree R, King H. Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. Diabetes Care 2004;27:1047-53.
17. Diabetes atlas. 3rd ed. Brussels: International Diabetes Federation, 2008. (Accessed February 26, 2010, at http://www.eatlas.idf.org/index-2.html.)
18. Tuomilehto J, Lindström J, Eriksson JG, et al. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. N Engl J Med 2001;344:1343-50.
19. Diabetes Prevention Program Research Group. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. N Engl J Med 2002;346:393-403.
20. Li G, Zhang P, Wang J, et al. The long-term effect of lifestyle interventions to prevent diabetes in the China Da Qing Diabetes Prevention Study: a 20-year follow-up study. Lancet 2008;371:1783-9.
21. Li G, Hu Y, Pan X. Prevalence and incidence of NIDDM in Daqing City. Chin Med J (Engl) 1996;109:599-602.
22. Leeder S, Raymond S, Greenberg H, Liu H, Esson K. A race against time: the challenge of cardiovascular disease in developing economies. New York: Columbia University, 2004.
23. Yang G, Kong L, Zhao W, et al. Emergence of chronic non-communicable diseases in China. Lancet 2008;372:1697-705.
24. Wang Y, Mi J, Shan XY, Wang QJ, Ge KY. Is China facing an obesity epidemic and the consequences? The trends in obesity and chronic disease in China. Int J Obes (Lond) 2007;31:177-88.
25. Singh RB, Bajaj S, Niaz MA, Rastogi SS, Moshiri M. Prevalence of type 2 diabetes mellitus and risk of hypertension and coronary artery disease in rural and urban population with low rates of obesity. Int J Cardiol 1998;66:65-72.
26. Reynolds K, Gu D, Whelton PK, et al. Prevalence and risk factors of overweight and obesity in China. Obesity (Silver Spring) 2007;15:10-8.
27. Muntner P, Gu D, Wildman RP, et al. Prevalence of physical activity among Chinese adults: results from the International Collaborative Study of Cardiovascular Disease in Asia. Am J Public Health 2005;95:1631-6.
28. Li LM, Rao KQ, Kong LZ, et al. A description on the Chinese national nutrition and health survey in 2002. Zhonghua Liu Xing Bing Xue Za Zhi 2005;26:478-84. (In Chinese.)
29. Borrell LN, Dallo FJ, White K. Educa-

tion and diabetes in a racially and ethnically diverse population. Am J Public Health 2006;96:1637-42.
30. Ko GTC, Chan JCN, Yeung VT, Chow CC, Tsang LW, Cockram CS. A low socioeconomic status is an additional risk factor for glucose intolerance in high risk Hong Kong Chinese. Eur J Epidemiol 2001;17:289-95.
31. Seeman T, Merkin SS, Crimmins E, Koretz B, Charette S, Karlamangla A. Education, income and ethnic differences in cumulative biological risk profiles in a national sample of US adults: NHANES III (1988-1994). Soc Sci Med 2008;66:72-87.
32. Yan LL, Liu K, Daviglus ML, et al. Education, 15-year risk factor progression, and coronary artery calcium in young adulthood and early middle age: the Coronary Artery Risk Development in Young Adults study. JAMA 2006;295:1793-800.
33. Chan JC, Malik V, Jia W, et al. Diabetes in Asia: epidemiology, risk factors, and pathophysiology. JAMA 2009;301:2129-40.