Original Article

Prevalence of metabolic syndrome and individual metabolic abnormalities in China, 2002–2012

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Background and Objectives: The purpose of our study was to estimate the national prevalence of metabolic syndrome, its individual components and its changes in the past decade. **Methods and Study Design:** Two national-representative cross-sectional surveys: the China National Nutrition and Health Survey 2002 (CNNHS 2002) and the Chinese National Nutrition and Health Surveillance 2010–2012 (CNNHS 2010–2012). A total of 48,235 and 104,098 participants aged 18 years or older who had completed data on physical examination, blood lipids, and fasting glucose tests from CNNHS 2002 and CNNHS 2010–2012, respectively, were included in current study. **Results:** The prevalence of metabolic syndrome in Chinese adults increased from 9.5% (95% confident interval [CI]: 9.2%–9.7%) in 2002 to 18.7% (18.3%–19.1%) in 2010–2012, corresponding to an estimated 83.6 million adults in 2002 and 189 million adults in 2010–2012 living with metabolic syndrome in China. The increment was more than doubled among young, rural residents and those from poor households. Abdominal obesity, hyperglycemia, high triglycerides, low HDL-C, and elevated blood pressure were found in 18.9% (18.5%–19.3%), 6.4% (6.2%–6.7%), 13.8% (13.5%–14.2%), 19.3% (18.9%–19.7%), and 34.0% (33.5%–34.5%) of adults in 2002, respectively, which was 25.8% (25.3%–26.2%), 16.2% (15.8%–16.5%), 23.7% (23.3%–24.2%), 32.6% (32.0%–33.1%), and 34.4% (33.9%–34.9%), respectively, in 2010–2012. **Conclusions:** Based on two nationally representative surveys, our results indicated that the prevalence of metabolic syndrome is widespread and increasing in China.

Key Words: metabolic syndrome, China National Nutrition and Health Survey (Surveillance), national representative

INTRODUCTION

Cardiovascular disease has surpassed infectious diseases and emerged as a leading cause of death in China.[1] As a cluster of cardiovascular risk factors, metabolic syndrome (MetS), as well as its individual metabolic abnormalities, is associated with an increased risk for developing cardiovascular disease,[2-4] type 2 diabetes,[2,3] all-cause mortality,[4] and even cancer.[5] Given the potential effect of MetS on the risk of health complications, it is important to understand the national trend of MetS and its individual components, especially for the development of public health policy, disease prevention, and health promotion.

Some previous studies from China have reported the prevalence of MetS in Chinese population;[6-9] however, their data[6-8] are not nationally representative and/or do not describe the prevalent trend.[9] Other studies based on nationally representative data reported the prevalence of individual metabolic abnormalities among the Chinese population, such as diabetes,[10] elevated blood pressure,[11] dyslipidemia,[12] and obesity;[13] however, only one of them had collected data of all individual factors,[9] so none reported the time trend of metabolic syndrome. Therefore, the purpose of our study was to estimate the national prevalence of MetS and its individual components and fully understand its changes in the past decade, using data from two cycles of the national nutrition and health survey.

METHODS

Study population

Data for this study were obtained from the China National Nutrition and Health Surveys (CNNHS), which were nationally representative cross-sectional studies conducted by the Chinese Center for Disease Control and Prevention to assess the health and nutrition of Chinese civilians in 2002 and 2010-2012. The subjects in the CNNHS 2002 were not intentionally overlapping with those in CNNHS 2010-2012. The two surveys were both conducted in 31 provinces, autonomous regions, and municipalities directly under the central government, throughout China (ex-

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cept Taiwan, Hong Kong, and Macao); and in both surveys, the sample was recruited using a stratified and multi-stage cluster, random sampling method (Figure 1).

The detailed description could be found in previous publications.[11,14-16] In brief, in CNNHS 2002, the first stage of sampling included 6 strata: big city, small to medium city, and type I to IV rural areas, based on geographic characteristics, economy, and social development information in 2000 provided by the China National Bureau of Statistics and the China Ministry of Health Statistics. CNNHS 2002 randomly selected 132 study sites; from each study sites, 6 committee/villages were randomly selected; and from each committee/villages, 90 households were randomly selected and invited for the physical examinations. Among these 90 households, 30 households (one third) were randomly selected to further participate in the dietary survey and blood tests. All family members from the 30 selected households were invited to participant dietary surveys and draw blood samples, among them, 53,058 participants aged 18 years or above (Figure 1). According to economic and social development characteristics as reported by 2010 China Population Census, CNNHS 2010-2012 selected 150 study sites from 4 strata: 34 big cities, 41 medium and small cities, 45 general rural areas, and 30 poor rural areas applying multistage stratified cluster random sampling method. CNNHS 2010-2012 also selected 6 committee/villages from each study sites, but 75 households from each committee/villages. All family members from the selected households were invited to draw blood samples, among them, 120,226 participants aged ≥18 year old (Figure 1). Our study included only respondents aged 18 years and older who had completed data on physical examination, blood lipids, and fasting glucose tests. The response rates were 90.9% in CNNHS 2002 and 86.6% in CNNHS 2010–2012; the final sample sizes for current study of MetS were 48,235 in the 2002 survey and 104,098 in the 2010–2012 survey.

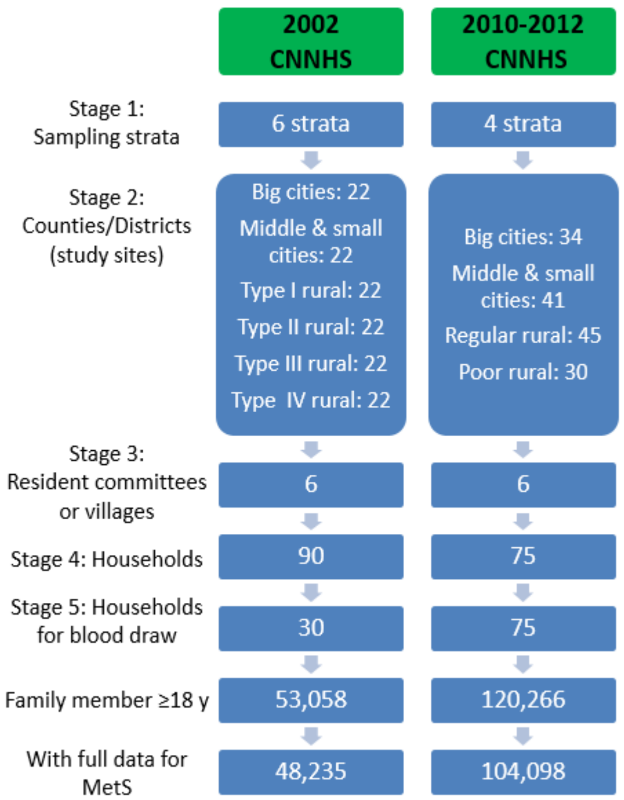

Figure 1. Sampling scheme of CNNHS 2002 and 2010-2012.

Ethics, consent and permissions

Written informed consent form was taken from each subject of his/her guardian after the nature of the study was fully explained. The study protocol was approved by the ethics committee of the National Institute for Nutrition and Health at the Chinese Center for Disease Control and Prevention.

Data collection

Both surveys included questionnaires, clinical physical examination, and laboratory tests. Household and family information were collected by face-to-face interviewer-administered questionnaires in the household, by trained and qualified investigators. The data collection interviewing, clinical measurements, blood collection procedure, processing, and determination were identical in the two surveys. All study staffs were trained to ensure standardization of data collection and measurements.

