Association between Adiponectin and Metabolic Syndrome in Older Adults from Major Cities of China[1]

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Objective To investigate the association between adiponectin and metabolic syndrome (MetS) and related diseases in older adults from major cities of China. **Methods** A total of 2 049 adults at the age of 60-96 years from 18 major cities of China were enrolled in the study. Plasma adiponectin and insulin concentrations were measured. Insulin resistance was assessed by homeostasis model assessment of insulin resistance (HOMA-IR). The definitions proposed by International Diabetes Federation (IDF) and American Heart Association/National Heart, Lung, and Blood Institute (AHA/NLHBI) were used to identify MetS. **Results** The adiponectin concentration increased with the advance of age and was higher in women than in men. The sex specific adiponectin concentration was inversely correlated with body mass index (BMI), waist circumference, diastolic blood pressure, triglycerides, glucose and fasting blood insulin, and positively correlated with HDL-C ($P<0.001$). The adiponectin concentration decreased with increasing MetS components. Compared with the 4th sex-specific adiponectin quartile, the odds ratio (OR) for prevalent MetS-IDF and MetS-AHA/NLHBI in subjects of the 1st quartile group was 3.25 (95% CI: 2.24, 4.71) and 3.21 (95% CI: 2.26, 4.55), respectively. The association was independent of age, sex, life-style factors, medication, family history of chronic diseases, BMI, and HOMA-IR. The OR for MetS was much higher than those of MetS components and its related diseases. **Conclusion** Adiponectin is strongly associated with MetS independent of insulin resistance and obesity in older adults from major cities in China. The adiponectin concentration is a useful predictor for the risk of MetS.

Key words: Adiponectin; Metabolic syndrome; Chinese older adults; Obesity; Insulin resistance

INTRODUCTION

Metabolic syndrome (MetS) is a disorder involving a cluster of risk factors such as hypertension, hyperglycemia, obesity and dyslipidemia which may be present in one individual. Over the past two decades, the prevalence of MetS has increased strikingly, becoming a global public health problem[1-2]. MetS is a well-established risk factor for cardiovascular disease (CVD) and diabetes mellitus (DM). Population-based studies have shown that the risk for CVD and DM has increased by about 2 and 5-folds in MetS subjects compared with individuals without MetS[3]. Since the morbidity and mortality of CVD and DM are high, it is crucial to conduct studies on mechanism and management of MetS for preventive purpose.

Adiponectin, an important adipokine exclusively and abundantly secreted from adipose tissue, is asscoiated with each MetS risk factor and MetS itself. Increasing evidence suggests that circulating adiponectin concentration is positively correlated with insulin sensitivity and negatively correlated with obesity[4-6]. Low adiponectin level is associated with the development of diabetes[4, 7-10], dyslipidemia[11-12], hypertension[13-14], cardiovascular disease[15-17] and metabolic syndrome[18-20].

Obesity and insulin resistance (IR) were thought to be the "common soil" of MetS. Since hypoadiponectinemia is strongly associated with MetS, obesity and IR, the issue whether adiponectin is a risk factor for MetS independent of the effects of obesity and IR remains unclear.

The prevalence of MetS varies with gender, age, ethnic background, and residence, and is higher in urban areas than in rural areas. Since the old population in cities has a higher risk for MetS than other populations[21-23], it is important to conduct

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more studies on MetS in this population. In the present study, we investigated the association between adiponectin and MetS and related diseases in old population of major cities based on the 2002 China National Nutrition and Health Survey.

