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Prevalence of and lifestyle factors associated with metabolic syndrome determined using multi-level models in Chinese adults from a cross-sectional survey

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Abstract

People living in the same area are more likely to experience similar socioeconomic characteristics, which leads to cluster effect and influences the generalizability of data regarding metabolic syndrome (MetS). However, previous studies did not consider or adjust for the cluster effect of living circumstances. The aim of this study was to determine the prevalence of MetS and associated lifestyle factors in Chinese adults 18 to 80 years of age, using multi-level generalized estimation equation (GEE).

The participants came from a large-scale cross-sectional population survey. A total of 28,062 participants underwent all the blood tests. Participants meeting at least 3 of the 5 diagnostic criteria were defined as having MetS. Multi-level GEE was used to evaluate the relationship between MetS and lifestyle covariates to control the cluster effect of living circumstances. Odds ratios (ORs) and their 95% confidence intervals (CIs) were used to assess the strength of each relationship.

A total of 65.70% of the participants had at least 1 clinical feature of MetS, and 2926 were diagnosed with MetS (prevalence 14.03%). 32.74%, 18.93%, 10.25%, 3.25%, and 0.53% of the participants had 1, 2, 3, 4, and 5 components, respectively. The prevalence of MetS in men (12.31%) was lower than in women (15.57%). After controlling for the cluster effect of living circumstances, many demographic and lifestyle characteristics were associated with MetS. Overweight (OR = 1.670, 95%CI: 1.600–1.743), obesity (OR = 2.287, 95% CI: 2.136–2.449), current alcohol consumption (OR = 1.053, 95% CI: 1.020–1.086), physical labor (OR=1.070, 95% CI: 1.040–1.101), a high-salt diet (OR=1.040, 95% CI: 1.009–1.071), hyperuricemia (OR=1.264, 95% CI: 1.215–1.316), short sleep duration (OR=1.032, 95% CI: 1.009–1.055), and a family history of cardiovascular disease (OR=1.065, 95% CI: 1.019–1.113), or cerebrovascular disease (OR=1.055, 95% CI: 1.007–1.104) increased the risk of MetS. The risk of MetS increased 6.9% (OR = 1.069, 95% CI: 1.053–1.085) with each 5% increase in body fat percentage.

MetS has become a serious public health challenge in China. Many lifestyle factors have been found to be closely associated with MetS, including obesity, a high-salt diet, alcohol consumption, and short sleep duration. Therefore, changes in lifestyle are very important for adults to reduce the prevalence of MetS.

Abbreviations: BMI = body mass index, CI = confidence interval, DBP = diastolic blood pressure, HDL-C = high density lipoprotein cholesterol, MetS = metabolic syndrome, NCEP ATP III = National Cholesterol Education Program Adult Treatment Panel III, OR = odds ratio, PBF = percentage of body fat, SBP = systolic blood pressure, SD = standard deviation, WGOC = working Group on Obesity in China.

Keywords: body fat percentage, body mass index, metabolic syndrome, sleep duration

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The data are held at the Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences. All relevant data are contained within the paper.

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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1. Introduction

The inhabitants of China and most countries around the world are currently achieving their highest life expectancy in history. As a result of economic growth and the associated sociodemographic changes, the burden of infectious disease has diminished, but changes in lifestyles have led to a greater burden of cardiovascular disease, diabetes, and other chronic diseases.[1–3] Metabolic syndrome (MetS), a cluster of cardiovascular risk factors that include dyslipidemia, abdominal obesity, hypertension, and hyperglycemia, is associated with the development of diabetes, cardiovascular disease, and kidney disease, which are the leading causes of mortality worldwide.[4–7] As overweight and obesity has increased worldwide, MetS has become common, not only in developed countries, but also in less developed countries. Sherling et al have stated that the overlap of several components of MetS in each disease state, resulting in atherogenesis, should be considered a broader entity, rather than these factors being considered separately.[8]

The incidence of MetS often parallels the incidences of obesity and type 2 diabetes.[9] However, prevalence estimates vary depending on the criteria used for the definition of MetS. Global data regarding MetS are hard to collect, but Saklayen estimated the global prevalence of MetS to be 25%, implying that over a billion people around the world now have MetS.[9] It has been reported that about one third of US adults have MetS,[10] and Gu has reported that the prevalence of MetS in China is 9.8% in men and 17.8% in women aged 35 to 74 years,[11] while Wang reported that the prevalence of MetS in China in 2017 was 15.5%.[12] In the absence of a national program for the prevention and control of MetS in China, its prevalence is likely to continue to increase in the near future.

