ORIGINAL RESEARCH

Prevalence and Correlation of Metabolic Syndrome: A Cross-Sectional Study of Nearly 10 Million Multi-Ethnic Chinese Adults

This article was published in the following Dove Press journal:
Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy

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Purpose: This study aimed to examine the prevalence and correlates of metabolic syndrome (MetS) in multi-ethnic populations of Northwest China based on Large-scale provincial health checking data.

Patients and Methods: A total of 9,745,640 Chinese aged ≥18 years in Xinjiang, the largest autonomous region of multi-ethnic in China, were enrolled from Feb. to Sep. 2019. MetS was defined by modified Adult Treatment Panel (ATP III) criteria.

Results: The overall prevalence of MetS was 20.85% [Sex: 20.06% female, 21.56% male; Age: 39.22% 60-years and above, 26.32% 40- to 59-years and 9.56% 18- to 39-years; Ethnicity: 28.19% Hui followed by Han (26.39%), Uyghur (18.56%), Other (18.61%), Kazak (17.98%), Mongolian (17.87%), Kyrgyz (14.44%)]. People living in cities and towns (23.03%) or North (24.78%) had higher prevalence of MetS than rural (19.94%) and South (17.66%). Although the prevalence of hypertension, smoking, drinking and lack of physical activity were higher in Kyrgyz, Mongolian and Kazak than those of other ethnic groups, the risk of MetS was lower.

Conclusion: The results indicated that a high prevalence of MetS in Hui and Han groups and people living in cities and towns. Living in North Xinjiang and elder population tend to have higher prevalence of MetS. The prevention and management of MetS in these populations should be prioritized.

Keywords: metabolic syndrome; MetS, Chinese, ethnic groups, adults, prevalence

Introduction

Metabolic syndrome (MetS) is caused by combined effects of multiple metabolic risk factors including central obesity, impaired sugar control, dyslipidemia, hypertension, insulin resistance (IR), hyperuricemia and microalbuminuria.[1] Patients with MetS are at increased risk for developing type 2 diabetes mellitus, cardiovascular diseases, and other chronic diseases with high mortality and morbidity.[2] A close correlation between MetS and increased risk of chronic diseases (e.g., cardiovascular disease, type 2 diabetes, arthritis, chronic kidney disease, schizophrenia) with short life-span have been reported.[2–4]

It is estimated that about 20–30% of the world's population suffer from MetS, and the prevalence is on the rise.[5] The prevalence of MetS varies between different regions. Based on the National Cholesterol Education Program data (NCEP) Adult Treatment Panel III (ATP III), the prevalence of MetS in ≥20-year-old adults in the United States was 34.7%;[6] whereas in Canada, it was nearly 25% in multi-ethnic

adult population;[7] and in sub-Saharan Africa, it was 17.1% in multi-ethnic adult population.[8] In Australia, the prevalence of MetS was 21.7% in adults ≥ 25-years-old in a national wide survey.[9] The prevalence of MetS in Indonesia was 21.66% among provinces and ethnic groups.[10] The latest national meta-analysis in 2016 estimated the prevalence of MetS in China as 24.5%,[11] but multi-ethnic population here aged ≥20 years showed a lower prevalence of MetS (15.9%) in the study.[12] As to mono-population, 30.0% prevalence of MetS was observed in Han ethnic group aged ≥18 years in Zhejiang province, China,[13] and a study in the Han group in northeast China reported an overall prevalence of MetS as 41.3%.[14] It is clear that the prevalence of MetS in the mono-population higher than that in the multiethnic population and the Chinese Han group is much higher than in other ethnic minorities in China. This is worth exploring the underlying reasons. In addition, MetS components such as hypertension, high blood sugar and dyslipidemia are major and modifiable risk factors for major chronic diseases. It is important to track the difference in MetS prevalence in different ethnic groups in order to obtain an insight into the occurrence of MetS, and to explore new risk factors. Recent studies of MetS in different regions and different populations of China were performed with different diagnosis standards,[15–18] and the results were inconsistent with small sample sizes, short age spans and different regional factors. Big data epidemiological analysis of risk factors of MetS in multi-ethnic groups in same region with same diagnosis standard is urgently needed.

