Changes in Features of the Metabolic Syndrome and Incident Impaired Glucose Regulation or Type 2 Diabetes in a Chinese Population

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The current understanding of the pathogenesis of type 2 diabetes is mainly based on a large number of cross-sectional and prospective studies (1–4) in which nondiabetic individuals were followed for several years to determine incident cases of diabetes without repeating assessment of other metabolic characteristics except for assay of plasma glucose during follow-up. In fact, only the studies in the Pima Indian population (5–7) have examined the changes in anthropometric characteristics, insulin secretion, and insulin action during the progression from normal glucose tolerance (NGT) to impaired glucose tolerance (IGT) to diabetes. Thus far, no study has directly addressed the effects of changes in the components of the metabolic syndrome on the transition to diabetes in other populations. The purpose of this study was to investigate the changes in the features of the metabolic syndrome during the transition from one state of glucose homeostasis to another in a cohort of Chinese people and to understand the relative contributions of these changes to the development of impaired glucose regulation (IGR) or type 2 diabetes.

RESEARCH DESIGN AND METHODS

— A total of 627 subjects without diabetes at baseline who participated in the National Diabetes Survey in 1994 and the follow-up survey in 1999 in the Beijing area (8) were included in this study. All of the subjects had measurements of BMI, blood pressure, fasting serum total cholesterol, triglecerides, insulin, plasma fasting glucose, and 2-h postload glucose (2-hPG) at baseline and follow-up separately. Past medical history, family history of diabetes, history of pharmacological treatment, smoking status, education, and occupation were determined with a standardized questionnaire. Obesity was defined as BMI $\geq$25.0 kg/m^2, according to the recommendations for Asians (9). Hypertension was defined as systolic blood pressure $\geq$140 mmHg and/or diastolic blood pressure $\geq$90 mmHg or using antihypertensive drugs (10). Insulin resistance was defined as upper fasting insulin quartile at baseline or upper fasting insulin quartile at baseline as a cutoff during the follow-up (11). Dyslipidemia was defined as serum triglycerides $\geq$1.7 mmol/l or taking hypolipidemic medication.

According to the World Health Organization 1999 criteria for glucose intolerance (10), the participants were classified into the following categories of glycemic status based on fasting plasma glucose (FPG) and 2-hPG: normal fasting glucose (NFG) and NGT (FPG $<$6.1 mmol/l and 2-hPG $<$7.8 mmol/l); IGR, including impaired fasting glucose (IFG) and/or IGT (FPG between 6.1 and 7.0 mmol/l and/or 2-hPG between 7.8 and 11.1 mmol/l); and diabetes (FPG $\geq$7.0 mmol/l and/or 2-hPG $\geq$11.1 mmol/l).

Statistical analyses

All statistical analyses were done with SPSS 11.0 software. Paired *t* tests and McNemar tests were performed to compare changes within groups. Between-group comparisons in mean changes or percentage changes among six groups were tested by repeated-measures ANOVA (time $\times$ group effect) for continuous variables or by the Mantel-Haenszel method for categorical variables adjusted for age and sex separately. A multiple logistic regression was applied with the change in obesity, hypertension, dyslipidemia, and insulin resistance as independent variables and glucose status at baseline and follow-up as the dependent variable. Subjects who retained NGT and those who had IGR at baseline and reverted to NGT during follow-up were created as a reference group, and subjects who retained IGR and who had NGT or IGR at baseline and progressed to IGR or diabetes during follow-up were defined as incident IGR or diabetes. The analyses multivariate models were carried out adjusting for age, sex, family history of diabetes, smoking, education, occupation, antihypertensive and hypolipidemic medication, FPG, 2-hPG, systolic blood pressure, BMI, total choles-

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Abbreviations: 2-hPG, 2-h postload glucose; FPG, fasting plasma glucose; IGR, impaired glucose regulation; IGT, impaired glucose tolerance; NFG, normal fasting glucose; NGT, normal glucose tolerance.