MATERIALS AND METHODS

Study Population

The China National Nutrition and Health Survey (CNHS) in 2002 was the first comprehensive survey conducted in the field of nutrition and health in China[24]. This survey covered a wide range of data representing the nutrition and health status of Chinese in 31 provinces and municipalities directly under the central government of China. Fasting blood samples were drawn from the participants in the survey and plasma samples were properly stored at -70 ℃ until analysis. In this study, we focused on data on initially sampled 18 major cities: Beijing, Shanghai, Tianjin, Chongqing, Harbin, Shenyang, Dalian, Jinan, Qingdao, Ningbo, Nanjing, Guangzhou, Shenzhen, Zhengzhou, Chengdu, Xian, Wuhan, and Xiamen. We retrieved 2 280 eligible plasma samples from older adults at the age of 60-96 years and 231 participants were excluded due to insufficient plasma samples for adiponectin testing. The final data included 2 049 participants (about 90%). All participants gave their informed consent for the original survey and further studies.

Data Collection and Measurement

During the 2002 National Nutrition and Health Survey, health status, health behavior, and physical activity data were collected by trained research staff using a standardized questionnaire. In this study, smoking was categorized as never, <20 cigarettes /week, and 20+ cigarettes /week. Alcohol drinking was grouped into never, moderate (<3-4 times per week and <100 g per time), and high (>3-4 times per week and >100 g per time). Medication was considered positive if the participants had one or more drugs for treatment of hypertension, DM and dyslipidemia. Family history of chronic disease was considered positive if the grandparents, parents or siblings of the participants had a history of one of the following diseases: coronary heart disease (CHD), hypertension, DM or stroke. Body weight, height and waist circumference were measured according to the WHO recommendations[25]. Physical activity level of each individual was classified as no (never do exercises), sometime (doing exercises <10 month per year and <20 days per month and <20 min per time) or regular (doing exercises >10 month per year and >20 days per month and >20 min per time). Blood pressure was measured with a uniform mercury column sphygmomanometer. High-density lipoprotein cholesterol (HDL-C), triglyceride (TG), total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C) and glucose levels were measured using a uniform standardized reagent. Plasma adiponectin concentration was measured with a commercially available ELISA kit (Phoenix Pharmaceuticals, Inc., Belmont, CA, U.S.A). All procedures were performed following the manufacturer's instructions with quality control parameters within the expected range recommended by the manufacturer. Every tenth sample was duplicated on the same plate. The minimum detectable concentration was 0.15 ng/mL, the intra-assay CV ranged 3%-6% and the inter-assay CV <10%. Plasma insulin level was measured with a commercial radioimmunoassay kit (Beijing North Institute of Biological Technology, China). The minimum detectable concentration was 2 μIU/mL, the intra-assay CV<10% and the inter-assay CV <15%. Due to insufficient plasma samples, insulin level in only 1 910 participants was measured. Insulin resistance (IR) was calculated with the homeostasis model assessment (HOMA-IR) method using the following equation: fasting plasma insulin (microunits/mL)×fasting plasma glucose (mmol/L)/22.5. Body mass index (BMI) was calculated as weight (kg) / [height (m)] ^{2}.

Definition of MetS and Its Related Diseases

Subjects were grouped according to the two definitions of MetS. One was proposed by the International Diabetes Federation (IDF) as IDF-MetS[26], the other was the updated National Cholesterol Education Program Adult Treatment Panel III (ATPIII) criteria proposed by American Heart Association/National Heart, Lung, and Blood Institute (AHA/NHLBI)[3]. Both definitions include the same five components: waist circumferences ⩾90 cm in men or ⩾80 cm in women (Chinese population waist circumference cutoffs), triglyceride ⩾1.7 mmol/L or drug treatment of elevated TG, HDL-C <1.03 mmol/L in men or <1.29 mmol/L in women or drug treatment of decreased HDL-C, systolic blood pressure (SBP) ⩾130 mmHg or diastolic blood pressure (DBP) ⩾85 mmHg or drug treatment of hypertension, fasting blood glucose ⩾5.6 mmol/L or drug treatment of DM. The IDF-MetS definition requires increased waist circumference plus at least 2 other abnormalities above while the AHA/NHLBI-MetS criteria need the presence of at least 3 of the components above.