Since the proportion and distribution of body fat in Asians are different from those in North America and Europe,[19,20] the definition of obesity applicable to the Western population may not fully apply to the Asian population. The Harmonized criteria have defined cutoffs for Asian central obesity (waist circumference: ≥ 90 cm for males; ≥ 80 cm for females) and reduced cutoff for Asian hyperglycemia (≥ 5.6 mmol/L, instead of 6.1 mmol/L in the NCEP-ATP III). Modified Adults Treatment of Obesity Panel (ATP III) criteria were reported as the most suitable for Asian populations.[21,22] The prevalence of MetS depends on a series of non-modifiable genetic (gender, age, ethnicity) and modifiable (lifestyle, diet) risk factors. These factors are known to, directly or indirectly, influence MetS among the populations. Studies indicated the significant but inconsistent influence of lifestyle habits on the prevalence.[23] The relationship of lifestyle behaviors and MetS among major ethnicities were not evaluated in

some studies.[24,25] Contribution of non-modifiable factors in some groups to MetS prevalence cannot be completely excluded.

To obtain a comprehensive and accurate understanding of multi-ethnic populations in Xinjiang area, this study was using a big data analysis of nearly 10 million people aged 18-years-old and above, with Harmonized ATPIII diagnosis standard, to show the prevalence and contributing risk factors of MetS and to provide evidence for preventive interventions against MetS and related diseases in China.

Materials and Methods
Study Design and Population

The study included data from 2019 health-checking program in Xinjiang, the largest autonomous multi-ethnic region in China. All residents of Xinjiang were offered this free checking organized and funded by the government. It contained socioeconomic variables, status of medical resource utilization, consultation and national health screening results, and status of clinic. This study analyzed 57.4% of the whole Xinjiang population aged ≥18-years-old. A total of 16,979,107 residents participated in this health-checking program by 2019. After excluding individuals who were aged < 18 years (n = 6,333,609), those who were unwilling to participate (n = 457,108), those whose data did not contain MetS contributing factors (WC, BP, FBG, TG or HDL) (n = 245,755), pregnant women (n = 96,923), potential duplicates (n = 25,638) and unreasonable outliers (n = 74,362), a total of 9,745,640 subjects (52.7% female = 5,134,110) were finally included in this study (see Figure 1).

Data Collection and Measurement

At multiple health check sites, uniformly trained staff collected data in accordance with the same standards.