Participants went to the study sites for anthropometric measurement in the morning. Body weight, height, and waist circumference were all measured in the fasting state by trained investigators. Barefoot height and fasting weight were measured to an accuracy of 1 mm and 0.1 kg, respectively. The waist circumference was measured to the nearest 0.1 cm at the midpoint between the bottom of the rib cage and the top of the iliac crest at the end of exhalation with bare belly using the skin touch measuring tape customized by CNNHS. Duplicate measurements in subgroups showed high reproducibility for weight, height and waist circumference.[15]

Subjects' seated blood pressure was measured three times,[13] using mercury sphygmomanometer on the right arm after 5 min of rest to the nearest 2 mmHg by uniformly trained staff from the local Centers for Disease Control and Prevention. The mean of the 3 measures was used for analysis. The cuff size was selected on the basis of the upper arm circumference to ensure that the cuff did not overlap. The percentage of agreement between observers for blood pressure measurement difference within 4 mmHg was at least 93%.[11]

Participants were invited for blood collection after approximately 10–14 h overnight fast. The samples were centrifuged at 1500 rpm for 10 min after being left standing for 30 to 60 min. The plasma glucose was measured using spectrophotometer with glucose oxidase kit in the lab of local Center for Disease Control and Prevention (CDC) within 4 hours of blood draw. Reagents were purchased from Beijing Zhongsheng Reagents Company. All local lab took part in the quality control program and passed through the control testing organized by the National Center for Clinical Laboratories. We did the oral glucose tolerance test (OGTT) for a whole study population in 2010–2012, but in 2002, it was required only when fasting plasma glucose was above 5.6 mmol/L. In both surveys, every tenth sample was duplicately measured with a correlation coefficient of 0.98 for fasting glucose duplicate measurements.[15] At the same time, one reference sample, one quality control sample and one blind sample were measured before every thirtieth sample. The quality control for acceptance of measurement range was settled up at 8%; 100% of the control measurements were qualified in CNNHS 2002, which was 98.6% to 99.8% in CNNHS 2010-2012 variated across different strata.

In both surveys, the centrifuged serum samples were transported to the central laboratory of the National Institute for Nutrition and Health and total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C) and triglycerides (TG) were measured by a Hitachi automatic biochemical analyzer (Model 7600) with reagents from Wako Pure Chemical Industries, Ltd. (Tokyo, Japan). Reagents of the same batch were used and purchased from Beijing Zhongsheng Reagents Company.[14] The quality control of lipid measurements included 5% duplicated measurements and reference serum samples measured 2-3 times per day during the period of lipid measurements. The 94.4% of duplicated measurements for triglycerides had a coefficient of variation less than 3%, which was 98.3% for HDL-C measurements.[14] The Lipids Standardization Program (LSP) of U.S. Center for Disease Control and Prevention (US CDC) also monitored the accuracy of the laboratory of China CDC over time for external quality control and the deviation precision was settle up at 10% and the observed relative differences ranged from -7.02% to 1.6% for TG and -1.05% to 4.21% for HDL-C measurements between China CDC and US CDC (https://www.cdc.gov/labstandards/lsp.html).[16]

Criteria for metabolic syndrome

We report the prevalence of metabolic syndrome, using the Chinese criteria defined by the China Diabetes Society (CDS).[17] According to the CDS criteria, participants having three or more of the following conditions were defined as having metabolic syndrome: abdominal obesity (waist circumference ≥90 cm in men and ≥85 cm in women); high TG (≥1.7 mmol/L); low HDL-C (HDL-C <1.04 mmol/L); elevated blood pressure (systolic blood pressure [SBP] ≥130 mmHg or diastolic blood pressure [DBP] ≥85 mmHg or under anti-hypertensive drug treatment in a patient with a history of elevated blood pressure); or hyperglycemia (fasting plasma glucose ≥6.1 mmol/L or two-hour glucose level after OGTT ≥7.8 mmol/L or using medications for elevated glucose). To be comparable with other studies, we also applied the definitions of MetS from the International Diabetes Federation (IDF),[18] the original National Cholesterol Education Program Adult Treatment Panel III criteria,[19] and the IDF/National Heart, Lung and Blood Institute/American Heart Association (IDF/NHLBI/AHA) jointly revised Adult Treatment Panel (ATP) III.[20]

Statistical analysis

Both surveys were designed to provide accurate estimates of the prevalence of chronic diseases according to sex, age, and level of economic development in Chinese population. Sample sizes were also estimated to meet recommended requirements for precision in a complex survey design.

In both surveys, the sample was not always selected with equal probability in order to expand the chance of availability for certain areas or subgroups. For this reason, the statistical samplers recorded the sample weight data and applied sample weights in the national estimations. Sampling weights were developed in two steps named basic sampling weight and post-stratification weight. The basic sampling weight were calculated based on the sampling proportion at different sampling strata, including study site, committee/villages, and households. Using the National Population Census data, post-stratification weight was developed basing on the national population distribution by living area, age and sex. The final sample weight was the product of the basic sampling weight and post-stratification weight. For the MetS estimations in our study, when the statisticians calculated the weights because of sample design, they also corrected the response rates for MetS measurements. In brief, the initial sample weight of each participant was produced by the CNNHS sampler using the sample selection probability and the response rate of each individual. We applied the SAS Survey packages to estimate the weighted prevalence of MetS and its individual abnormalities account for the complex design effect and taking into account the unequal sample weights. The estimates of the prevalence of MetS were calculated for the overall population and for subgroups according to age, sex, and economic levels. Estimated population living with MetS and its individual metabolic abnormalities in 2002 and 2010–2012 were estimated with the multiple of the weighted prevalence of total adult population in 2000 and 2010, respectively, as released by the 2000 and 2010 China Population Census of the People's Republic of China.

Statistical analyses were performed using the survey procedures in SAS software. The statistical significance of the change in prevalence of MetS between the two surveys was examined by Surveylogistic models in considering the sample weight (Surveyreg models were applied for the continuous variates). All statistical analyses were conducted with the use of SAS software, version 9.4 (SAS Institute, Cary, NC).

RESULTS

A total of 48,235 and 104,098 participants from CNNHS 2002 and CNNHS 2010–2012, respectively, aged 18 years or older were included in our study. The average age, body mass index (BMI), waist circumference, TG, low HDL-C, blood pressure, and fasting blood glucose are shown in Table 1. The age and living area–adjusted means of BMI, waist circumference, TG, blood pressure, and fasting blood glucose were significantly higher in 2010–2012 than in 2002, whereas the low HDL-C level was significantly lower in 2010–2012 than in 2002.

The overall prevalence of MetS (≥3 individual metabolic abnormalities) in the Chinese adults has increased from 9.5% (9.2%–9.7%) in 2002 to 18.7% (18.3%–19.1%) in 2010–2012, with a relative change of 96.8% and an absolute increase of 9.2% from 2002 to 2010–2012 (Table 2).

The overall adult population, as released by China Population Census, was 880 million in 2000 and 1.01 billion in 2010; the estimated adults living with MetS was 83.6 million in 2002 and 189 million in 2010–2012. The prevalence of MetS was higher in men (11.1%) than in

Table 1. Characteristics of the study population

	Total	Men	Women
2002			
N	48,235	22,722	25,513
Age (year)	45.5±14.5	45.8±14.8	45.2±14.2
BMI (kg/m^2)	23.1±0.02	23.0±0.03	23.1±0.03
SBP (mmHg)	121±0.10	122±0.13	120±0.15
DBP (mmHg)	77.7±0.06	79.2±0.08	76.1±0.08
Waist circumference (cm)	78.0±0.06	80.1±0.08	75.7±0.07
Fasting blood glucose (mg/dL)	4.94±0.01	4.95±0.01	4.93±0.01
TG (mg/dL)	1.15±0.00	1.21±0.01	1.10±0.00
HDL-C (mg/dL)	1.29±0.00	1.25±0.00	1.33±0.00
2010-2012			
N	104,098	44,500	59,598
Age (year)	52.0±14.4	52.9±14.5	51.4±14.2
BMI (kg/m^2)	23.6±0.02	23.6±0.04*	23.5±0.03
SBP (mmHg)	122±0.10	123±0.15*	120±0.14*
DBP (mmHg)	77.4±0.06	78.9±0.10*	75.8±0.08*
Waist circumference (cm)	80.7±0.06	82.8±0.10*	78.6±0.08*
Fasting blood glucose (mg/dL)	5.27±0.01	5.29±0.01*	5.25±0.01*
TG (mg/dL)	1.38±0.01	1.51±0.01*	1.25±0.01*
HDL-C (mg/dL)	1.20±0.00	1.15±0.00*	1.25±0.00*