Hypertension has been defined as SBP≥140 mmHg or DBP≥90 mmHg or on regular antihypertensive drugs[27], DM as fasting plasma glucose≥7.0 mmol/L or on drug treatment of DM[28], central obesity as ≥90 cm in men or ≥80 cm in women using the waist circumference cutoff point for Chinese.

Statistical Analysis

Continuous variables were expressed as mean (SD). Skewed continuous variables of adiponectin, insulin, and HOMA-IR were log-transformed and presented as geometric mean with 95% confidence interval (CI). Categorical variables were presented as number and percentage. Continuous variables were compared using *t*-test or analysis of variance (ANOVA). Chi square test was used to compare categorical variables. Sex specific prevalence of MetS by IDF and AHA/NHLBI definitions across the quartiles were calculated. Logistic regression model was used to estimate the odds ratio (OR) adjusting potential confounding variables. Dependent variables in the logistic regressions were the MetS-IDF, MetS-AHA/NHLBI or the MetS components and its related diseases. Potential confounding variables included age, smoking, alcohol drinking, physical activity, family history of chronic diseases (hypertension, DM, stroke and CHD), medication for hypertension, DM and dyslipidemia, intake of energy and macronutrient. In addition, BMI and HOMA-IR were further adjusted for the assessment of whether the correlation between adiponectin and MetS and its related diseases is independent of obesity and IR. Data management and statistical analyses were performed using Stata statistical software version10[29].

RESULTS

Characteristics of Participants

The characteristics of the study participants are presented in Table 1. Men had a lower score of the levels of adiponectin, BMI, TC, TG, HDL-C, LDL-C, insulin, and HOMA-IR were lower in men than in women (P<0.001), while the DBP, waist circumference and intake of energy, protein, fat, and carbohydrate were lower in women than in men (P<0.001). The proportion of alcohol drinkers and regular cigarette smokers was greater in men than in women.

TABLE 1

Characteristics of Participants

Characteristics	Male (n=953)	Female (n=1 096)	P Value
Age (year)	68.5 (6.1)	68.1 (6.2)	0.108
Adiponectin (mg/ L)[a]	10.7 (10.3, 11.2)	13.2 (12.6, 13.7)	<0.001
SBP (mmHg)	139.2 (20.8)	140.8 (22.7)	0.076
DBP (mmHg)	82.9 (11.4)	80.8 (10.8)	<0.001
BMI (kg/m^2)	24.6 (3.5)	25.2 (3.8)	<0.001
Waist Circumference (cm)	86.5 (10.3)	83.9 (10.1)	<0.001
FBG (mmol/L)	5.50 (1.71)	5.69 (1.98)	0.020
Triglyceride (mmol/L)	1.17 (0.58)	1.37 (0.70)	<0.001
HDL Cholesterol (mmol/L)	1.26 (0.30)	1.37 (0.32)	<0.001
Total Cholesterol (mmol/L)	4.33 (0.92)	4.77 (0.98)	<0.001
LDL Cholesterol (mmol/L)	2.49 (0.79)	2.72 (0.84)	<0.001
Insulin (mIU/L)[a]	6.42 (6.16, 6.71)	7.26 (6.98, 7.56)	<0.001
HOMA-IR[a]	1.52 (1.46, 1.59)	1.76 (1.68, 1.84)	<0.001
Energy (Kcal/day)	1942 (20)	1676 (16)	<0.001
Fat (g/day)	84.1 (1.3)	71.6 (1.1)	<0.001
Protein (g/day)	66.7 (0.8)	58.2 (0.7)	<0.001
Carbohydrate (g/day)	229.6 (2.8)	199.8 (2.2)	<0.001
MetS-IDF (%)	220 (23.08)	452 (41.24)	<0.001
MetS-AHA/NLHBI (%)	263 (27.60)	499 (45.53)	<0.001
Hypertension (%)	574 (60.23)	667 (60.86)	0.772

(to be continued)

(continued)