Demographic data and lifestyle risk factors, such as age, sex, marital status, education, smoking status, alcohol consumption, physical activity, were all collected through face-to-face interviews. Waist circumference was measured to 1 decimal point (0.1 cm), at the middle point between the lowest rib and the highest iliac crest line under exhaled condition, using a measuring tape. Body mass index (BMI) was calculated by dividing weight (kg) by squared height (m). Blood pressure was measured on left arm three times using an automated electronic device (OMRON Model HEM-7071, Omron Company)
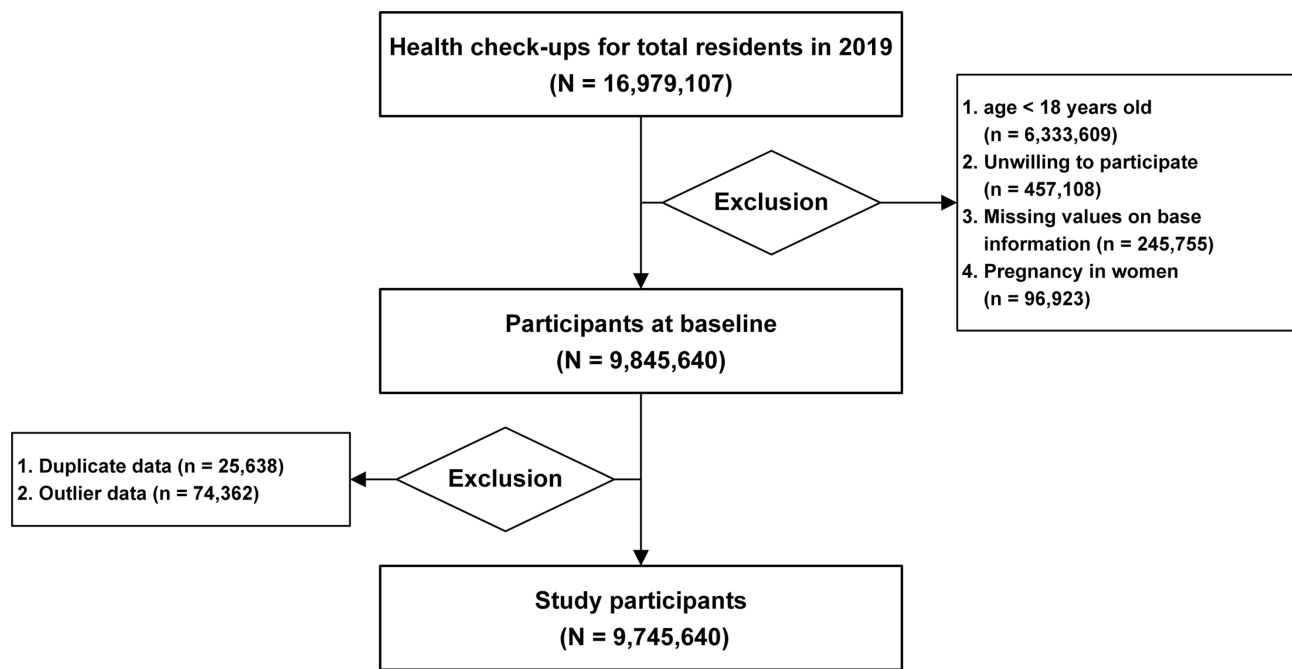
Figure 1 Flow chart of the study.

after sitting down for 5 min to calculate mean value of the 2nd and 3rd blood pressure readings as the final blood pressure value.

Blood was collected from the antecubital vein after at least 8 h of fasting, refrigerated, and analyzed within 4 h at qualified laboratories. TG, HDL-C, LDL-C and FBG were measured according to the equipment and manufacturer's instruction.

Definition of MetS

In the present study, we used the Harmonized criteria from the National Cholesterol Educational Program (the revised NCEP-ATP III for Asians in 2009[26]) to define MetS, which required the presence of three or more of the following five MetS components: 1) Central obesity (according to the Asian crowd standard, waist circumference (WC) $\geq$ 90 cm in men and $\geq$ 80 cm in women); 2) Raised serum triglycerides (high-TG) $\geq$ 1.7 mmol/L (150 mg/dL); 3) Low high-density lipoprotein cholesterol (low-HDL-C) < 1.0 mmol/L (40 mg/dL) in males and < 1.3 mmol/L (50 mg/dL) in females; 4) High blood pressure (high-BP) as SBP $\geq$ 130 mmHg or DBP $\geq$ 85 mmHg or taking antihypertensive drugs; and 5) Raised fasting blood glucose (hyperglycemia, high-FBG) $\geq$ 5.6 mmol/L (100 mg/dL) or taking anti-hyperglycemia drugs.

Statistical Analysis

All data analyses were conducted using The R Foundation for Statistical Computing Platform R version 4.0.2. Variables were summarized as mean for continuous data and percentage or proportion for categorical data. The 95% CIs were calculated for means, percentages, or proportions. The Student t test, one-way ANOVA and Rao-Scott χ^2 test were used to assess the differences across groups for continuous and categorical variables respectively. A multivariable logistic regression analysis was conducted to evaluate the associated factor for MetS and its components. All tests were two tailed, and P<0.05 was considered statistically significant. Outliers are judged by Mahalanobis-MCD (Mahalanobis-Minimum Covariance Determinant) distance, as whit of MCD75 and a chi-square at P=0.001 for outliers.[27]