Despite the existing information, more evidence is needed regarding the prevalence of MetS in Chinese populations that cover a broader age range and include more minorities and cover more regions. People living in the same area are more likely to experience similar environmental influences, which influences the generalizability of data regarding MetS and its components. However, most previous studies of MetS did not consider or adjust for the cluster effect of living circumstances, which would have influenced their findings. Therefore, the aim of the present study was to determine the prevalence of MetS and associated lifestyle factors in Chinese adults across a broad age range, from 18 to 80 years, using a national, large-scale, cross-sectional survey. A multi-level generalized estimation equation (GEE) was constructed to evaluate the relationship between MetS and lifestyle factors, controlling for the cluster effect of living circumstances.

2. Material and methods

2.1. Sampling and participants

The study sample was obtained from a large-scale cross-sectional population survey regarding physiologic constants and health conditions that was conducted in China in 2007 to 2011.[13] A 2-stage cluster sampling method was used to recruit eligible individuals. Briefly, this survey was carried out in 6 provinces or autonomous regions of China: Hunan Province, Yunnan Province, Heilongjiang Province, Inner Mongolia Autonomous Region, Sichuan Province, and Ningxia Hui Autonomous Region. Two or 3 cities were sampled on the basis of their economic status, then several communities were randomly selected within each city. In these selected communities, all the eligible individuals were surveyed. The inclusion criteria of individuals included 3 aspects. First, individuals aged from 18 to 80 years old. Second, individuals did not suffer from severe chronic diseases, such as cancer, cardiovascular diseases, cerebrovascular diseases, chronic kidney diseases, diabetes, etc. Third, individuals did not experience a high fever in the preceding 15 days.

After providing written informed consent, the participants attended temporary physical examination centers voluntarily to take part in the survey and interview. The study was approved by the ethics review board of the Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences (No. 005-2008).

2.2. Survey and interview

The survey and interview were conducted in 6 provinces at different time frames by the same team of trained investigators. 20 investigators were involved in the realization of interviews. About 100 subjects were surveyed and interviewed by 20 investigators per day. The survey and interview lasted about 1 hour for each subject. In each province, about 3500 subjects took part in the survey and interview, and it took 1 and half months for investigators to complete all the survey and interview.

The survey included clinical laboratory tests, blood pressure measurement, body composition analyzing and face to face interview. The content of the interview included demographic characteristics such as birth date, gender, occupation, ethnicity, etc and lifestyle factors such as smoking, alcohol drinking, high-salted diet, sleep duration, etc.

2.3. Clinical laboratory tests

All clinical laboratory tests were performed following a 9 to 12-hour overnight fast, when a blood sample was drawn from an antecubital vein. Total cholesterol, low-density lipoprotein-cholesterol (LDL-C), high-density lipoprotein-cholesterol (HDL-C), and triglyceride concentrations were measured using a Beckman AU Series automated biochemical analyzer (Japan) and Sekisui Medical (Japan) reagents. Fasting blood glucose, creatinine, blood urea nitrogen, and uric acid were measured with the same instrument and with Beckman AU reagents.

2.4. Blood pressure measurement

Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured in the morning after the participants had rested for 5 minutes in a seated position, with their back supported, feet on the floor, and right arm supported, with the cubital fossa at the level of the heart. The appropriate cuff was chosen for each participant's arm circumference. OMRON HEM-7000 electronic sphygmomanometers (OMRON Health-Care, Kyoto, Japan) were used to measure SBP and DBP.

2.5. Definition of MetS

According to the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III), individuals meeting at least 3 of the following 5 criteria were defined as having MetS: fasting hyperglycemia, hypertension, low HDL-C concentration, hypertriglyceridemia, and abdominal obesity.[14,15] The definitions are provided below in more detail.

1) Hyperglycemia: fasting blood glucose ≥ 110 mg/dL or a diagnosis of diabetes;
2) Hypertension (SBP ≥ 130 mm Hg and/or DBP ≥ 85 mm Hg) or a history of hypertension;
3) Low HDL-C: serum HDL-C concentration < 40 mg/dL in men and < 50 mg/dL in women;
4) Hypertriglyceridemia: serum triglyceride concentration ≥ 150 mg/dL;
5) Abdominal obesity: waist circumference ≥ 102 cm in men and ≥ 88 cm in women, as measured to the nearest 0.1 cm at the level of the navel, using a flexible steel tape.