Characteristics	Male (n=953)	Female (n=1 096)	P Value
Diabetes (%)	135 (14.17)	201 (18.34)	0.011
Abdominal Obesity (%)	369 (38.72)	724 (66.06)	<0.001
Family History (%)	359 (37.67)	411 (37.50)	0.937
Physical activity (%)			0.060
No	386 (40.5)	500 (45.5)	
Sometimes	83 (8.71)	82 (8.05)	
Regular	484 (50.79)	514 (46.9)	
Medication (%)	341 (35.78)	437 (39.87)	0.057
Alcohol (%)			0<0.001
Never	632 (66.32)	1 047 (95.53)	
Moderate	219 (22.98)	45 (4.11)	
High	102 (10.70)	4 (0.36)	
Smoking Status (%)			0.001
Never	613 (64.32)	1 011 (92.24)	
<20 Cigarettes /Week	64 (6.72)	17 (1.55)	
20+ Cigarettes /Week	276 (28.96)	68 (6.20)	

Note. Data are shown as mean (SD). SBP: systolic blood pressure; DBP: systolic blood pressure; BMI: body mass index; FBG: fasting blood glucose; HDL: high density lipoprotein; LDL: low density lipoprotein. HOMA-IR: homoeostasis model assessment of insulin resistance; MetS-IDF: metabolic syndrome defined by International Diabetes Federation; MetS-AHA/NHLBI: metabolic syndrome defined by American Heart Association/National Heart, Lung, and Blood Institute.[a]The results for continuous variables are geometric mean with 95% confidence interval.

Characteristics of the Population According to Sex-specific Quartiles of Plasma Adiponectin

Since the plasma adiponectin level was higher in women than in men, participants were stratified by sex-specific adiponectin quartiles (Table 2). The cut-off point for plasma adiponectin quartiles was <6.8, 6.8-12.0, 12.0-18.0, and >18.0 mg/L in men and <8.8, 8.8-14.3, 14.3-20.9, and >20.9 mg/L in women, respectively. The BMI, waist circumference, DBP, FBG, TG, insulin, HOMA-IR, intake of energy, protein and fat were inversely correlated with sex-specific adiponectin quartiles (P<0.001 except for energy intake P=0.030 and for fat intake P=0.013), while the HDL-C and age were positively correlated with adiponectin (P<0.001). The prevalence of hypertension, DM, MetS both defined by IDF and AHA/NHLBI, family history of chronic diseases and medication proportion, decreased with increasing adiponectin quartiles. The SBP, TC, LDL-C, smoking, physical activity, alcohol drinking, and carbohydrate intake were not significantly correlated with adiponectin level.

TABLE 2

Characteristics of the Population across Sex-specific Plasma Adiponectin Quartiles

	Sex-specific Plasma Adiponectin Quartiles[a]				
	Quartile 1 (514)	Quartile 2 (512)	Quartile 3 (511)	Quartile 4 (512)	P Value
Continuous Variables					
Age	67 (6)	68 (6)	69 (6)	70 (7)	<0.001
BMI (kg/m^2)	25.7 (3.4)	25.6 (3.5)	24.9 (3.5)	23.4 (3.7)	<0.001
Waist (cm)	87.9 (9.6)	86.8 (9.6)	84.9 (10.0)	81 (10.8)	<0.001
SBP (mmHg)	140 (21)	141 (22)	141 (22)	138 (22)	0.113
DBP (mmHg)	82 (11)	82 (11)	82 (11)	80 (12)	<0.001
FBG (mmol/L)	5.94 (2.13)	5.61 (1.91)	5.56 (1.83)	5.30 (1.47)	<0.001

(to be continued)

(continued)

