 DOI: 10.1017/S1368980007226023

An urban–rural comparison of the prevalence of the metabolic syndrome in Eastern China

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Submitted 8 July 2005: Accepted 3 April 2006

Abstract

Objective: To assess the impact of urbanisation on the prevalence of the metabolic syndrome in Chinese adults.
Design: As part of a community-based cross-sectional survey conducted in 2002, a sample from rural and urban populations in East China was obtained. The metabolic syndrome is defined by the National Cholesterol Education Program Adult Treatment Panel III criteria (ATP III) and the modified ATP III, which recommended a lower waist circumference cut-off for Asians.
Setting: Field sites in Jiangxi and Anhui provinces and the Jing'an District of Shanghai, China.
Subjects: A total of 529 non-pregnant, non-lactating urban and rural adults, aged 20–64 years without diagnosed diabetes.
Results: Dwelling in urban areas was associated with higher dietary fat intake and slightly lower total energy intake, and with significantly lower occupational physical activity. Using the ATP III criteria, the prevalence of the metabolic syndrome was significantly higher for urban than rural men (12.7 vs. 1.7%, $P < 0.001$), and was similar between urban and rural women (10.1 vs. 9.7%, $P = 0.17$). These urban–rural differences were greatly enhanced when the modified ATP III criteria for the syndrome were used, for men (34.3 vs. 2.7%, $P < 0.01$) and women (24.1 vs. 11.4%, $P = 0.07$). The Asian waist circumference cut-offs (90 and 80 cm for men and women, respectively) had a better combination of sensitivity and specificity in identifying other metabolic disorders, which included high glucose, high blood pressure, high triglycerides and low high-density lipoprotein cholesterol, for this population.
Conclusion: For the Chinese population, urban dwelling was associated with higher prevalence of the metabolic syndrome, especially in men.

Keywords
Metabolic syndrome
Urban
Rural
Central obesity
China

Substantial socio-economic and demographic changes have taken place in China over the past two decades. Since 1982, the urban population increased from 21 to 36%[1]. A number of studies have shown that urban dwelling is associated with an increase in adverse health risk behaviours and lifestyle changes[2–4]. In the case of China, these demographic changes have been temporally associated with a rapid rise in the prevalence of cardiovascular disease, which is now the leading cause of death[2,5].

The metabolic syndrome, also called insulin resistance syndrome or syndrome X, is a cluster of metabolic disorders that includes central obesity, insulin resistance, dyslipidaemia and hypertension[6]. It is a well-recognised risk factor for type 2 diabetes mellitus[7–9] and cardiovascular disease (CVD)[10–12].

There are no uniform criteria for diagnosis of the metabolic syndrome. The widely accepted working definition, proposed by the National Cholesterol Education Program Adult Treatment Panel III (ATP III)[13], uses five variables for diagnosis of the syndrome, including central obesity, high triglycerides, low high-density lipoprotein (HDL) cholesterol, high blood pressure and higher fasting glucose. Since the ATP III's definition of central obesity as waist circumference $\geq$102 cm for men and 88 cm for women might be inappropriate for Asian populations, some studies suggested modifying the APT III by incorporating the Asian-Pacific waist circumference cut-off (90 cm for men and 80 cm for women)[14,15]. This adjustment has been incorporated into the International Diabetes Federation (IDF) definition of metabolic syndrome[16]. IDF also modified the original ATP III criteria by giving a higher weight for central obesity than other disorders and by incorporating the lowered fasting plasma glucose cut-off as proposed by the American Diabetes Association[16].

The purpose of this study was to assess the impact of urbanisation on the risk of chronic diseases, by comparing

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the prevalence of the metabolic syndrome in rural and urban adults in East China.

Subjects and methods

Subjects

The China Nutrition Transition study was a community-based cross-sectional survey performed in 2002. A three-stage stratified random sampling method was used to select the study sample, residing in the National Disease Surveillance Points (DSP) in East China. The DSP registry system was established in 1989 and was comprised of 145 nationally representative 'disease surveillance points', across seven geographic regions and 30 provinces of China[17]. In the first stage, we randomly selected two rural regions (Wuning County in Jiangxi Province and Juchao County in Anhui Province) and one urban district (Jing'an District of Shanghai) from ~20 disease registry points in East China. In the second stage, we selected at random 10 villages or neighbourhoods from each region. The third stage consisted of a random selection of 10 households from each village or neighbourhood based on local household census data. Because we sampled only three sites, the data may not be representative of the whole population of Eastern China, but it is still a valid sample to compare urban–rural differences in that region.