Ethical Approval and Consent to Participate

The Medical Ethics Committee of the First Affiliated Hospital of Xinjiang Medical University approved the study protocol (20190225–105). The national health examination of whole population in Xinjiang was a health benefit program offered to the residents, and the program mainly covered the common physical examination items as reported in this manuscript. The data were used for

baseline analysis (such as MetS prevalence and risk factors analysis, etc.) and disease management measures. Collection of the data has been approved by the Autonomous Regional Health Commission, with written Consent Form approved by each and every related resident involved in this research. The use of the national health checking data has been approved by the Primary Health Department, who is responsible for the health information security in China. The content of this article has been examined and approved for scientific publication by the Department. The data are not available without approval.

Results

Data from Physical Exams and Laboratory Tests

General population characteristics are shown in Table 1 and anthropometry measurements, blood test results and health behavior characteristics are shown in Table 2 with the averages of BMI, WC, SBP, DBP, LDL-c, HDL-c, TC, FBG and the percentage of smoking, drinking and physical activity. The results showed that all averages were significantly

Table I Sample Descriptive Characteristic (N = 9,745,640)

Variables	Total (n=9,745,640)	Percentage (%)
Sex		
Male	5,134,110	52.68
Ages		
18–39 ys	4,412,117	45.27
40–59 ys	3,731,961	38.29
≥60 ys	1,601,562	16.43
Ethnicity		
Han	2,481,787	25.47
Uyghur	5,645,419	57.93
Kazak	799,942	8.21
Hui	404,253	4.15
Kyrgyz	113,716	1.17
Mongolian	79,165	0.81
Other	221,358	2.27
Household registration		
Rural	6,870,013	70.49
Geographical location		
North	4,364,234	44.78
Education		
6 years or less	5,729,947	58.79

different among different groups of sex, age, ethnicity, household registration, geographical location and education (*P*<0.0001).

In terms of sex, except that the HDL-c in male group was lower than that in female, the other indexes of male group were higher than that in female (*P*<0.0001). Smoking and drinking accounted for the highest level in the 40–59 age group, and physical activity was the highest in 60-years and over group.

In terms of age, all indexes were the lowest in 18- to 39-year-old group; and the highest weight, BMI and TG were observed in 60-years and over group with middle ranges for 40- to 59-year group (*P*<0.0001); the highest drinking and smoking rates were in the 40- to 59-years group while the highest physical activities in 60-years and over group (*P*<0.0001).

In terms of ethnicity, in Uyghur, TC was the lowest and all other indexes were in middle or lower levels; in Han, TC was the highest, and other indexes were at higher levels; in Kazak, SBP and HDL-c were the highest, TG was the lowest, and other indexes were at higher levels; in Hui, FBG was the highest, and other indexes were at higher levels; in Kyrgyz, LDL-c was the highest, and weight, WC, SBP, and DBP were the lowest, and other indexes were at lower levels; in Mongolian, height, weight, BMI, WC, DBP, and HDL-c were the highest and other indexes were at lower levels (*P*<0.0001). As for lifestyles, Kyrgyz had the highest drinking rates followed by Mongolian, Kazak, Uyghur, Han, and Hui; Kyrgyz also had the least people doing physical activity followed by Uyghur, Kazak, Hui, Mongolian, and Han.

Prevalence of Metabolic Syndrome

The prevalence of MetS was markedly different between sex, household registration, residential geographical location and education, showing higher in male (21.60%), in 60-years and over age group (39.22%), in city and town residents (23.03%), in North Xinjiang area (24.78%), and in 7 or more-years education group (24.54%). There were significant differences in ages. Prevalence was 9.56% in 18- to 39-year group and increased up to 39.22% in ≥60-years group. There were significant differences in prevalence between ethnicities, showing the highest in Hui (28.19%), followed by Han (27.3%), others (18.61%), Uyghur (18.56%), Mongolian (17.98%), Kazak (17.87%) and Kyrgyz (14.44%) (Table 3).