BMI: Body mass index; SBP: Systolic blood pressure; DBP: diastolic blood pressure; HDL-C: high-density lipoprotein cholesterol; TG: triglycerides
*Statistically significant between 2002 and 2010–2012 after adjustment by age and living area, $p<0.05$.

women (7.8%) in 2002; this gender difference increased in 2010–2012 (men 21.7% and women 15.6%) with a greater absolute increase in men than in women from 2002 to 2010–2012 (Table 2). More than double (>100%) the prevalence, comparing 2010–2012 to 2002, was observed among younger adults aged 18–49 years, the elder population aged above 80 years, residents living in rural areas, and adults in the lowest income level (Table 2). The remarkable increase from 2002 to 2010–2012 was observed for all age groups (Figure 2), all individual metabolic abnormalities (Figure 3A), and all clusters of individual components (Figure 3B). The overall prevalence of clustered individual metabolic abnormalities ≥1, ≥2, ≥4, and 5 was 55.4%, 24.4%, 2.7%, and 0.4%, respectively, in 2002 and 67.1%, 38.0%, 7.3%, and 1.6%, respectively, in 2010–2012 (Figure 4). The weighted prevalence of MetS and its individual abnormalities were much higher among overweight than normal weight participants (Table 2-3). Prevalence of MetS in CNNHS 2010-2012 was no more than 4% when BMI being less than 22 kg/m^2 and 9.9% for adults with BMI of 22-23.9 kg/m^2, which increased rapidly with around 10% per 2 unit of BMI, reached 59.5% for obese adults (Figure 5).

In a comparison of the prevalence of individual metabolic abnormalities between 2002 and 2010–2012, the prevalence of abdominal obesity increased from 18.9% to 25.8%; hyperglycemia increased from 6.4% to 16.2%; high TG increased from 13.8% to 23.7%; low HDL-C increased from 19.3% to 32.6%; and elevated blood pressure increased from 34.0% to 34.4% (Table 3). The prevalence of low HDL-C, high TG and hyperglycemia showed remarkable increases from 2002 to 2010–2012 in the whole population, whereas the prevalence of abdominal obesity showed remarkable changes, mainly among young adults, with relatively stable prevalent of elevated blood pressure (Table 3). In 2002, the estimated numbers of Chinese adults with abdominal obesity, hyperglycemia, high TG, low HDL-C, and elevated blood pressure were 190.3, 64.7, 139.6, 194.6, and 343.0 million, respectively; in 2010-2012, they were 259.8, 162.9, 239.4, 328.6, and 347.3 million, respectively (Figure 6). Among the patients with MetS, the most common com-

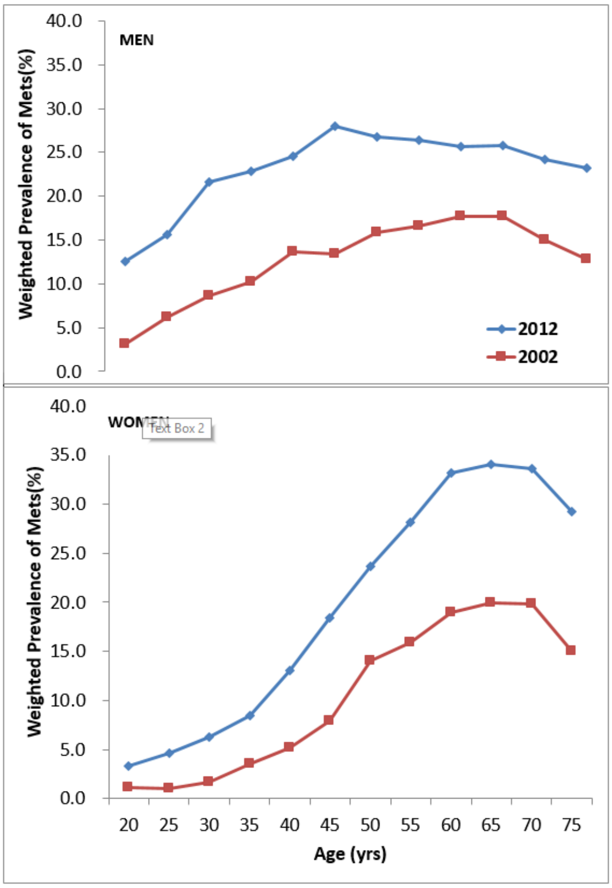

Figure 2. Prevalence of metabolic syndrome in 2002 and 2010-2012 by age groups.

Table 2. Weighted prevalence (%) of metabolic syndrome among Chinese adults aged ≥18 years based on CNNHS 2002 and CNNHS 2010–2012

	N		MetS			
	2002	2010–2012	2002†	2010–2012‡	Relative change (%)§	Absolute difference (%)¶
Total	48,235	104,098	9.5 (9.2, 9.7)	18.7 (18.3, 19.1)*	96.8	9.2
Sex						
Male	22,722	44,500	11.1 (10.6, 11.5)	21.7 (21.0, 22.4)*	95.5	10.6
Female	25,513	59,598	7.8 (7.4, 8.1)	15.6 (15.2, 16.0)*	100.0	7.8
Age (year)						
18-	6898	8065	2.5 (2.1, 2.9)	8.4 (7.4, 9.3)*	236.0	5.9
30-	11,785	13,738	6.2 (5.7, 6.7)	15.0 (14.1, 16.0)*	141.9	8.8
40-	10,976	24,225	10.0 (9.4, 10.7)	20.9 (20.1, 21.6)*	109.0	10.9
50-	9548	25,931	15.6 (14.8, 16.4)	26.2 (25.4, 27.0)*	67.9	10.6
60-	6165	20,542	18.5 (17.5, 19.5)	29.6 (28.7, 30.5)*	60.0	11.1
70-	2470	9788	16.6 (15.0, 18.1)	28.3 (27.0, 29.6)*	70.5	11.7
80-	393	1809	11.7 (8.4, 14.9)	25.2 (22.3, 28.1)*	115.4	13.5
Area						
Urban	16,624	52,858	12.1 (11.6, 12.6)	20.8 (20.1, 21.4)*	71.9	8.7
Rural	31,611	51,240	6.8 (6.5, 7.1)	16.6 (16.1, 17.1)*	144.1	9.8
Family income level (household annual income per capita, Yuan)						
<5000	34,320	26,467	7.9 (7.6, 8.2)	17.6 (16.9, 18.3)*	122.8	9.7
5000-	8312	24,553	12.7 (11.9, 13.4)	17.8 (17.0, 18.6)*	40.2	5.1
10000-	3718	19,346	12.9 (11.8, 14.0)	18.4 (17.5, 19.4)*	42.6	5.5
15000-		10,336		20.5 (19.0, 22.0)		
20000-	958	7330	10.5 (8.5, 12.4)	21.2 (19.6, 22.8)*	101.9	10.7
25000-		10,012		19.7 (18.4, 21.0)		
Ethnic groups						
Han	43,445	94,192	9.9 (9.6, 10.2)	19.1 (18.7, 19.5)*	92.9	9.2
Mongolian	421	1256	9.6 (6.3, 12.8)	17.9 (14.8, 20.9)*	86.4	8.3
Hui	485	1189	8.8 (6.0, 11.6)	18.1 (14.9, 21.4)*	105.7	9.3
Tibetan	307	1505	4.5 (2.3, 6.7)	7.7 (5.8, 9.5)	71.1	3.2
Miao	560	1102	2.4 (1.0, 3.8)	7.5 (5.9, 9.2)*	212.5	5.1
Others	3017	4854	4.3 (3.5, 5.1)	13.1 (11.3, 14.9)*	204.7	8.8
BMI (kg/m^2)						
<25	35,107	67,423	2.7 (2.5, 2.9)	7.2 (6.9, 7.5)*	166.7	4.5
≥25	48,235	36,675	27.7 (26.8, 28.5)	42.9 (41.9, 43.8)*	54.9	15.2

†Weighted prevalence (%) of metabolic syndrome in 2002 (P2).
‡Weighted prevalence (%) of metabolic syndrome in 2012 (P1).
§The relative change = $(P_1\text{-}P_2)/P_2$
¶The absolute difference percentages=$P_1\text{-}P_2$
*p<0.05, comparing 2002 with 2010–2012 after adjustment of sex, age, living area, socioeconomic status and ethnicity, where appropriate.