	Sex-specific Plasma Adiponectin Quartiles[a]				
	Quartile 1 (514)	Quartile 2 (512)	Quartile 3 (511)	Quartile 4 (512)	*P* Value
Triglyceride (mmol/L)	1.44 (0.76)	1.39 (0.72)	1.21 (0.55)	1.07 (0.49)	<0.001
HDL-C (mmol/L)	1.23 (0.27)	1.26 (0.30)	1.36 (0.32)	1.43 (0.31)	<0.001
Total-C (mmol/L)	4.56 (1.00)	4.55 (0.92)	4.57 (1.00)	4.56 (0.99)	0.988
LDL-C (mmol/L)	2.62 (0.83)	2.61 (0.79)	2.61 (0.86)	2.60 (0.83)	0.989
Insulin (mIU/L)[b]	7.99 (7.52,8.49)	7.02 (6.62,7.44)	6.80 (6.42,7.20)	5.79 (5.48,6.12)	<0.001
HOMA[b]	2.02 (1.88,2.15)	1.68 (1.58,1.79)	1.61 (1.51,1.71)	1.33 (1.25,1.41)	<0.001
Energy (kcal/day)	1 852 (622)	1 816 (571)	1 784 (562)	1 747 (563)	0.030
Fat (g/day)	81.6 (40)	76.7 (35.3)	77.4 (36.7)	73.9 (37.5)	0.013
Protein (g/day)	64.5 (24.7)	64.3 (24.4)	61 (22.3)	58.9 (23.2)	<0.001
Carbohydrate (g/day)	215 (85)	217 (77.3)	211 (77)	212 (78)	0.563
Categorical Variables					
Male Gender (%)	240 (46.7)	237 (46.4)	238 (46.5)	238 (46.5)	1.000
Hypertension (%)	319 (60.6)	313 (61.3)	330 (64.5)	279 (54.5)	0.008
Diabetes (%)	126 (24.5)	84 (16.4)	75 (14.7)	51 (10.0)	<0.001
Abdominal Obesity (%)	326 (63.4)	315 (61.6)	259 (50.6)	193 (37.7)	<0.001
MetS-IDF (%)	234 (45.5)	212 (41.5)	139 (27.2)	87 (17.0)	<0.001
MetS-AHA/NHLBI (%)	262 (51.0)	234 (45.8)	164 (32.0)	102 (19.9)	<0.001
Family History (%)	211 (41.1)	206 (40.3)	185 (36.1)	168 (32.8)	0.021
Heavy Smoke (%)	85 (16.5)	85 (16.5)	94 (18.4)	80 (15.6)	0.494
Regular Physical Activity (%)	258 (50.2)	256 (50.1)	258 (50.4)	226 (44.1)	0.199
Heavy Alcohol Drinker (%)	28 (5.5)	31 (6.1)	23 (4.4)	24 (4.7)	0.654
Medication (%)	236 (45.9)	194 (38.0)	195 (38.1)	153 (29.9)	<0.001

Note. SBP: systolic blood pressure; DBP: systolic blood pressure; BMI: body mass index; FBG: fasting blood glucose; HDL-C: high density lipoprotein cholesterol; LDL-C: low density lipoprotein cholesterol; HOMA-IR: homoeostasis model assessment of insulin resistance; MetS-IDF: metabolic syndrome defined by International Diabetes Federation; MetS-AHA/NHLBI: metabolic syndrome defined by American Heart Association/National Heart, Lung, and Blood Institute.[a]The cut-off point for plasma adiponectin quartiles was <6.8, 6.8-12.0,12.0-18.0 and >18.0mg/L in men and <8.8, 8.8-14.3, 14.3-20.9 and >20.9 in women, respectively. [b]The results for continuous variables are geometric mean with 95% confidence interval.

Association between Adiponectin Level and MetS and Its Related Diseases

The adiponectin level ranged 0.68-48.83 mg/L in the study population. The adiponectin concentration decreased progressively as the number of MetS components increased in both sexes (for trend $P<0.001$) (Fig. 1). The prevalence of MetS defined by IDF and AHA/NHLBI decreased steadily as adiponectin increased from the lowest to the highest quartiles. The prevalence of MetS-AHA/NHLBI was slightly higher than that of MetS-IDF in each quartile of both sexes (Fig. 2). For each component of all adiponectin quartiles, the prevalence of MetS was higher in women than in men.