The prevalence of five MetS components showed that central obesity was the highest (51.71%), followed by

Table 2 Anthropometry measurements, blood test results and health behavior characteristics of the sample (N=9,745,640)

Variables	Height(cm)	Weight(kg)	BMI (kg/m2)	WC (cm)	SBP (mmHg)	DBP (mmHg)	LDL-C (mg/dL)	HDL-C (mg/dL)	TC (mg/dL)	TG (mg/dL)	FBG (mg/dL)	Smoking n (%)[a]	Drinking n (%)[a]	Physical Activity n (%)[a]
Overall	163.16±8.92	66.14±12.52	24.81 ±4.09	85.39 ±12.15	119.26 ±18.11	72.82 ±11.42	2.45±0.74	1.41±0.56	4.36 ±1.26	1.43 ±1.17	5.28 ±1.61	1,278,212 (13.12)	113,618 (13.48)	1,370,180 (14.06)
Age														
18–39ys	164.77±8.79	64.68±12.62	23.76 ±3.91	82.37 ±11.56	111.88 ±13.25	69.37 ±9.72	2.3±0.64	1.39±0.52	4.08 ±1.21	1.3±1.1	4.98 ±1.09	3,795,244 (13.98)	3,768,262 (14.59)	3,911,577 (11.34)
40–59ys	162.74±8.52	68.45±12.33	25.81 ±4.04	87.87 ±12.02	122.25 ±17.84	75.11 ±11.76	2.57±0.76	1.43±0.59	4.55 ±1.24	1.56 ±1.27	5.43 ±1.78	3,186,548 (14.61)	3,187,005 (14.60)	3,191,388 (14.48)
≥60ys	159.71±9.1	64.79±11.88	25.37 ±4.01	87.96 ±12.15	132.66 ±20.51	77.01 ±12.19	2.61±0.86	1.45±0.61	4.69 ±1.3	1.51 ±1.06	5.78 ±2.15	1,485,636 (7.24)	1,476,757 (7.79)	1,272,497 (20.55)
Sex														
Men	169.13±7.05	71.14±12.18	24.85 ±3.82	87.79 ±11.56	121.30 ±17	74.1 ±11.35	2.47±0.74	1.39±0.57	4.37 ±1.27	1.57 ±1.33	5.32 ±1.65	3,347,159 (27.42)	3,473,053 (24.69)	3,943,753 (14.48)
Women	157.8±6.77	61.65±11.04	24.78 ±4.32	83.23 ±12.26	117.44 ±18.87	71.67 ±11.36	2.44±0.74	1.44±0.55	4.35 ±1.26	1.31 ±0.99	5.24 ±1.58	5,120,269 (0.27)	4,958,971 (3.41)	4,431,709 (13.68)
Ethnicity														
Uyghur	162.24±8.95	65.29±12.54	24.79 ±4.26	85.8 ±12.5	117.38 ±18.24	71.44 ±11.47	2.42±0.65	1.39±0.53	4.22 ±1.22	1.40 ±1.11	5.22 ±1.59	4,896,487 (13.27)	4,950,831 (12.30)	5,193,222(8.01)
Han	164.18±8.64	66.44±11.69	24.59 ±3.52	84.26 ±10.85	122.11 ±16.87	74.84 ±10.65	2.51±0.89	1.45±0.66	4.58 ±1.34	1.58 ±1.32	5.41 ±1.74	2,203,758 (11.20)	2,121,181 (14.53)	1,839,242 (25.89)
Kazak	165.13±8.93	69.51±13.78	25.45 ±4.45	86.04 ±13.43	122.75 ±19.36	75.01 ±12.12	2.44±0.75	1.47±0.45	4.58 ±1.27	1.24 ±1.00	5.20 ±1.22	663,934 (17.00)	686,531 (14.18)	706,576(11.67)
Hui	164.31±8.63	68.34±12.43	25.28 ±3.95	85.91 ±11.71	121.65 ±18.19	74.59 ±11.4	2.47±0.79	1.40±0.49	4.44 ±1.19	1.5 ±1.23	5.60 ±1.85	364,453 (9.85)	378,033 (6.49)	339,318(16.06)
Kyrgyz	163.72±9.09	65.28±12.45	24.33 ±4.07	84.31 ±11.82	114.31 ±17.35	73.08 ±11.46	2.49±0.74	1.41±0.56	4.36 ±1.27	1.25 ±0.91	5.21 ±1.12	87,390 (23.15)	86,713 (23.75)	105,399(7.31)