2.6. Definition of covariates

Participants were categorized into 3 age groups, young (18–34 years old), middle-aged (35–59 years old), and older adults (60–80 years old).

Body mass index (BMI) was defined as body mass (kg) divided by the square of height (m^2). Body mass was measured to the nearest 0.1 kg. Height and waist circumference were measured to the nearest 1 mm. According to Chinese Guidelines for the Prevention and Control of Adult Overweight and Obesity,[16] normal weight is defined by a BMI < 24 kg/m^2, overweight by a BMI ≥ 24 kg/m^2, but < 28 kg/m^2, and obesity by a BMI ≥28 kg/m^2. The percentage of body fat (PBF) was defined as the percentage of total body mass that was fat, and was measured using the bioelectric impedance method (Biodynamics BI-310 body composition analyzer; American Biodynamics Corporation). Participants were too fast, refrain from strenuous exercise at least 4 hours before measuring and refrain from drinking 24 hours before measuring.

2.7. Quality control

First, the project survey questionnaires, operation manual, and training manual were developed to guarantee the quality of the study. Before the survey was formally conducted, all investigators and medical professionals were trained based on training manuals and pilot survey was conducted to ensure that all of them were proficient in the survey process. Trained medical professionals carried out the survey and face to face interview and the responsibilities of the research team members were clarified and established. The training content included clinical laboratory tests, blood pressure measurement, body composition analyzing and face to face interview.

Second, the same brand and model of body composition analyzer, biochemical analyzer and sphygmomanometers were used at each center, and these were adjusted every day before measurements were made to minimize measurement errors. All survey and interview were conducted by the same team of trained investigators.

Finally, the survey questionnaires and the raw data were double-checked to guarantee the authenticity and accuracy including effective data logic control and editing checks. The database was constructed using EPI3.02 software (the EpiData Association, Odense, Denmark.), and data were entered twice, by 2 data managers, to guarantee its accuracy and integration.

2.8. Statistical analysis

Statistical analyses were conducted using SAS9.4 software (SAS Institute Int. Cary, NC, USA) software. Two-tailed analyses were conducted, in which $P<.05$ was defined as indicating statistical significance. Continuous data are summarized using means and standard deviations (SDs) and were compared using Student *t* test. Categorical data are summarized using numbers and percentages and were compared using the Chi-squared test.

Given that participants living in the same area were more likely to experience similar living circumstances and socioeconomic characteristics, we used the residence area to reflect subjects' living circumstances and socioeconomic characteristics. The residence area was defined as the community, city and province where subjects resided for a long time. A multi-level GEE model was used to determine the relationship between MetS and lifestyle factors to control for the cluster effect of living circumstances and socioeconomic characteristics. Odds ratios (ORs) and their 95% confidence intervals (CIs) were used to assess the strength of each relationship.

3. Results

The mean age of the 20,862 participants was 43.4 ± 16.1 years, that of the 9864 men was 43.3 ± 16.7 years, and that of the 10,998 women was 43.4 ± 15.6 years. The participants were of dozens of ethnicities, including Han (13,279; 63.7%), Yi (2031; 9.7%), Miao (343; 1.6%), Mongolian (1143; 5.5%), Tibetan (608; 2.9%), Korean (717; 3.4%), Hui (1808; 8.7%), Tujia (625; 3.0%), and others (308; 1.5%).

A total of 65.70% (n = 13,707) of all the participants had at least 1 clinical feature of MetS. Specifically, 32.74%, 18.93%, 10.25%, 3.25%, and 0.53% of the participants had 1, 2, 3, 4, and 5 components, respectively. These components, listed in order of their prevalence, were hypertension (41.90%), hypertriglyceridemia (28.14%), low HDL-C concentration (27.14%), hyperglycemia (10.82%), and abdominal obesity (9.21%). The most common pair of components occurring together were hypertension and low HDL-C concentration (9.64%) and the most common grouping of 3 components comprised hypertension, hypertriglyceridemia, and low HDL-C concentration (5.56%).