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

Table 1—*Within- and between-group comparisons of changes in characteristics between baseline and follow-up among six groups*

	Baseline NGT			Baseline IGR			Time × group effect*
	Follow-up			Follow-up			
	NGT	IGR	Diabetes	NGT	IGR	Diabetes	
n	213	94	51	90	84	95	
Age at baseline (years)†	47 ± 11	48 ± 10	49 ± 11	47 ± 11	51 ± 10	50 ± 10	0.013
BMI at baseline (kg/m^2)†	23.7 ± 3.2	24.9 ± 3.2	25.2 ± 3.7	24.6 ± 3.3	24.9 ± 3.0	26.2 ± 3.5	0.001
BMI at follow-up (kg/m^2)†	24.6 ± 3.4	26.2 ± 5.2	26.1 ± 3.5	25.0 ± 3.5	26.1 ± 3.1	26.6 ± 3.2	0.002
Change in BMI (kg/m^2)	**0.9 ± 2.1 (3.8)**	**1.3 ± 4.7 (5.2)**	**0.9 ± 2.1 (3.6)**	**0.4 ± 2.0 (1.6)**	**1.2 ± 3.0 (4.8)**	0.4 ± 2.3 (1.5)	NS
Change in obesity‡	5 (16)	**20 (44)**	14 (30)	0 (0)	**19 (40)**	6 (9.4)	0.002
Change in hypertention	**8 (31)**	**16 (40)**	**12 (22)**	**10 (21)**	**16 (39)**	**17 (33)**	NS
Change in dyslipidemia	0 (0)	3 (11)	0 (0)	−10 (−27)	3 (7.3)	4 (7)	NS
Change in insulin resistance	**6 (35)**	**19 (73)**	**16 (64)**	7 (29)	**13 (54)**	**14 (34)**	NS

Data are means ± SD or percentage (percentage change). Percentage change (given in parentheses) in a variable is expressed as a percentage at the baseline examination. $P < 0.05$ within-group comparisons between baseline and follow-up are in bold. *Between-group comparisons adjusted for age and sex among all six groups. †ANOVA adjusted for sex (age at baseline) and age. ‡Adjusted OR for incident IGR or diabetes was 2.20 (95% CI 1.36–3.57).

terol, triglycerides, and fasting insulin at baseline.

RESULTS — Table 1 shows within- and between-group comparisons of changes in characteristics between baseline and follow-up among six groups. The highest increased trend of these risk factors, especially for the mean values of BMI and prevalence of obesity, hypertension, and insulin resistance, occurred during the transition from NGT to IGR and was followed by the retaining IGR and the transition from NGT to diabetes during follow-up. The smallest increased trend in prevalence of obesity, hypertension, and insulin resistance was seen in the subjects who reverted from IGR to NGT; however, the difference of change between groups was significant only for obesity. Change in obesity was positively and significantly associated with the risk of incident IGR or diabetes with an odds ratio (OR) of 2.20 (95% CI 1.36–3.57) after adjustment for age, sex, family history of diabetes, smoking, education, occupation, antihypertensive and hypolipidemic medication, FPG, 2-hPG, systolic blood pressure, BMI, total cholesterol, triglycerides, fasting insulin at baseline, and change in hypertension, dyslipidemia, and insulin resistance.

CONCLUSIONS — In this study, the subjects who remained normal glucose tolerant and those who progressed from NGT to diabetes during follow-up had an almost similar increase in mean BMI. Nevertheless, the former still kept the mean BMI <25 kg/m^2 (24.6 kg/m^2) during the follow-up, while the progressors had a mean BMI of 26.1 kg/m^2. Interestingly, BMI also increased in the subjects who reverted from IGR to NGT during follow-up, but their mean BMI remained ~25 kg/m^2, and no change in the prevalence of obesity was observed. Furthermore, an increase in obesity rather than change in other features of the metabolic syndrome predicted the progression of IGR or diabetes, after adjustment of the confounding factors. These results implicate that obesity may be a more important risk factor for the development of IGR or diabetes than other features of the metabolic syndrome. The lifestyle intervention aiming at preventing diabetes should place higher importance on obesity than IGR, because IGR can still revert to a normal glucose state if an increase in obesity does not occur or mean BMI is being kept <25 kg/m^2.

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