(Continued)

Table 2 (Continued).

Variables	Height(cm)	Weight(kg)	BMI (kg/m2)	WC (cm)	SBP (mmHg)	DBP (mmHg)	LDL-C (mg/dL)	HDL-C (mg/dL)	TC (mg/dL)	TG (mg/dL)	FBG (mg/dL)	Smoking n (%) [a]	Drinking n (%) [a]	Physical Activity n (%) [a]
Mongolian	164.72±8.84	69.56±13.37	25.60 ±4.28	86.48 ±12.82	122.58 ±18.75	75.23 ±11.68	2.47±0.63	1.47±0.98	4.49 ±1.27	1.27 ±1.05	5.23 ±1.31	62,582 (20.95)	63,742 (19.48)	62,524(21.02)
Other	165.16±8.72	67.51±13.03	24.68 ±3.98	84.65 ±11.92	119.86 ±16.62	73.42 ±10.48	2.57±0.78	1.38±0.44	4.52 ±1.19	1.48 ±1.2	5.17 ±1.55	4,896,487 (13.27)	4,950,831 (12.30)	5,193,222(8.01)
Area														
North	164.63±8.68	67.92±12.54	25.02 ±3.97	85.47 ±11.95	122.34 ±17.88	74.67 ±11.24	2.5±0.84	1.44±0.6	4.57 ±1.29	1.48 ±1.22	5.37±1.7	3,802,246 (12.88)	3,709,019 (15.01)	4,915,843(8.65)
South	161.97±8.94	64.69±12.31	24.64 ±4.18	85.33 ±12.31	116.77 ±17.92	71.33 ±11.35	2.42±0.65	1.39±0.53	4.20 ±1.22	1.40 ±1.12	5.21 ±1.53	4,665,182 (13.31)	4,723,005 (12.23)	3,459,619 (20.73)
Education														
≤6ys	164.34±8.59	66.5±12.61	24.58 ±4.01	84.71 ±11.98	117.2 ±16.69	72.21 ±11.03	2.42±0.74	1.41±0.58	4.31 ±1.24	1.43 ±1.19	5.26 ±1.43	3,563,108 (11.27)	500,965 (12.48)	582,697(14.51)
≥7ys	161.48±9.12	65.62±12.37	25.15 ±4.19	86.36 ±12.33	122.22 ±19.6	73.7±11.9	2.51±0.74	1.41±0.53	4.44 ±1.29	1.43 ±1.13	5.32 ±1.84	4,904,320 (14.41)	812,651 (14.18)	787,481(13.74)
Permanent address														
City and town	164.66±8.63	67.3±12.51	24.78 ±3.98	85.1 ±11.96	120.02 ±17	73.58 ±10.84	2.49±0.85	1.43±0.62	4.48 ±1.36	1.53 ±1.28	5.25 ±1.77	2,564,803 (10.81)	2,450,668 (14.78)	2,124,404 (26.12)
Rural	162.53±8.97	65.66±12.49	24.83 ±4.14	85.52 ±12.23	118.95 ±18.55	72.51 ±11.64	2.44±0.69	1.41±0.53	4.31 ±1.22	1.39 ±1.12	5.3±1.54	5,902,625 (14.08)	5,981,356 (12.94)	6,251,058(9.01)