In total, 2926 participants were diagnosed with MetS (prevalence 14.03%). The prevalence of MetS in men (12.31%) was lower than in women (15.57%, $P<.0001$). The mean age of participants with MetS was 53.4 ± 12.9 years and that for participants without MetS was 41.8 ± 16.0 years. The prevalence of MetS was 3.59% in young participants, 16.72% in middle-aged participants, and 26.13% in older adult participants. The prevalence of MetS increased gradually with age ($P<.0001$). Among the minorities studied, Tibetan participants had the lowest prevalence of MetS (5.59%) and Korean participants the highest (20.50%). Physical laborers had a higher prevalence (17.39%) of MetS than their counterparts. Participants with hyperuricemia (26.56%) or who habitually consumed a high-salt diet (15.74%) had higher prevalences of MetS than their counterparts. Compared with participants without a family history, those with a family history of cardiovascular disease (17.41%) or cerebrovascular disease (17.75%) had higher prevalence rates of MetS. Participants who normally slept for < 6 hours a day had a higher prevalence (15.50%) of MetS than their counterparts. Compared with participants with normal body mass, those who were overweight or obese had higher prevalences (21.10% and 46.40%, respectively) of MetS. The mean PBF was 26.9% ± 7.9% for participants with MetS and 21.0% ± 8.6% for those without

Table 1

The prevalence of metabolic syndrome in participants classified according to a range of demographic characteristics.

	Total	1 component	2 components	3 components	4 components	5 components	MetS	P*
All subjects	20862	6831 (32.74)	3950 (18.93)	2139 (10.25)	677 (3.25)	110 (0.53)	2926 (14.03)	
Age (yr)								<.0001
18–34	6963	2275 (32.67)	727 (10.44)	209 (3.00)	38 (0.55)	3 (0.04)	250 (3.59)	
35–59	10156	3326 (32.75)	2283 (22.48)	1269 (12.50)	382 (3.76)	47 (0.46)	1698 (16.72)	
60–80	3743	1230 (32.86)	940 (25.11)	661 (17.66)	257 (6.87)	60 (1.60)	978 (26.13)	
Gender								<.0001
Male	9864	3377 (34.24)	2106 (21.35)	978 (9.91)	216 (2.19)	20 (0.20)	1214 (12.31)	
Female	10998	3454 (31.41)	1844 (16.77)	1161 (10.56)	461 (4.19)	90 (0..82)	1712 (15.57)	
Occupation								<.0001
Physical laborer	11081	3687 (33.27)	2329 (21.02)	1364 (12.31)	475 (4.29)	88 (0.79)	1927 (17.39)	
Mental laborer	9781	3144 (32.14)	1621 (16.57)	775 (7.92)	202 (2.07)	22 (0.22)	999 (10.21)	
Ethnicity								<.0001
Han	13279	4156 (31.30)	2466 (18.57)	1415 (10.66)	475 (3.58)	79 (0.59)	1969 (14.83)	
Yi	2031	784 (38.60)	408 (20.09)	140 (6.89)	33 (162)	5 (0.25)	178 (8.76)	
Miao	343	102 (29.74)	63 (18.37)	32 (9.33)	11 (3.21)	0	43 (12.54)	
Mongolia	1143	369 (32.28)	216 (18.90)	132 (11.55)	32 (2.80)	5 (0.44)	169 (14.79)	
Tibetan	608	208 (34.21)	63 (10.36)	24 (3.95)	8 (1.32)	2 (0.33)	34 (5.59)	
Korean	717	241 (33.61)	152 (21.20)	108 (15.06)	35 (4.88)	4 (0.56)	147 (20.50)	
Hui	1808	675 (37.33)	417 (23.06)	218 (12.06)	68 (3.76)	14 (0.77)	300 (16.59)	
Tujia	625	207 (33.12)	115 (18.40)	47 (7.52)	9 (1.44)	1 (0.16)	57 (9.12)	
Others	308	89 (28.90)	50 (16.23)	23 (7.47)	6 (1.95)	0	29 (9.42)	
Smoker								.6483
No	15550	5018 (32.27)	2803 (18.03)	1552 (9.98)	523 (3.36)	96 (0.62)	2171 (13.96)	
Yes	5312	1813 (34.13)	1147 (21.59)	587 (11.05)	154 (2.90)	14 (0.26)	755 (14.21)	
Alcohol drinker								.7354
No	15688	5074 (32.34)	2799 (17.84)	1570 (10.01)	528 (3.37)	95 (0.61)	2193 (13.98)	
Yes	5174	1757 (33.96)	1151 (22.25)	569 (11.00)	149 (2.88)	15 (0.29)	733 (14.17)	
High-salted diet								.0170
No	18759	6172 (32.90)	3536 (18.85)	1897 (10.11)	605 (3.23)	93 (0.50)	2595 (13.83)	
Yes	2103	659 (31.34)	414 (19.69)	242 (11.51)	72 (3.42)	17 (0.81)	331 (15.74)	
Hyperuricemia								<.0001
No	18207	6116 (33.59)	3292 (18.08)	1630 (8.95)	475 (2.61)	75 (0.41)	2180 (11.97)	
Yes	2564	701 (27.34)	656 (25.59)	446 (17.39)	200 (7.80)	35 (1.37)	681 (26.56)	
Family history of cardiovascular diseases								<.0001
No	18972	6230 (32.84)	3548 (18.70)	1889 (9.96)	607 (3.20)	101 (0.53)	2597 (13.69)	
Yes	1890	601 (31.80)	402 (21.27)	250 (13.23)	70 (3.70)	9 (0.48)	329 (17.41)	
Family history of cerebrovascular diseases								.0009
No	19938	6551 (32.86)	3767 (18.89)	2017 (10.12)	642 (3.22)	103 (0.52)	2762 (13.85)	
Yes	924	280 (30.30)	183 (19.81)	122 (13.20)	35 (3.79)	7 (0.76)	164 (17.75)	
BMI								<.0001
Normal	12204	4284 (35.10)	1547 (12.68)	446 (3.65)	83 (0.68)	8 (0.07)	537 (4.40)	
Overweight	6436	2137 (33.20)	1721 (26.74)	1030 (16.00)	292 (4.54)	36 (0.56)	1358 (21.10)	
Obesity	2222	410 (18.45)	682 (30.69)	663 (29.84)	302 (13.59)	66 (2.97)	1031 (46.40)	
sleep duration								<.0001
>=6 h	14212	4725 (33.25)	2680 (18.86)	1418 (9.98)	405 (2.85)	59 (0.42)	1882 (13.24)	
<6 h	6650	2106 (31.67)	1270 (19.10)	721 (10.84)	272 (4.09)	51 (0.77)	1044 (15.70)	