All family members aged 8–64 years were eligible for the study. We excluded pregnant and lactating women, and subjects who had been diagnosed with diabetes and were taking antidiabetic medications. The present report is restricted to adult subjects 20–64 years of age. All subjects were of the Han ethnicity, the most predominant group in China. The participation rate was 78% in rural and 70% in urban areas. The main reason for non-participation was absence from the residential area on the day of the examination.

All subjects gave their written, informed consent. The study protocol was approved by the Committee on Human Research of The Johns Hopkins University Bloomberg School of Public Health and by the Chinese Academy of Medical Science.

Measurement

Participants were asked to fast overnight and to attend a local health care station for a physical exam. Under the supervision of study investigators, data collection was performed by local health care workers after comprehensive training on each specific tool and methodology employed. Weight and height were measured with subjects wearing light clothing and no shoes. Waist circumference was measured at the level of the navel.

Socio-economic status, education, occupation, smoking status, alcohol consumption and physical activity were assessed using Behavior Risk Factor Survey System Questionnaire[18]. The usual amount and frequency of alcohol intake for each kind of alcoholic beverage in the past year were obtained. Since only 24 subjects (4.67%) in this study population are ex-smokers, we grouped smoking status into current smoker and non-current smoker categories. We dichotomised physical activity into sedentary and non-sedentary categories, based on occupational physical activity, which in the Chinese population accounts for almost 80% of daily physical activity[19]. Four 24-hour dietary recalls were collected in rural sites, one per season. Three dietary recalls were conducted in the urban site in spring, summer and autumn. All days of the week were equally represented in the collection of dietary recall. A complete set of Chinese food models was displayed to help subjects estimate the amount of food eaten. The 2002 Chinese food composition table was used to calculate macronutrient intake.

Systolic and diastolic blood pressures were measured twice after 5 min rest in the seated position using a mercury sphygmomanometer. First and fifth Korotkoff sounds were taken as systolic and diastolic blood pressure, respectively. All subjects underwent an oral glucose tolerance test following the World Health Organization protocol[20].

Blood specimens were centrifuged immediately after blood was drawn at each site, and shipped in the frozen state, using dry ice, to a central clinical laboratory in Shanghai No. 6 People's Hospital. Specimens had been stored at −70°C until laboratory assays could be carried out. Plasma glucose was measured in an automated analyser (Hitachi High-Technologies Corporation) using the glucose oxidase method (intra- and inter-assay coefficient of variation (CV) $<5\%$). Triglycerides and HDL cholesterol were measured in the same analyser by an enzymatic method (triglycerides: intra- and inter-assay CV $<5\%$; HDL cholesterol: intra-assay CV 1.5%, inter-assay CV 2.1%)[21]. Plasma insulin was determined by radioimmunoassay (intra- and inter-assay CV $<10\%$) (Linco Research, Inc.).

Definition of the metabolic syndrome

The metabolic syndrome was defined according to the ATP III definition[13] as the presence of three or more of the following criteria: central obesity as waist circumference $\geq$ 102 cm (men) and 88 cm (women); plasma triglycerides $\geq 1.7\ \text{mmol l}^{-1}$; HDL cholesterol $<1.0\ \text{mmol l}^{-1}$ (men) and $1.3\ \text{mmol l}^{-1}$ (women); fasting plasma glucose $\geq 6.1\ \text{mmol l}^{-1}$; and blood pressure $\geq$135/95 mmHg. The ATP III criteria are ambiguous about subjects who are being treated for hypertension. We classified subjects using antihypertensive medications as having hypertension. We also modified the ATP III by incorporating the Asian waist circumference cut-off point at 90 cm for men and 80 cm for women[16,22]. In addition, we diagnosed metabolic syndrome using the IDF criteria: central obesity ($\geq$80 cm for women, 90 cm for men) plus two of the following: raised triglycerides, reduced HDL cholesterol, raised blood pressure or raised fasting plasma glucose. In contrast to ATP III, IDF used a lower cut-off of $5.6\ \text{mmol l}^{-1}$ to define raised fasting plasma glucose[16].