The ORs for MetS and its related diseases by adiponectin quartiles are shown in Table 3. The ORs for MetS and its related diseases decreased from the 1st to the 4th adiponectin quartiles ($P<0.001$ except for hypertension $P=0.002$). With the highest adiponectin quartile as the reference group, the age and sex adjusted ORs for the lowest quartile were 4.25 (95% CI 3.21-5.62) for MetS-IDF, 4.12 (95% CI 3.08-5.52) for MetS-AHA/NHLBI, 2.94 (95% CI 2.06-4.19) for DM, 2.92 (95% CI 2.13-4.01) for high TG, 2.85 (95% CI 2.21-.68) for central obesity, 2.82 (95% CI 2.14-3.73) for low HDL-C and 1.47 (95% CI 1.14-1.89) for hypertension, respectively (model 1). After further adjustment for smoking, alcohol drinking, physical activity, family history of chronic diseases and medication for hypertension, diabetes and blood lipid, intake of energy, fat and protein, the ORs for MetS and other diseases remained significantly high though the magnitude decreased slightly. After further adjustment for BMI and HOMA-IR, the ORs decreased substantially. The ORs for the subjects in the 1st quartile group was 3.25 (95% CI: 2.24, 4.71) and 3.21 (95% CI: 2.26, 4.55) for MetS-IDF and MetS-AHA/NLHBI, respectively, which was much higher than those for MetS components and its related diseases.

TABLE 3

Odds Ratio and 95% Confidence Interval for MetS and Its Related Diseases according to the Sex-specific Adiponectin Quartriles

	Adiponectin Quartile				*P* Value
	Q1	Q2	Q3	Q4	
MetS-IDF					
Model 1	4.12 (3.08, 5.52)	3.49 (2.61, 4.68)	1.83 (1.35, 2.47)	1.00	<0.001
Model 2	4.00 (2.93, 5.47)	3.66 (2.67, 5.00)	1.69 (1.22, 2.34)	1.00	<0.001
Model 3	3.25 (2.24, 4.71)	2.67 (1.84, 3.88)	1.32 (0.90, 1.95)	1.00	<0.001
MetS-AHA/NHLBI					
Model 1	4.25 (3.21, 5.62)	3.44 (2.60, 4.55)	1.91 (1.43, 2.53)	1.00	<0.001
Model 2	4.17 (3.07, 5.66)	3.72 (2.74, 5.05)	1.80 (1.32, 2.46)	1.00	<0.001
Model 3	3.21 (2.26, 4.55)	2.74 (1.94, 3.88)	1.42 (1.00, 2.04)	1.00	<0.001
Central Obesity					
Model 1	2.85 (2.21, 3.68)	2.64 (2.05, 3.41)	1.69 (1.32, 2.17)	1.00	<0.001
Model 2	2.76 (2.11, 3.60)	2.64 (2.04, 3.43)	1.58 (1.22, 2.05)	1.00	<0.001
Model 3	1.71 (1.18, 2.50)	1.37 (0.94, 1.99)	0.90 (0.61, 1.29)	1.00	<0.002
Hypertension					
Model 1	1.47 (1.14, 1.89)	1.40 (1.09, 1.80)	1.56 (1.21, 2.01)	1.00	0.002
Model 2	1.12 (0.84, 1.50)	1.28 (0.96, 1.70)	1.49 (1.12, 1.98)	1.00	0.036
Model 3	0.83 (0.61, 1.12)	0.90 (0.66, 1.23)	1.26 (0.92, 1.71)	1.00	0.046
Diabetics					
Model 1	2.94 (2.06, 4.19)	1.78 (1.23, 2.59)	1.55 (1.06, 2.27)	1.00	<0.001
Model 2	2.24 (1.53, 3.30)	1.59 (1.07, 2.38)	1.28 (0.85, 1.93)	1.00	<0.001
Model 3	1.70 (1.12, 2.60)	1.41 (0.92, 2.12)	1.02 (0.65, 1.60)	1.00	0.023
Low HDL-C					
Model 1	2.82 (2.14, 3.73)	2.73 (2.07, 3.61)	1.36 (1.02, 1.82)	1.00	<0.001
Model 2	2.99 (2.24, 3.99)	2.90 (2.18, 3.87)	1.37 (1.01, 1.85)	1.00	<0.001
Model 3	2.47 (1.82, 3.37)	2.46 (1.81, 3.33)	1.20 (0.87, 1.65)	1.00	<0.001
High TG					
Model 1	2.92 (2.13, 4.01)	2.67 (1.94, 3.67)	1.73 (1.24, 2.41)	1.00	<0.001
Model 2	2.48 (1.76, 3.48)	2.62 (1.87, 3.69)	1.59 (1.12, 2.27)	1.00	<0.001
Model 3	2.16 (1.51, 3.09)	2.24 (1.56, 3.20)	1.41 (0.97, 2.04)	1.00	<0.001