BMI = body mass index, MetS = metabolic syndrome.

* *P* values were obtained using the Chi-squared test to compare differences in the prevalence of metabolic syndrome between groups with different demographic characteristics.

MetS. The prevalences and factors related to MetS, classified according to demographic characteristics, are listed in Table 1.

Table 2 shows the results of the univariate and multivariate multi-level GEE models constructed using the factors associated with MetS. After controlling for the cluster effect of living circumstances and other covariates, no significant associations were found between sex or smoking status and MetS. Compared with young participants, middle-aged (OR = 1.461, 95% CI: 1.371–1.557), and older adult participants (OR = 1.667, 95% CI: 1.535–1.812) had higher prevalences of MetS. Compared with normal-weight participants, overweight (OR = 1.670, 95% CI: 1.600–1.743) and obese participants (OR = 2.287, 95% CI: 2.136–2.449) had higher prevalences of MetS. Thus, being older or having a higher BMI increases the risk of MetS.

Compared with Hans, Koreans were more likely to have MetS (OR=1.120, 95% CI: 1.053–1.191), whereas Yis (OR=0.953, 95% CI: 0.923–0.984), and Tibetans (OR=0.853, 95% CI: 0.813–0.895) were less likely to have MetS. Current drinkers (OR = 1.053, 95% CI: 1.020–1.086), physical laborers (OR = 1.070, 95% CI: 1.040–1.101), participants consuming a high-salt diet (OR = 1.040, 95% CI: 1.009–1.071), those with hyperuricemia (OR = 1.264, 95% CI: 1.215–1.316), those who typically slept for < 6 hours a day (OR = 1.032, 95% CI: 1.009–1.055), and those with a family history of cardiovascular disease

Table 2

Risk factors associated with the metabolic syndrome.