Statistical analysis

Statistical analysis was performed sing SAS software, version 8.0 (SAS Institute, Inc.) and STATA, version 7.0 (Stata Corp.). The sampling weights were calculated based on the year 2000 China Population Census data and our sampling scheme, and took into account non-response and demographic differences in age and gender between the sample and the total population. The sampling weight and complex sampling design were incorporated into all statistical analyses to derive the weighted mean, percentage and standard error. Natural logarithm transformation was used for right-skewed variables, including fasting and 2 h glucose and insulin, triglycerides, total, low-density lipoprotein (LDL) and HDL cholesterol and the ratio of LDL to HDL cholesterol. We stratified the analysis by location and gender. Logistic regression models were used to contrast the urban–rural difference with adjustment for age; likewise, linear regression models were used to compare continuously distributed risk factor levels with controlling for age. The prevalence of the metabolic syndrome and its components was age-standardised by a direct method using the 2000 adult population of China (20–64 years) as the standard population.

Results

Subjects' characteristics

More than 90% of our rural subjects were farmers, fishermen or housewives, while the majority of urban residents were civil servants, salesmen, health care workers and industrial labourers. Urban residents had a higher income and education level than their rural counterparts. Smoking prevalence, daily alcohol and energy intake were higher in men than in women, and slightly higher in rural residents than in urban residents. The percentage of dietary fat intake was higher in urban than in rural subjects, especially in women. More than 75% of urban adults had a sedentary occupational physical activity, as compared with a rate of <15% in rural residents (Table 1).

Urban–rural comparison of the metabolic syndrome

Table 2 compares the age-adjusted mean of various anthropometric and metabolic indices by location in men and women separately. Body mass index (BMI), waist circumference and 2 h glucose were significantly higher in urban men than in rural men, but the urban–rural difference was not significant in women. Dwelling in urban areas was associated with significantly higher 2 h plasma insulin, triglycerides, and total and LDL cholesterol in both men and women. In men, HDL cholesterol was higher in rural than urban residents while the urban–rural difference was the opposite in women. As for gender difference in each location, we observed that urban women had significantly lower waist circumference and triglycerides and higher HDL cholesterol than urban men. Conversely, rural women had higher metabolic risk than rural men, as demonstrated by higher BMI, waist circumference, fasting and 2 h plasma insulin and triglycerides.

Table 3 shows the age-standardised prevalence of the metabolic syndrome and its components. The prevalence of high triglycerides was significantly greater in urban residents than in rural adults. No significant urban–rural difference in the prevalence of high fasting plasma glucose was observed. In men, urban subjects had a higher prevalence of low HDL cholesterol and hypertension, as compared with rural men. In women, the prevalence of low HDL cholesterol was significantly higher in rural areas. According to the original ATP III criteria, very few subjects were centrally obese, especially for men: none among rural men, and 2% among urban men. The prevalence of the metabolic syndrome was significantly higher for urban men (12.7%) than for rural men (1.7%), and was similar between urban women (10.1%) and rural women (9.7%).

Using the modified ATP III criteria, the prevalence of central obesity increased by 18-fold for men and 2.5-fold for women, and the rate was significantly higher in urban subjects than rural subjects in men (39.01 vs. 4.67%, $P < 0.001$) and women (55.81 vs. 40.76%, $P = 0.02$). Also, the prevalence of the metabolic syndrome increased more