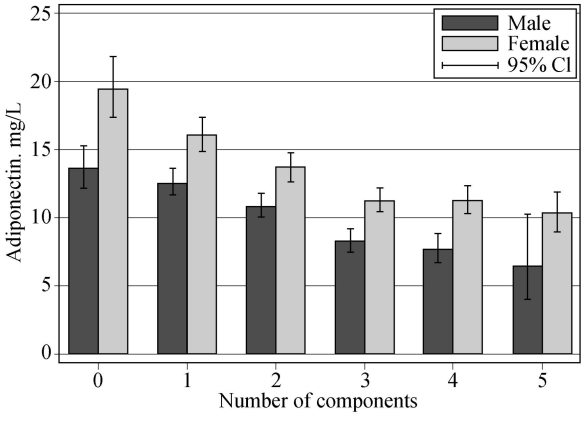

FIG. 1. Correlation between plasma adiponectin level and the number of MetS components with adiponectin concentration expressed as geometric mean (95% CI).

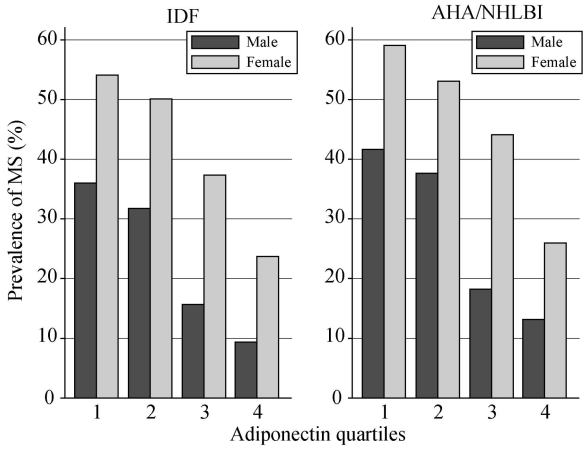

FIG. 2. Prevalence of MetS-IDF and MetS-AHA/NHLBI in each quartile of adiponectin concentration.

Model 1 was adjusted for age and sex; model 2 was further adjusted for smoking, alcohol drinking, macronutrients (protein, fat) and energy intake, physical activity, family history of chronic diseases and medication; model 3 was further adjusted for BMI and HOMA-IR.

DISCUSSION

This study showed that adiponectin was associated with MetS, which was independent of lifestyle factors, family history of chronic diseases, medication, BMI and IR in older adults from major cities in China.