Table 3. Weighted prevalence (%) of individual metabolic abnormalities of metabolic syndrome among Chinese adults aged ≥18 years: CNNHS 2002 and CNNHS 2010–2012 (CDS criteria)

	CNNHS 2002					CNNHS 2010–2012				
	Abdominal obesity	Hyperglycemia	High TG	Low HDL-C	Elevated blood pressure	Abdominal obesity	Hyperglycemia	High TG	Low HDL-C	Elevated blood pressure
Total	18.9 (18.5, 19.3)	6.4 (6.2, 6.7)	13.8 (13.5, 14.2)	19.3 (18.9, 19.7)	34.0 (33.5, 34.5)	25.8 (25.3, 26.2)*	16.2 (15.8, 16.5)*	23.7 (23.3, 24.2)*	32.6 (32.0, 33.1)*	34.4 (33.9, 34.9)*
Sex										
Male	19.3 (18.7, 19.8)	6.5 (6.1, 6.8)	16.2 (15.6, 16.7)	23.7 (23.1, 24.3)	36.8 (36.1, 37.5)	26.0 (25.3, 26.8)*	16.8 (16.2, 17.4)*	28.3 (27.5, 29.1)*	39.4 (38.5, 40.3)*	37.7 (36.9, 38.5)
Female	18.5 (18.0, 19.0)	6.3 (6.0, 6.7)	11.5 (11.0, 11.9)	14.7 (14.2, 15.2)	31.1 (30.5, 31.7)	25.5 (24.9, 26.1)*	15.5 (15.1, 16.0)*	19.0 (18.5, 19.5)*	25.5 (24.9, 26.1)*	31.1 (30.5, 31.7)*
Age (year)										
18-	7.2 (6.5, 7.9)	1.6 (1.3, 1.9)	7.9 (7.2, 8.6)	19.8 (18.8, 20.8)	11.6 (10.8, 12.5)	16.2 (15.0, 17.5)*	7.1 (6.3, 7.9)*	16.0 (14.7, 17.3)*	32.9 (31.3, 34.6)*	12.6 (11.5, 13.8)*
30-	14.6 (13.8, 15.3)	3.0 (2.6, 3.4)	13.2 (12.5, 13.9)	19.7 (18.9, 20.5)	20.2 (19.4, 21.0)	23.1 (22.0, 24.1)*	10.0 (9.3, 10.7)*	23.8 (22.7, 24.9)*	33.6 (32.4, 34.7)*	20.2 (19.2, 21.2)
40-	21.0 (20.2, 21.9)	5.9 (5.4, 6.4)	16.1 (15.3, 16.8)	19.3 (18.5, 20.2)	34.5 (33.5, 35.4)	28.6 (27.8, 29.4)*	15.8 (15.2, 16.5)*	27.4 (26.6, 28.3)*	33.8 (33.0, 34.7)*	35.7 (34.8, 36.5)
50-	28.3 (27.3, 29.3)	11.3 (10.6, 12.0)	18.5 (17.6, 19.4)	19.0 (18.2, 19.9)	51.0 (49.9, 52.1)	33.2 (32.3, 34.0)*	23.3 (22.5, 24.0)*	29.4 (28.6, 30.2)*	31.8 (31.0, 32.6)*	51.4 (50.5, 52.3)
60-	31.5 (30.3, 32.7)	14.1 (13.3, 15.0)	17.5 (16.5, 18.4)	18.7 (17.7, 19.7)	64.6 (63.4, 65.8)	34.0 (33.1, 35.0)*	29.3 (28.3, 30.2)*	27.3 (26.4, 28.2)*	31.0 (30.1, 31.9)*	63.4 (62.4, 64.4)
70-	28.5 (26.7, 30.4)	14.2 (12.7, 15.6)	14.5 (13.0, 16.0)	18.2 (16.6, 19.8)	73.4 (71.5, 75.2)	31.0 (29.6, 32.3)*	33.2 (31.8, 34.6)*	22.7 (21.5, 23.9)*	29.3 (28.0, 30.5)*	72.5 (71.2, 73.8)
80-	24.3 (20.0, 28.6)	10.8 (7.6, 13.9)	12.7 (9.3, 16.2)	14.1 (10.6, 17.5)	74.4 (70.0, 78.8)	29.5 (26.4, 32.7)*	37.1 (33.6, 40.6)*	18.4 (15.8, 21.0)	25.2 (22.3, 28.1)*	75.2 (72.4, 78.0)
Area										
Urban	24.2 (23.5, 24.8)	8.8 (8.4, 9.2)	15.6 (15.0, 16.1)	18.8 (18.2, 19.5)	35.8 (35.0, 36.5)	27.9 (27.2, 28.6)*	16.5 (16.0, 17.0)*	25.6 (24.9, 26.4)*	32.8 (32.0, 33.6)*	36.3 (35.6, 37.1)*
Rural	13.5 (13.1, 13.9)	4.0 (3.8, 4.2)	12.1 (11.7, 12.5)	19.8 (19.3, 20.3)	32.2 (31.7, 32.8)	23.6 (23.0, 24.2)*	15.8 (15.3, 16.3)*	21.8 (21.2, 22.4)*	32.3 (31.6, 33.1)*	32.5 (31.8, 33.2)

HDL-C:high-density lipoprotein cholesterol ;TG: triglycerides

* $p<0.05$, comparing 2002 with 2010–2012 after adjustment after adjustment of sex, age, living area, socioeconomic status and ethnicity, where appropriate.