Table 1 Selected characteristics of the rural and urban study populations

	Men			Women		
	Rural ($n = 177$)	Urban ($n = 81$)	P*	Rural ($n = 191$)	Urban ($n = 80$)	P*
Education less than senior high school (%)	94.26	17.12	<0.001	98.43	16.78	<0.001
Self-reported monthly family income <500 ¥	95.96	2.98	<0.001	98.78	3.41	<0.001
Current smoker (%)	74.02	50.23	0.05	1.27	0.90	0.73
Alcohol intake (g day^{-1})	14.63 ± 40.17	8.98 ± 27.54	0.50	0.60 ± 1.93	0.37 ± 2.59	0.18
Energy intake (kcal day^{-1})	2600 ± 984	2500 ± 864	0.23	2059 ± 621	2001 ± 688	0.52
Fat intake (%)	30.27 ± 24.48	32.92 ± 9.90	0.17	28.92 ± 6.50	37.42 ± 5.37	<0.001
Sedentary occupation (%)	7.89	71.92	<0.001	13.11	82.54	<0.001

Data are mean ± standard deviation or %.
* P-value for urban–rural comparison with adjustment for age in men and women.

Table 2 Age-adjusted comparison of metabolic indices between locations and between genders

	Rural	Urban	P^*
BMI (kg m^{-2})			
Men	21.10 ± 4.39	23.85 ± 3.78	<0.001
Women	22.36 ± 5.94	22.62 ± 2.95	0.69
P-value†	0.014	0.06	
Waist circumference (cm)			
Men	75.37 ± 11.04	86.02 ± 13.68	< 0.001
Women	79.07 ± 12.85	81.21 ± 9.66	0.21
P-value†	0.001	0.025	
Fasting plasma glucose (mmol l^{-1})‡			
Men	5.00 ± 1.33	5.03 ± 0.81	0.93
Women	5.05 ± 1.38	4.81 ± 0.63	0.04
P-value†	0.23	0.013	
2 h plasma glucose (mmol l^{-1})‡			
Men	5.47 ± 2.39	6.55 ± 2.61	0.003
Women	5.81 ± 1.80	5.96 ± 1.97	0.68
P-value†	0.09	0.06	
Fasting plasma insulin (μU ml^{-1})‡			
Men	7.77 ± 9.05	8.67 ± 8.91	0.41
Women	9.39 ± 5.80	8.41 ± 7.60	0.31
P-value†	0.03	0.71	
2 h plasma insulin (μU ml^{-1})‡			
Men	19.20 ± 19.42	42.53 ± 50.22	<0.001
Women	30.72 ± 29.42	47.46 ± 33.54	<0.001
P-value†	<0.001	0.78	
Triglycerides (mmol l^{-1})‡			
Men	0.65 ± 0.67	1.52 ± 0.99	<0.001
Women	0.78 ± 0.41	1.04 ± 0.80	0.006
P-value†	0.003	0.003	
Total cholesterol (mmol l^{-1})‡			
Men	3.39 ± 1.73	4.22 ± 0.72	<0.001
Women	3.39 ± 1.11	4.45 ± 0.72	<0.001
P-value†	0.95	0.05	
LDL cholesterol (mmol l^{-1})‡			
Men	1.98 ± 1.60	2.73 ± 0.72	<0.001
Women	1.99 ± 0.83	2.73 ± 0.89	<0.001
P-value†	0.91	0.98	
HDL cholesterol (mmol l^{-1})‡			
Men	1.22 ± 0.40	1.09 ± 0.18	0.001
Women	1.20 ± 0.41	1.42 ± 0.54	0.001
P-value†	0.27	<0.001	
LDL to HDL ratio‡			
Men	1.62 ± 1.20	2.51 ± 0.90	<0.001
Women	1.66 ± 0.55	1.91 ± 1.16	0.09
P-value†	0.59	0.001	

BMI – body mass index; LDL – low-density lipoprotein; HDL – high-density lipoprotein.
Data are mean ± standard deviation.
**P*-value for comparison between sites in men and women respectively.
†*P*-value for comparison between gender at each site.
‡Geometric mean and standard error are given.

in urban subjects than in rural subjects, and we observed a significant urban–rural difference in the metabolic syndrome prevalence in both men (34.3 vs. 2.7%, $P < 0.01$) and women (24.1 vs. 11.4%, $P = 0.07$). The prevalence estimated using IDF's definition was very close to that using the modified ATP III criteria, and showed a significant urban–rural difference in men (30.49 vs. 2.25, $P < 0.01$), and a less evident difference in women (25.01 vs. 14.58, $P = 0.18$). Regardless of whether the original or modified ATP III criteria or IDF's definition was used, our logistic regression analysis demonstrated a significant interaction between gender and residency for the odds ratio of having the metabolic syndrome ($P < 0.01$)