To our knowledge, the 2002 CHNS represents the current nutrition and health status in the Chinese people and is the first representative large-scale study on the correlation between adiponectin and MetS and its related diseases in older adults of major Chinese cities. When the correlation between adiponectin and MetS was assessed, a comprehensive list of potential confounding factors including obesity, insulin resistance, macronutrients and energy intake, physical activities, medication, and family history were adjusted. These confounding factors had not been or only had been partially adjusted[18].

In our study, there was a difference in adiponectin levels between gender and age and the adiponectin level was higher in women than in men, which was postively related with age, and our finding is consistent with the reported data[20, 30-32].

In this study, some important lifestyle factors closely related with MetS such as physical activity, alcohol drinking and smoking[33-35] were not significantly related to adiponectin level while increased intake of energy, fat and protein were inversely correlated with plasma adiponectin level. Lac *et al.*[36] found that the adiponectin level was higher in rats fed with fat-rich diets than in rats fed with standard diets. Yannakoulia *et al.*[37] showed that neither total caloric intake nor macronutrient composition of diet had any substantial effect on serum adiponectin level in healthy young Greek subjects. In our study, the correlation between lifestyles and adiponectin level was evaluated. Further in-depth studies are required to assess whether lifestyles, such as physical activity, alcohol drinking, smoking, intake of energy and macronutrients, play a role in decreasing adiponectin level and development of MetS. After adjustment for lifestyle and dietary factors, adiponectin was correlated with MetS, suggesting that adiponectin may contribute to the risk of developing MetS independent of lifestyles and dietary factors.

We applied two current definitions of MetS in this study and found that the prevalence of MetS in older Chinese adults from major cities was 23.08% for men and 41.42% for women by IDF definition and 27.60% for men and 47.53% for women by AHA/ NHLBI criteria. The prevalence of MetS diagnosed by AHA/ NHLBI was higher due to more people effected with three of abnormalities without abdominal obesity. This study showed the prevalence of MetS in older adults from major Chinese cities was about 2-3 times as that of Chinese adults from another national survey in 2000-2001[23]. The older population in major Chinese cities has a higher risk of developing MetS than population of other age groups.

IR was previously thought to be “common soil” of MetS. It was reported that IR plays an important role in the pathophysiology of MetS and is the underlying cause for MetS[38-39]. However, the question whether IR can explain the mechanism underlying MetS remains controversial[40]. BMI is an important measurement for defining obesity. It has been shown that central obesity is a higher risk factor for health and waist circumference is a better predictor for diabetes, dyslipidemia, hypertension and MetS than BMI[41-42]. Adiponectin can sensitize insulin by decreasing hepatic glucose output, thus regulating whole-body glucose homeostasis, and hypoadiponectinemia is associated with insulin resistance in humans[4, 43]. It was reported that adiponectin level is more strongly correlated with intra-abdominal fat than with subcutaneous fat[42].

It has been widely believed that adiponectin is a factor to the development of MetS. However, the correlation between adiponectin level and MetS is not clear, particularly among older Chinese adults. In this study, after adjustment for a comprehensive list of confounding factors, adiponectin was correlated with MetS independent of IR and BMI, suggesting that the correlation between adiponectin and MetS is beyond the effect of BMI and IR. The results of our study imply that adiponectin is a useful independent clinical biomarker for predicting MetS. Subjects in the lowest quartile group were 3.25 (IDF) and 3.21 (AHA/NHLBI) times likely to have MetS as those in the highest quartile group.

There are several limitations in this study. Our study was cross-sectional in which no cause-effect relationship was established. Moreover, there are different molecular weight multimers of adiponectin in circulation. It was reported that the high molecular weight (HMW) multimer is the active form of adiponectin, which is more useful than total adiponectin in evaluating MetS and IR[44]. Further study on HMW or on correlation between HMW and total adiponectin ratio of MetS is warranted.

In summary, adiponectin is strongly correlated with MetS independent of IR and obesity. Adiponectin level is a useful predictor for MetS. Further study on the cut-off point of adiponectin level is needed for its clinical application.

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