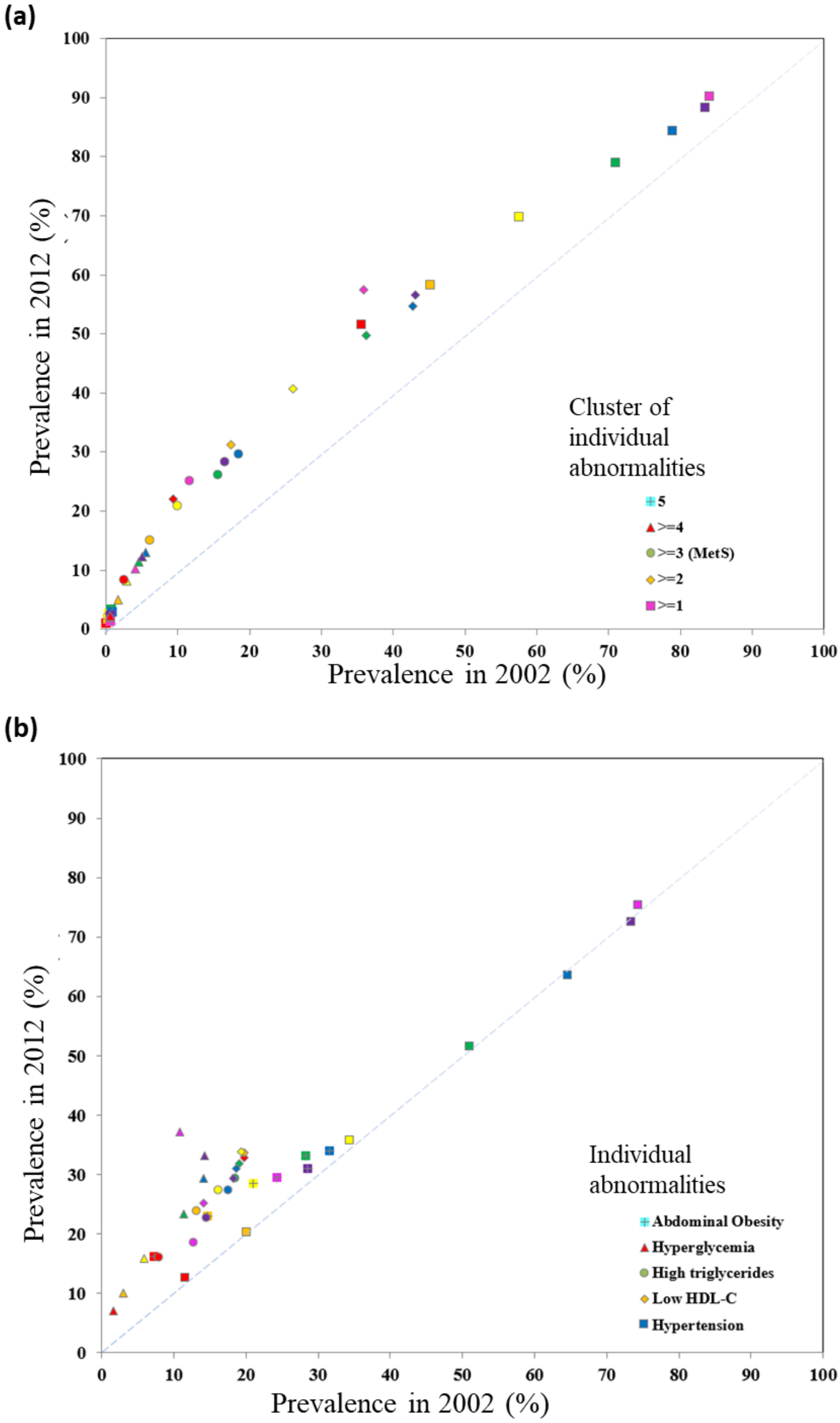

Figure 3. Prevalence of metabolic syndrome in 2002 and 2010-2012 by age groups.

ponents were elevated blood pressure, followed by abdominal obesity and high TG in 2002. In 2010–2012, the most common components were low HDL-C, followed by abdominal obesity and elevated blood pressure (Table 4).

The prevalence of MetS was lowest when based on the original ATP III criteria, followed by the CDS definition and IDF criteria, and highest when defined with the IDF/NHLBI/AHA joint revised ATP III definition (Table 5).

DISCUSSION

Based on two nationally representative databases, we observed a rapid increase in the prevalence of MetS, irrespective of the definitions used for both men and women and in all age groups. More than one in six adults, corresponding to an estimated 189 million Chinese adults in 2010–2012, was estimated to have MetS according to CDS criteria, which doubled the estimations of 10 years before. The increasing trend is observed all over the country, in both urban and rural, no matter poor or rich

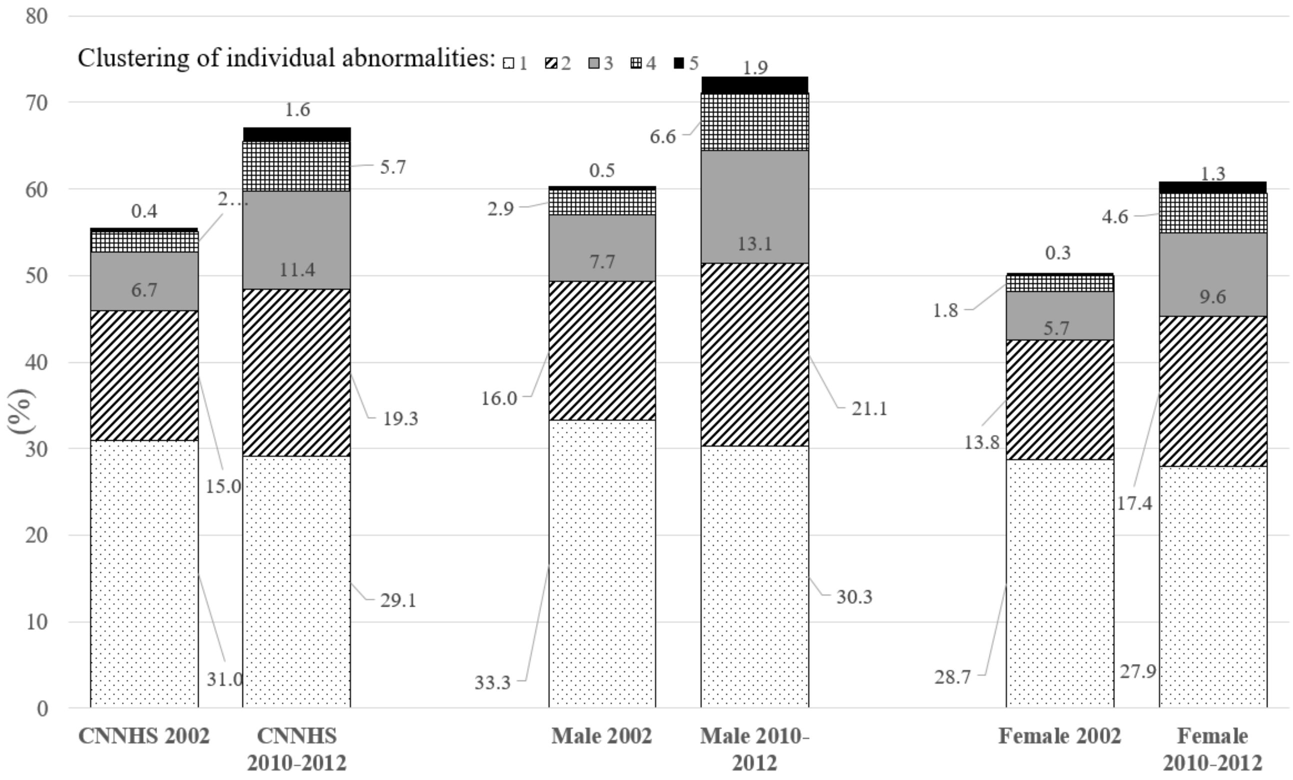

Figure 4. Clustering of metabolic abnormalities in 2002 and 2010–2012 among Chinese adults aged ≥18 years: CNNHS 2002 and CNNHS 2010–2012 (CDS criteria), % clusters mean the number of metabolic abnormalities.

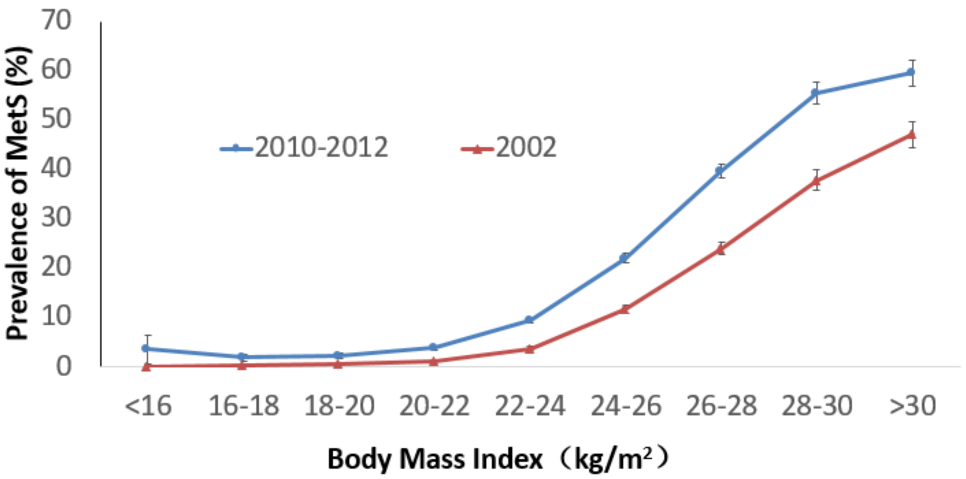

Figure 5. Weighted prevalence (%) of metabolic syndrome (MetS) across BMI among Chinese adults aged ≥18 years based on data of CNNHS2002 and CNNHS 2010–2012 applying CDS criteria.