Characteristics	Univariate GEE model		Multivariate GEE model	
	OR	95%CI	OR	95%CI
Age (yr)				
18–34	1.0 (Ref.)		1.0 (Ref.)	
35–59	2.000	1.838–2.176	1.461	1.371–1.557
60–80	2.570	2.319–2.847	1.667	1.535–1.812
Gender				
Male	1.0 (Ref.)		1.0 (Ref.)	
Female	0.997	0.927–1.073	0.993	0.934–1.055
Occupation				
Physical laborer	1.419	1.320–1.526	1.070	1.040–1.101
Mental laborer	1.0 (Ref.)		1.0 (Ref.)	
Ethnicity				
Han	1.0 (Ref.)		1.0 (Ref.)	
Yi	0.835	0.667–1.045	0.953	0.923–0.984
Miao	0.905	0.747–1.096	1.028	0.945–1.118
Mongolia	0.904	0.827–0.989	0.986	0.939–1.035
Tibetan	0.959	0.912–1.009	0.853	0.813–0.895
Korean	1.194	1.060–1.034	1.120	1.053–1.191
Hui	0.923	0.831–1.024	0.979	0.953–1.005
Tujia	0.835	0.667–1.045	1.020	0.931–1.119
Others	0.837	0.729–1.960	0.936	0.854–1.026
Smoker				
No	1.0 (Ref.)		1.0 (Ref.)	
Yes	1.078	1.018–1.143	1.031	0.997–1.066
Alcohol drinker				
No	1.0 (Ref.)		1.0 (Ref.)	
Yes	1.103	1.054–1.153	1.053	1.020–1.086
High-salted diet				
No	1.0 (Ref.)		1.0 (Ref.)	
Yes	1.097	1.038–1.159	1.040	1.009–1.071
Hyperuricemia				
No	1.0 (Ref.)		1.0 (Ref.)	
Yes	1.582	1.511–1.655	1.264	1.215–1.316
Family history of cardiovascular diseases				
No	1.0 (Ref.)		1.0 (Ref.)	
Yes	1.145	1.083–1.211	1.065	1.019–1.113
Family history of cerebrovascular diseases				
No	1.0 (Ref.)		1.0 (Ref.)	
Yes	1.127	1.048–1.212	1.055	1.007–1.104
BMI				
Normal	1.0 (Ref.)		1.0 (Ref.)	
Overweight	2.077	1.941–2.223	1.670	1.600–1.743
Obesity	3.183	2.901–3.493	2.287	2.136–2.449
sleep duration				
>=6 h	1.0 (Ref.)		1.0 (Ref.)	
<6 h	1.158	1.089–1.230	1.032	1.009–1.055
PBF (5%)	1.184	1.157–1.212	1.069	1.053–1.085

*CI = confidence interval, GEE = generalized estimation equation, OR = odds ratio, PBF = percentage of body fat.

(OR = 1.065, 95% CI: 1.019–1.113) or cerebrovascular disease (OR = 1.055, 95% CI: 1.007–1.104) had higher prevalences of MetS. We found that the risk of MetS increased by 6.9% (OR = 1.069, 95% CI: 1.053–1.085) with each 5% increase in PBF. In contrast to the results of the univariate analysis, the multivariate model did not show a significant association between current smoking status and MetS.

In summary, after controlling for the cluster effect of living circumstances, age, sex, occupation, ethnicity, alcohol drinking, high-salt diet, BMI, PBF, sleep duration, and family history of disease were associated with MetS.

4. Discussion

Individuals living in the same area were more likely to experience similar socioeconomic characterisitcs, which has an inevitable effect on the generalizability of findings regarding MetS and its components. The present study used a multi-level GEE to evaluate the relationship between MetS and lifestyle factors, while controlling for the cluster effect of same living areas and similar living circumstances, which substantially improves the accuracy and generalizability of the results. In addition, we conducted the study using standardized protocols and instruments, and strict training processes and vigorous quality

assurance programs were put in place to ensure the quality of the data.

The prevalence of MetS was 14.03% across all the participants, and was lower in men (12.31%) than women (15.57%). These prevalences are similar to those previously reported.[11,12]

Changes in lifestyles and diet have led not only to an increase in life expectancy, but also a greater burden of chronic disease. We have shown that over-eating (overweight and obesity), alcohol drinking, a high-salt diet, and a shorter sleep duration increase the risk of MetS.