Sensitivity and specificity analysis of waist circumference cut-offs

Using receiver operating characteristic analysis, we compared the capability of waist circumference cut-offs of the APT III and Asian criteria in identifying at least two other features of the metabolic syndrome, which included high glucose, high blood pressure, high triglycerides and low HDL cholesterol. The Asian cut-off had a better combination of sensitivity (0.64) and specificity (0.72) than those of the ATP III (sensitivity 0.23, specificity 0.93). Also, the area under curve for Asian cut-offs was significantly higher than those of the ATP III (0.69 vs. 0.58, $P < 0.001$) (Fig. 1)

Discussion

In the present study, we assessed urbanisation's impact on the risk of chronic diseases by comparing urban–rural differences in the prevalence of the metabolic syndrome. As defined by the ATP criteria, we found a significantly higher prevalence of the syndrome in urban than in rural men (12.7 vs. 1.7%, $P < 0.01$) and essentially no difference among women (10.1 vs. 9.7%, $P = 0.17$). The crude prevalence for the whole population sample was ~7%, which was comparable with the rate of 10% in Chinese aged 30–74 years[23]. When we modified the ATP III criteria on the basis of recommendations for Asian populations, the urban–rural differences became more pronounced for both genders: 34.3 vs. 2.7% ($P < 0.01$) in men, and 24.1 vs. 11.4% ($P = 0.07$) in women. Using the most recent definition proposed by the IDF, the prevalence rate is similar to that using the modified APT III criteria.

In the present study, we excluded subjects with a self-reported history of diagnosed diabetes; however, a recent national survey has shown that only 2–3% of urban adults and 1% of rural adults had such self-reported history[24]. Therefore, this exclusion should make our prevalence only slightly lower than that in the general population. As shown by our data, the prevalence of the metabolic syndrome in China is much lower than in the USA[25], but is comparable with that from other Asian populations using the ATP III criteria. A study in Taiwanese adults reported a prevalence of 9.5%[26], and other studies have reported prevalences of 6–14% in Hong Kong residents[27,28]. A recent study in urban Koreans aged 30–80 years showed that 16% of men and 10% of women had the syndrome[14]. A cross-sectional study in Singapore that included 18–69 year olds, showed a prevalence of 12% for all races and of 9.4% for Chinese[15]. However, the direct comparison must be made with caution since the selection of the samples was different, for example the age distribution and proportion of urban to rural populations, and the time of the study, which affect the prevalence estimate.

Using either the original or the modified ATP III criteria, our results showed that urbanisation's impact on the prevalence of metabolic syndrome was significantly modified by gender: the urban–rural difference was

Table 3 Age-standardised prevalence of the metabolic syndrome in the rural and urban men (M) and women (W)

	Men			Women		
	Rural ($n = 177$)	Urban ($n = 81$)	P*	Rural ($n = 191$)	Urban ($n = 80$)	P*
Triglycerides $\geq 1.7\,\text{mmol l}^{-1}$	2.73	41.78	<0.001	4.99	18.06	0.02
HDL cholesterol $< 1.0\,\text{mmol l}^{-1}$ (M), $< 1.3\,\text{mmol l}^{-1}$ (W)	20.03	33.41	0.15	59.22	39.01	0.04
Blood pressure ≥130/85 mmHg or using medication	24.05	38.74	0.22	14.49	15.97	0.73
Fasting plasma glucose $\geq 6.1\,\text{mmol l}^{-1}$	4.93	2.65	0.29	4.40	2.95	0.54
Fasting plasma glucose $\geq 5.6\,\text{mmol l}^{-1}$	23.11	9.47	0.25	26.25	5.51	0.02
Waist circumference ≥102 cm (M), 88 cm (W)	0.00	2.47	0.19	18.39	17.70	0.92
Waist circumference ≥90 cm (M), 80 cm (W)	4.67	39.01	<0.001	40.76	55.81	0.02
ATP III metabolic syndrome	1.66	12.65	0.009	9.67	10.12	0.17
Modified ATP III metabolic syndrome	2.72	34.26	<0.001	11.40	24.07	0.07
IDF metabolic syndrome	2.25	30.49	<0.001	14.58	25.01	0.18