and also among some ethnic minority groups, with a relatively larger changes were observed among young, low-income, and rural residents. The rapid increases from 2002 to 2010–2012 were observed in the prevalence of hyperglycemia, low HDL-C, high TG, and abdominal obesity among young adults, with relatively stable prevalent of elevated blood pressure. As the first national time trend estimation of this cluster of metabolic disorders, our findings would be important for health policy and disease prevention in China, where the awareness, treatment, and control rates were very low for diabetes,[21] elevated blood pressure,[11] and dyslipidemia.[22]

Comparison to previous studies in China A rapid increase in the prevalence of diabetes was reported in several previous national or regional studies, from 0.9% in 1980,[23] to 2.5% in 1994,[24] 2.6% in 2002,[25] to 9.7% in 2007,[26] to 11.5% in 2010,[26] and to 10.9% in 2013.10 Meanwhile, prevalence of clinical hypertension that applying a more strict criteria increased from 5.1% in 1959[27] to 7.7% in 1979,[28] to 13.6% in 1991,[28] to 17.7% in 2002,[11] and to 22.8% in 2010;[29] the prevalence of low HDL-C increased from 19.2% in 2000–2001[30] to 22.3% in 2007–2008.[21] The magnitude of increasing in prevalent of high blood pressure in much lower than other four individual abnormalities, that might because of the reason for high blood pressure in China not only resulted from the Western lifestyles, but also resulted from the high sodium intakes among Chinese population, especially in poor rural areas; so the prevalence of high blood pressure was already quite high in 2002. From the other side,

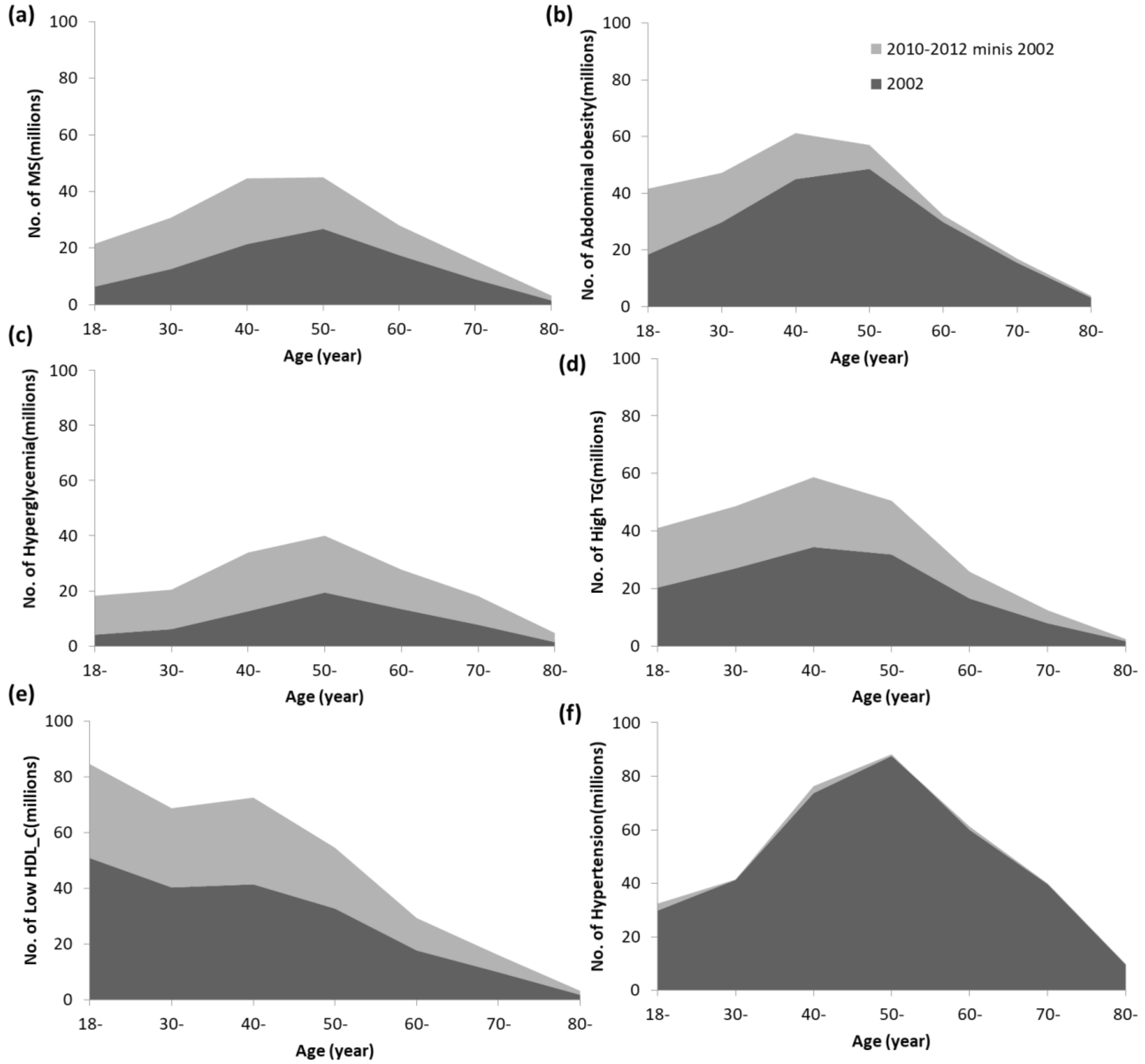

Figure 6. Number of Chinese adults with metabolic syndrome and individual metabolic abnormalities in 2002 and 2010–2012 (a: metabolic syndrome; b: abdominal obesity; c: hyperglycemia; d: high triglyceride; e: low HDL-C; f: elevated blood pressure).

Table 4. Prevalence (%) of individual metabolic abnormalities among patients of metabolic syndrome (MetS) based on data of CNNHS 2002 and CNNHS 2010–2012

Year	Total	Men	Women
2002			
Abdominal obesity	81.6 (80.4, 82.8)	80.5 (78.8, 82.2)	83.2 (81.5, 84.9)
Hyperglycemia	37.6 (36.1, 39.2)	33.6 (31.6, 35.7)	43.5 (41.3, 45.8)
High TG	66.2 (64.7, 67.7)	67.5 (65.5, 69.5)	64.2 (62.0, 66.4)
Low HDL-C	61.2 (59.7, 62.8)	68.4 (66.4, 70.4)	50.7 (48.4, 53.0)
Elevated blood pressure	86.4 (85.2, 87.5)	84.8 (83.2, 86.4)	88.6 (87.1, 90.1)
2010-2012			
Abdominal obesity	75.5 (74.5, 76.5)	74.7 (73.2, 76.1)	76.6 (75.4, 77.8)
Hyperglycemia	45.9 (44.8, 47.0)	42.4 (40.8, 44.0)	51.0 (49.6, 52.4)
High TG	74.6 (73.7, 75.6)	76.6 (75.3, 77.9)	71.8 (70.6, 73.0)
Low HDL-C	76.5 (75.6, 77.4)	81.3 (80.1, 82.6)	69.6 (68.4, 70.9)
Elevated blood pressure	75.2 (74.2, 76.3)	73.5 (71.9, 75.0)	77.8 (76.5, 79.1)

though the prevalence of high blood pressure did not increased a lot from 2002 to 2012, the prevalence of clinical hypertension did still increasing from 17.7% in 2002,[11] and to 22.8% in 2010.[29]