Overweight and obesity are the major determinants of MetS, a common and serious clinical and public health challenge.[8] Visceral fat tends to account for a higher percentage of total body fat in men, whereas subcutaneous fat tends to predominate in women.[17] Excess visceral body fat in particular is associated with MetS.[18] Visceral adiposity is associated with BMI, must be assessed as a cardiometabolic risk factor, and may serve as a marker and therapeutic target in cardiometabolic disease.[19] Indeed, Djibo found that body adiposity index could distinguish ethnic differences in MetS[20] and Liu found that higher fat mass index was independently and positively associated with the presence of MetS regardless, of BMI and PBF, when the body composition of a Chinese population attending annual health checks was measured in a single hospital.[21]

Suliga has reported that the daily consumption of alcohol is significantly associated with a higher risk of MetS.[22] However, the association between drinking alcohol and the prevalence of MetS and its components is not consistent. One prospective study found a linear increase in the risk of MetS with an increase in alcohol consumption,[23] whereas another study found that the consumption of 0.1 to 5.0 g of alcohol/d was associated with a lower prevalence of MetS and its components, including hypertriglyceridemia and low HDL-C concentration.[24] To better characterize the relationship between alcohol consumption and MetS and its components, large-scale prospective studies should be conducted.

High salt intake was closely associated with hypertension, which was an important component of MetS. For example, Saha showed in a cross-sectional survey that the prevalences of obesity, hypertension, diabetes, dyslipidemia, and MetS, and short-term cardiovascular disease risk score are higher in urban dwellers consuming a high-salt diet.[25]

Smiley has reported an association between MetS and sleep duration; specifically that short sleep duration is associated with a higher risk of MetS and more severe MetS in men.[26] Furthermore, Iftikhar showed a dose-response relationship between short sleep duration and MetS, with individuals who reported a sleep duration of < 5 hours having a 1.5 times higher risk of MetS.[27] This was part of a wider phenomenon because habitual lack of sleep is associated with numerous chronic health conditions, such as hypertension, cancers, depression, obesity, and diabetes, as well as higher mortality.[28–32]

Several limitations of the present study have to be mentioned. First, owing to its cross-sectional design, it is not possible to draw conclusions with regard to the causality of the relationships between covariates and MetS. Second, given that our analysis excluded individuals with certain severe chronic diseases and those who have experienced a fever in the preceding 15 days, it is likely that the true prevalence of MetS in this Chinese population has been underestimated. Third, because MetS can be defined in several ways, it is difficult to compare the findings of the present study with those of other studies of the prevalence of MetS.

5. Conclusions

Our findings show that MetS has become a serious public health challenge in China. Many lifestyle factors have been found to be closely associated with MetS, including obesity, a high-salt diet, alcohol consumption, and short sleep duration. Therefore, changes in lifestyle are very important for adult population to reduce the prevalence of MetS.

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Author contributions

Tao Xu participated in the design of the study and the field survey, performed the statistical analysis, and drafted the manuscript. Guangjin Zhu conceived the study. Shaomei Han conceived the study and participated in its design. All the authors read and approved the final manuscript.

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References

[1] Yusuf S, Reddy S, Ounpuu S, et al. Global burden of cardiovascular diseases: part I: general considerations, the epidemiologic transition, risk factors, and impact of urbanization. Circulation 2001;104:2746–53.
[2] Popkin BM, Horton S, Kim S, et al. Trends in diet, nutritional status, and diet-related noncommunicable diseases in China and India: the economic costs of the nutrition transition. Nutr Rev 2001;59:379–90.
[3] Yao C, Wu Z, Wu Y. The changing pattern of cardiovascular diseases in China. World Health Stat Q 1993;46:113–8.
[4] Samson SL, Garber AJ. Metabolic syndrome. Endocrinol Metab Clin North Am 2014;43:1–23.
[5] Chen J, Muntner P, Hamm LL, et al. The metabolic syndrome and chronic kidney disease in U.S. adults. Ann Intern Med 2004;140:167–74.
[6] Eckel RH, Grundy SM, Zimmet PZ. The metabolic syndrome. Lancet 2005;365:1415–28.
[7] Haffner SM, Valdez RA, Hazuda HP, et al. Prospective analysis of the insulin-resistance syndrome (syndrome X). Diabetes 1992;41:715–22.
[8] Sherling DH, Perumareddi P, Hennekens CH. Metabolic syndrome. J Cardiovasc Pharmacol Ther 2017;22:365–7.
[9] Saklayen MG. The Global Epidemic of the Metabolic Syndrome. Curr Hypertens Rep 2018;20:12.
[10] National Center for Health Statistics, Division of Health Interview Statistics. Crude and age-adjusted percentage of civilian, noninstitutionalized adults with diagnosed diabetes, United States, 1980-2010. National Center for Chronic Disease Prevention and Health Promotion, Ed. Atlanta, GA, Centers for Disease Control and Prevention, Division of Diabetes Translation. 2012.
[11] Gu D, Reynolds K, Wu X, et al. Prevalence of the metabolic syndrome and overweight among adults in China. Lancet 2005;365:1398–405.
[12] Wang Y, Mi J, Shan X, et al. Is China facing an obesity epidemic and the consequences? The trends in obesity and chronic disease in China. Int J Obesity 2007;31:177–88.