HDL – high-density lipoprotein; ATP III – Adult Treatment Panel III; IDF – International Diabetes Foundation.
Data are the percentage and prevalence age-standardized by using the year 2000 Chinese population aged 20–64 years.
* P-value for urban–rural difference with adjustment for age in men and women.

much more evident in men than in women. Previous studies have reported a similar pattern for the prevalence of hypertension, diabetes, impaired fasting glucose and the metabolic syndrome[5,23,24]. We also observed that urban Chinese women had a higher HDL cholesterol level than rural women, consistent with other reports[4,23].

Our study found that urban dwellers had higher fat intake and higher levels of physical inactivity than their rural counterparts, which was consistent with a previous report[2]. While these differences were similar for men and women, the urban–rural difference in metabolic syndrome prevalence was much more evident for men than for women. In other words, for the metabolic syndrome, rural women were similar to urban women. The reasons for this are unclear. Rural women have a higher fertility rate than urban women (≥2.5 vs. 1.2)[1]. It has been suggested that multiple pregnancies may increase the risk of developing central obesity, insulin resistance and hypertension[29,30], all components of the metabolic syndrome. If so, the favourable effects of rural dwelling on metabolic indices may be diminished by the unfavourable effects of the higher fertility rate of rural women.

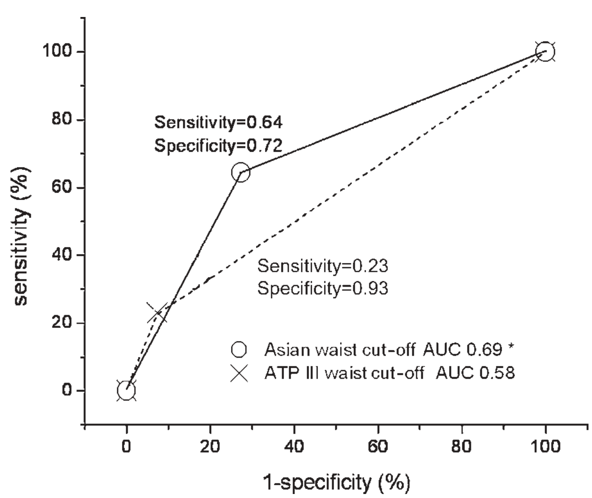

Fig. 1 Sensitivity and specificity of waist circumference cut-off for Asians and the Adult Treatment Panel III (ATP III) in identifying metabolic disorders. *The area under the curve (AUC) of the Asian waist cut-off is significantly higher than that of the ATP III ($\chi^2 = 16.68$, df $= 1$, $P < 0.001$)

Another interesting finding is the opposite gender effect on the metabolic syndrome in rural and urban areas: in the urban environment women had a lower risk than men, whereas the opposite was true in rural areas. Like our results, studies in Korean population showed the same pattern of difference across gender[14,23,31]. In China, previous studies have shown that urban men have a higher risk of obesity[32], metabolic syndrome[33], hypertension[5], diabetes and impaired fasting glucose[24], and cardiovascular disease[32], as compared with urban women. However, studies in rural China have shown that rural women have a higher prevalence of obesity and have higher triglyceride concentrations than rural men[24,34,35].

In conclusion, our results indicate a significantly higher prevalence of the metabolic syndrome among urban-dwelling Chinese, especially men. In contrast, the prevalence of the metabolic syndrome among rural women was similar to that or urban women.

Acknowledgements

Sources of funding: This study was funded by the Center of a Livable Future, Johns Hopkins Bloomberg School of Public Health.

Conflict of interest declaration: No author declares a conflict of interest with this work.

Authorship responsibilities: X.W. performed the statistical analysis. The manuscript was drafted by X.W. and B.C. All authors participated in the study design, data collection and interpretation, and reviewed and approved the manuscript.

Acknowledgements: We gratefully acknowledge the valuable assistance of the staff of the regional offices of the Chinese Center for Disease Control and Prevention in Wuning (Jiangxi Province), Chaohu (Anhui Province) and the Jian'an District of Shanghai.

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