At the same time, the BMI of Chinese adults increased from 21.7 kg/m^2 in 1991 to 23.5 kg/m^2 in 2011 in parallel with declining average physical activity level from 379 MET-hours/week in 1991 to 190.3 MET-hours/week in 2011, and increasing consumption of red meat, processed meat, and sugar-sweetened beverages of the adopted Westernizing dietary pattern.[31] Total energy intake decreased substantially from 2,783 kcal/day in 1982 survey

Table 5. Weighted prevalence (%) of metabolic syndrome (MetS) and individual metabolic abnormalities among Chinese adults aged ≥18 years based on data of CNNHS 2002 and CNNHS 2010–2012 applying IDF, ATP III, and CDS criteria

		MetS	Abdominal obesity	Hyperglycemia	High TG	Low HDL-C	Elevated blood pressure
	Criteria for MetS	Original ATP III criteria:[16] ≥ 3 individual metabolic abnormalities					
	Criteria for individual component		>102 cm (Male) >88 cm (Female)	FPG ≥6.1 mmol/L or previously diagnosed type II diabetes	≥1.7 mmol/L	<1.04 mmol/L(male) <1.29 mmol/L(Female)	≥130/85 or treatment of previously diagnosed elevated blood pressure
2002	Total	8.3 (8.0, 8.6)	7.4 (7.1, 7.6)	6.1 (5.9, 6.4)	13.8 (13.5, 14.2)	35.7 (35.2, 36.2)	34.0 (33.5, 34.5)
	Men	6.2 (5.9, 6.6)	2.6 (2.4, 2.9)	6.3 (5.9, 6.6)	16.2 (15.6, 16.7)	23.7 (23.1, 24.3)	36.8 (36.1, 37.5)
	Women	10.4 (10.0, 10.8)	12.3 (11.8, 12.7)	6.0 (5.7, 6.3)	11.5 (11.0, 11.9)	48.1 (47.4, 48.8)	31.1 (30.5, 31.7)
2010-2012	Total	15.4 (15.0, 15.7)	10.4 (10.1, 10.7)	12.0 (11.7, 12.3)	23.7 (23.3, 24.2)	49.3 (48.7, 49.9)	34.4 (33.9, 34.9)
	Men	13.4 (12.9, 13.9)	4.0 (3.7, 4.4)	12.8 (12.3, 13.3)	28.3 (27.5, 29.1)	39.4 (38.5, 40.3)	37.7 (36.9, 38.5)
	Women	17.4 (17.0, 17.9)	17.0 (16.5, 17.4)	11.3 (10.9, 11.7)	19.0 (18.5, 19.5)	59.5 (58.8, 60.2)	31.1 (30.5, 31.7)
	Criteria for MetS	IDF (2005)[15] Abdominal obesity plus two or more metabolic abnormalities					
	Criteria for individual component		≥90 cm (Male) ≥80 cm (Female)	FPG ≥5.6 mmol/L or previously diagnosed type II diabetes	≥1.7 mmol/L or specific treatment for this lipid abnormality	<1.04 mmol/L (Male) <1.29 mmol/L (Female) or specific treatment for this lipid abnormality	≥130/85 or treatment of previously diagnosed elevated blood pressure
2002	Total	12.1 (11.8, 12.4)	25.2 (24.8, 25.6)	9.7 (9.4, 10.0)	13.8 (13.5, 14.2)	35.7 (35.2, 36.2)	34.0 (33.5, 34.5)
	Men	9.5 (9.1, 9.9)	19.3 (18.7, 19.8)	10.2 (9.8, 10.6)	16.2 (15.6, 16.7)	23.7 (23.1, 24.3)	36.8 (36.1, 37.5)
	Women	14.8 (14.3, 15.3)	31.3 (30.7, 32.0)	9.2 (8.8, 9.6)	11.5 (11.0, 11.9)	48.1 (47.4, 48.8)	31.1 (30.5, 31.7)
2010-2012	Total	20.7 (20.3, 21.1)	34.4 (33.9, 35.0)	25.5 (25.0, 26.0)	23.7 (23.3, 24.2)	49.3 (48.7, 49.9)	34.4 (33.9, 34.9)
	Men	17.1 (16.5, 17.7)	26.0 (25.3, 26.8)	27.0 (26.3, 27.7)	28.3 (27.5, 29.1)	39.4 (38.5, 40.3)	37.7 (36.9, 38.5)
	Women	24.4 (23.8, 24.9)	43.1 (42.4, 43.9)	23.9 (23.4, 24.5)	19.0 (18.5, 19.5)	59.5 (58.8, 60.2)	31.1 (30.5, 31.7)
	Criteria for MetS	IDF/NHLBI/AHA joint revised ATP III criteria:[17] ≥3 individual metabolic abnormalities					
	Criteria for individual component		≥90 cm (Male) ≥80 cm (Female)	FPG ≥5.6 mmol/L or previously diagnosed type II diabetes	≥1.7 mmol/L or specific treatment for this lipid abnormality	<1.04 mmol/L (Male) <1.29 mmol/L (Female) or specific treatment for this lipid abnormality	≥130/85 or treatment of previously diagnosed elevated blood pressure
2002	Total	14.3 (14.0, 14.6)	25.2 (24.8, 25.6)	9.7 (9.4, 10.0)	13.8 (13.5, 14.2)	35.7 (35.2, 36.2)	34.0 (33.5, 34.5)
	Men	12.1 (11.6, 12.6)	19.3 (18.7, 19.8)	10.2 (9.8, 10.6)	16.2 (15.6, 16.7)	23.7 (23.1, 24.3)	36.8 (36.1, 37.5)
	Women	16.5 (16.0, 17.0)	31.3 (30.7, 32.0)	9.2 (8.8, 9.6)	11.5 (11.0, 11.9)	48.1 (47.4, 48.8)	31.1 (30.5, 31.7)
2010-2012	Total	25.9 (25.5, 26.4)	34.4 (33.9, 35.0)	25.5 (25.0, 26.0)	23.7 (23.3, 24.2)	49.3 (48.7, 49.9)	34.4 (33.9, 34.9)
	Men	24.0 (23.2, 24.7)	26.0 (25.3, 26.8)	27.0 (26.3, 27.7)	28.3 (27.5, 29.1)	39.4 (38.5, 40.3)	37.7 (36.9, 38.5)
	Women	27.9 (27.4, 28.5)	43.1 (42.4, 43.9)	23.9 (23.4, 24.5)	19.0 (18.5, 19.5)	59.5 (58.8, 60.2)	31.1 (30.5, 31.7)
	Criteria for MetS	CDS criteria (2013):[14] ≥ 3 individual metabolic abnormalities					
	Criteria for individual component		≥90 cm (Male) ≥85 cm (Female)	FPG ≥6.1 mmol/L or OGTT ≥7.8mmol/L or previously diagnosed type II diabetes	≥1.7 mmol/L	<1.04 mmol/L	≥130/85 or treatment of previously diagnosed elevated blood pressure
2002	Total	9.5 (9.2, 9.7)	18.9 (18.5, 19.3)	6.4 (6.2, 6.7)	13.8 (13.5, 14.2)	19.3 (18.9, 19.7)	34.0 (33.5, 34.5)
	Men	11.1 (10.6, 11.5)	19.3 (18.7, 19.8)	6.5 (6.1, 6.8)	16.2 (15.6, 16.7)	23.7 (23.1, 24.3)	36.8 (36.1, 37.5)
	Women	7.8 (7.4, 8.1)	18.5 (18.0, 19.0)	6.3 (6.0, 6.7)	11.5 (11.0, 11.9)	14.7 (14.2, 15.2)	31.1 (30.5, 31.7)
2010-2012	Total	18.7 (18.3, 19.1)	25.8 (25.3, 26.2)	16.2 (15.8, 16.5)	23.7 (23.3, 24.2)	32.6 (32.0, 33.1)	34.4 (33.9, 34.9)
	Men	21.7 (21.0, 22.4)	26.0 (25.3, 26.8)	16.8 (16.2, 17.4)	28.3 (27.5, 29.1)	39.4 (38.5, 40.3)	37.7 (36.9, 38.5)
	Women	15.6 (15.2, 16.0)	25.5 (24.9, 26.1)	15.5 (15.1, 16.0)	19.0 (18.5, 19.5)	25.5 (24.9, 26.1)	31.1 (30.5, 31.7)