[13] Xu T, Liu J, Liu J, et al. Relation between metabolic syndrome and body compositions among Chinese adolescents and adults from a large-scale population survey. BMC Public Health 2017; 17:337.
[14] Grundy SM. Metabolic syndrome scientific statement by the American Heart Association and the National Heart, Lung, and Blood Institute. Arterioscler Thromb Vasc Biol 2005;25:2243–4.
[15] Cook S, Weitzman M, Auinger P, et al. Prevalence of a metabolic syndrome phenotype in adolescents: findings from the third National Health and Nutrition Examination Survey, 1988–1994. Arch Pediatr Adolesc Med 2003;157:821–7.
[16] Zhou BF. Effect of body mass index on all-cause mortality and incidence of cardiovascular diseases–report for meta-analysis of prospective studies open optimal cut-off points of body mass index in Chinese adults. Biomed Environ Sci 2002;15:245–52.
[17] Smith U. Abdominal obesity: a marker of ectopic fat accumulation. J Clin Invest 2015;125:1790–2.
[18] Szymańska E, Bouwman J, Strassburg K, et al. Gender-dependent associations of metabolite profiles and body fat distribution in a healthy population with central obesity: towards metabolomics diagnostics. OMICS 2002;16:652–67.
[19] Shah RV, Murthy VL, Abbasi SA, et al. Visceral adiposity and the risk of metabolic syndrome across body mass index: the MESA study. JACC Cardiovasc Imaging 2014;7:1221–35.
[20] Djibo DA, Araneta MR, Kritz-Silverstein D, et al. Body adiposity index as a risk factor for the metabolic syndrome in postmenopausal Caucasian, African American, and Filipina women. Diabetes Metab Syndr 2015;9:108–13.
[21] Liu P, Ma F, Lou H, et al. The utility of fat mass index vs. body mass index and percentage of body fat in the screening of metabolic syndrome. BMC Public Health 2013;13:629.
[22] Suliga E, Kozieł D, Ciesla E, et al. Consumption of alcoholic beverages and the prevalence of metabolic syndrome and its components. Nutrients 2019;11:E2764.
[23] Baik I, Shin C. Prospective study of alcohol consumption and metabolic syndrome. Am J Clin Nutr 2008;87:1455–63.
[24] Kim SK, Hong SH, Chung JH, et al. Association between alcohol consumption and metabolic syndrome in a community-based cohort of Korean adults. Med Sci Monit 2017;23:2104–10.
[25] Saha S, Gupta K, Kumar S. Cardiovascular health among healthy population of Northeast region of India: a cross-sectional study comparing urban-tribal difference. J Indian Med Assoc 2013;111:810–4.
[26] Smiley A, King D, Bidulescu A. The Association between sleep duration and metabolic syndrome: the NHANES 2013/2014. Nutrients 2019;11: E2582.
[27] Iftikhar IH, Donley MA, Mindel J, et al. Sleep duration and metabolic syndrome. An updated dose-risk metaanalysis. Ann Am Thorac Soc 2015;12:1364–72.
[28] Jiao L, Duan Z, Sangi-Haghpeykar H, et al. Sleep duration and incidence of colorectal cancer in postmenopausal women. Br J Cancer 2013; 108:213–21.
[29] Holliday EG, Magee CA, Kritharides L, et al. Short sleep duration is associated with risk of future diabetes but not cardiovascular disease: a prospective study and meta-analysis. Plos One 2013;8:e82305.
[30] Wang Q, Xi B, Liu M, et al. Short sleep duration is associated with hypertension risk among adults: a systematic review and meta-analysis. Hypertens Res 2012;35:1012–8.
[31] Cappuccio FP, D'Elia L, Strazzullo P, et al. Sleep duration and all-cause mortality: a systematic review and meta-analysis of prospective studies. Sleep 2010;33:585–92.
[32] Cappuccio FP, Taggart FM, Kandala NB, et al. Meta-analysis of short sleep duration and obesity in children and adults. Sleep 2008;31:619–26.