MetS: metabolic syndrome; IDF: International Diabetes Federation; ATPIII: Adult Treatment Panel; CDS: China Diabetes Society.

to 2,064 kcal/day in 2010-2012 survey to 2012, largely reflecting a dramatic decrease in physical activity levels accompanied by rapid urbanization.[32] Although a slightly decreasing prevalence of smoking and sodium consumption, and increasing fruit, fiber, and seafood intakes had been previously reported, the current levels of these factors remain below optimal levels,[31,33] so it is not surprising to observe the increasing trend toward metabolic syndrome, the cluster of those metabolic abnormalities as a result of those lifestyle transitions. The magnitude of increment in prevalence of elevated blood pressure was relatively lower as compared to other MetS abnormalities, which might because the prevalence of elevated blood pressure was already high in 2002. Besides the Westernizing diet and sedentary activities that always associated with the MetS abnormalities, another major cause of elevated blood pressure was high consumption of sodium, especially among poor rural area where salted foods were popular. So the increasing of elevated blood pressure exceeded the increasing of other MetS abnormalities and had been more than one third of the Chinese adults at 2002. Even though, we still observed a significantly increasing trend of the overall prevalent elevated blood pressure from 2002 to 2010-2012, especially among young and very low income population, which was consistent with our previous observation.[33]

What really triggers alarm is the increment of MetS more than doubling among young, rural residents and people from poor households. Our previous study observed a similar pattern of more rapid increments of BMI and blood pressure among young and poor residents.[33] In 2002, the MetS was lower in rural areas and among poor resident, as rural residents had higher energy expenditure than urban resident and lower incomes in rural areas had less consumption of unhealthy foods, such as red and processed meat.[34] With the rapid economic development in last decade in China, the physical activity level decreased rapidly in rural China and more and more foods are affordable to poor residents,[33] the urban-rural difference and difference across economic groups narrowed with a rapidly increase in rural poor residents. The early onset of these symptoms means a higher lifespan burden from its related disease risks, including cardiovascular disease, type 2 diabetes, and cancer.[2-5] The chronic diseases are the most costly and will impose a heavy financial burden on patients. The situation will be even worse for rural residents with low income, because poor households have catastrophic health expenses twice as often as wealthier households.[35]

Comparing different definitions

The criteria were all in agreement on the definitions of elevated blood pressure and high TG but varied somewhat in specific cut-off points for central obesity, low HDL-C, and hyperglycemia. The CDS (2013) and ATP III definitions gave equal weight to the five components, including abdominal obesity, elevated blood pressure, hyperglycemia, high TG, and low HDL-C, but IDF required abdominal obesity as an essential criterion.[18] Compared to the original ATP III criteria, the CDS criteria set up stricter criteria for low HDL-C but lower cut-off points for central obesity. When compared to the IDF/NHBLI/AHA joint revised ATP III criteria, the CDS criteria have relatively strict criteria for hyperglycemia.

Applying the same standards as IDF/NHLBI/AHA joint revised ATPIII criteria, a recent national survey of chronic diseases in China reported an estimation of MetS of 33.9% (Male 31.0%; female 36.8%);[9] applying the same criteria, our estimation was 25.9% (Male 24.0%, female 27.9%). The prevalence of abdominal obesity was 32.7% in 2010 CNDS compared to 34.4% in our study (2010-2012 CNNHS); hyperglycemia: 37.3% vs. 25.5%; high TG: 20.9% vs. 23.7%; low HDL-C: 60.6% vs. 49.3%; and elevated blood pressure: 49.9% vs. 34.4%. The replacement of sample might be one reason; as only one family member from each household was invited for the survey in their study,[9] when the selected member refused, then another family member would be randomly selected until one family member accepted the invitation; if no one from the family agreed to participate, then a new household would replace it. Replacement in the sampling procedure might result in the loss of representativeness of the target population[36] and the intent to treat effect that sicker people might more likely to attend the free physical examination, which might be the reason for CNDS had a higher prevalence of elevated blood pressure, hyperglycemia, and low HDL-C as well as overall MetS. Other potential reasons include the differences in measurements of blood pressure and lipid. CNNHS used mercury sphygmomanometer, which will result in a lower elevated blood pressure rate as compared with the electronic sphygmomanometer,[29] the latter was used in the other study.[9] CNDS also reported a much lower HDL level with a 60.6% of low HDL-C in 2010, which was much higher than our estimation, and even higher than the results from The China National Diabetes and Metabolic Disorders Study,[22] the latter is close to our estimations. Though we could not totally rule out the possibility that our estimation of the MetS prevalence in China is under estimated, if it is true, the situation of potential disease and economic burdens will be even worse.

Among all those criteria, only CDS applied a uniform cutoff point of HDL for both male and female, by considering that there is minimum gender difference of HDL-C among Chinese population as compared to other countries.[37] However, despite these differences, there is an agreement between the previous and present findings that all highlighted the importance of the clustering of those metabolic abnormalities with an estimation of MetS ranging from 15.4% to 33.9%; all estimations are high enough to call for attention in future health reforms.

Compared to other countries Among young adults aged 18–29, our estimated prevalence of MetS in China was 8.4% in 2010–2012, which was higher than the estimations in most of the counties included in the recent meta-analysis.[38] Among the whole population, the prevalence of MetS was close to the estimation among Chinese living in Singapore[37] but relatively lower than Asian-Indians,[39] Malays,[39] and Americans.[40] According to the revised ATP III definition, the prevalence of MetS in the United States was 34.7%,[38] which was higher than that reported in our study and in European populations,[41,42] but the relative increases in prevalence for all participants in our study, in both men (116.1%) and women (67.3%), dramatically exceeded the increases among U.S. adults.[3] An increasing trend of MetS prevalence in U.S. adults was reported by comparing the Third National Health and Nutrition Examination Survey (NHANES III) and NHANES 1999–2006 data, which reported increases from 1988–1994 to 1999–2006, and more in women (28.4%) than in men (16.8%).[43] After that, the prevalence of MetS remained stable from 2007 until at least 2010.[40] The dominant individual abnormalities of MetS patients in the United States were abdominal obesity and high TG,[44] whereas the dominant MetS abnormalities in patients in China were low HDL-C and elevated blood pressure besides abdominal obesity. Compared with the average dietary intakes of American adults, Chinese adults reported a much higher intake of sodium and vegetables, but a lower intake of fruit, fish milk, nuts, sugar sweetened beverages, red and processed meat;[45] those difference might partially explain the difference of MetS between Chinese and American adults.

This study had several strengths. All study staff were trained to ensure standardization of data collection. The sample was nationally representative because 31 provinces of China were included. Our study also had limitations that warranted consideration when interpreting our findings. First, we did the OGTT for a whole study population in 2010–2012, but in 2002, it was required only when fasting plasma glucose was above 5.6 mmol/L, which might result in underreporting hyperglycemia in 2002. In China, around 46.6% of the participants with undiagnosed diabetes had isolated increased two-hour plasma glucose levels after an OGTT.[21] Second, so far, we only have two periods of estimation, so it is hard to predict the following trend. However, the increasing trend of MetS is consistent with the time trend of individual metabolic abnormalities[23-29] and the lifestyle transition trends[31-33] observed in previous studies that implied that the prevalence of MetS is likely to continue to increase.

MetS has become more common in China over the past decade, regardless of the set of criteria used to define it. Based on nationally representative data, we found that nearly one in six Chinese adults has metabolic syndrome, almost double the estimations in 10 years, and the increasing trend is dominant in the young population.

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AUTHOR DISCLOSURES

The authors have no competing interests.

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