Notes: [a] Using a Chi-squared test. Data are expressed as the mean ± SD or as n (%). BMI body mass index, WC waist circumference, SBP systolic blood pressure, DBP diastolic blood pressure, TG triglyceride, LDL-C low-density lipoprotein cholesterol, HDL-C high-density lipoprotein cholesterol, FPG fasting plasma glucose. All P values <0.0001

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Table 3 Rates of Metabolic Syndrome and Its Components (N=9,745,640)

Variables	Metabolic syndrome		Central obesity		High triglycerides		Low high-density lipoprotein cholesterol		Elevated blood pressure		Elevated fasting plasma glucose	
	%	P	%	P	%	P	%	P	%	P	%	P
Total	20.85	<0.001	51.71	<0.001	23.71	<0.001	4.68	<0.001	23.16	<0.001	26.59	<0.001
Sex												
Female	21.56	<0.001	60.83	<0.001	19.37	<0.001	5.69	<0.001	21.70	<0.001	28.27	<0.001
Male	20.06		41.56		28.53		9.89		24.81		25.80	
Ages												
18–39	9.56	<0.001	40.79	<0.001	18.66	<0.001	7.46	<0.001	6.71	<0.001	16.94	<0.001
40–59	26.32		60.86		28.15		7.30		28.12		30.48	
≥60 岁	39.22		60.48		27.24		9.15		56.96		44.14	
Ethnicity												
Uyghur	18.56	<0.001	52.80	<0.001	22.98	<0.001	7.88	<0.001	20.69	<0.001	23.89	<0.001
Han	26.39		48.93		27.75		8.11		26.49		32.69	
Kazak	17.98		52.47		16.78		4.53		26.96		23.84	
Hui	28.19		54.85		26.04		8.09		26.21		35.68	
Kyrgyz	14.44		47.01		16.69		7.79		19.55		25.57	
Mongolian	17.87		55.94		17.74		3.53		27.18		24.17	
Other	18.61		47.51		23.45		9.66		30.13		21.69	
Permanent address												
City and	23.03	<0.001	51.12	<0.001	26.65	<0.001	7.94	<0.001	23.81	<0.001	26.56	0.122
Rural	19.94		51.96		22.48		7.57		22.90		26.61	
Area												
North	24.78	<0.001	52.18	<0.001	24.91	<0.001	7.18	<0.001	27.20	<0.001	30.28	<0.001
South	17.66		51.33		22.73		8.08		19.90		23.60	
Education												
6 years or	18.26	<0.001	48.92	<0.001	23.51	<0.001	7.34	<0.001	17.49	<0.001	24.89	<0.001
7 years or	24.54		55.70		23.98		8.16		31.27		29.01	
Smoking												
Yes	20.45	<0.001	44.24	<0.001	32.00	<0.001	8.02	<0.001	21.25	<0.001	27.90	<0.001
No	20.94		52.84		22.45		7.62		23.46		26.39	
Drinking												
Yes	20.85	0.978	46.09	<0.001	30.35	<0.001	9.01	<0.001	23.37	<0.001	26.50	0.009
No	20.85		52.59		22.67		7.47		23.14		26.61	
Physical												
Yes	25.80	<0.001	52.85	<0.001	27.11	<0.001	8.96	<0.001	31.46	<0.001	28.64	<0.001
No	20.04		51.53		23.15		7.47		21.81		26.26	

Notes: Color explanation: orange represents two-classified variables, blue is three-classified variables, green represents more than three-classified variables, and the light to deep color represents the low to high values.

high-FBG (26.59%), high-TG (23.71), high-BP (23.16%), and low-HDL-C (4.68%). Central obesity and high-FBG were more prevalent in women than that in men; high-TG, low-HDL-C, high-BP were more often in men than that in women. As to age, the prevalence of high-FBG, high-BP and low-HDL-C were the highest in the 60-years and over age group, while central obesity and high-TG were the highest in 40- to 59-years-old. The prevalence of high-FBG, high-TG and low-HDL-C were remarkably higher in Hui (35.68%, 26.04% and 8.09%, *P*< 0.0001), and Han

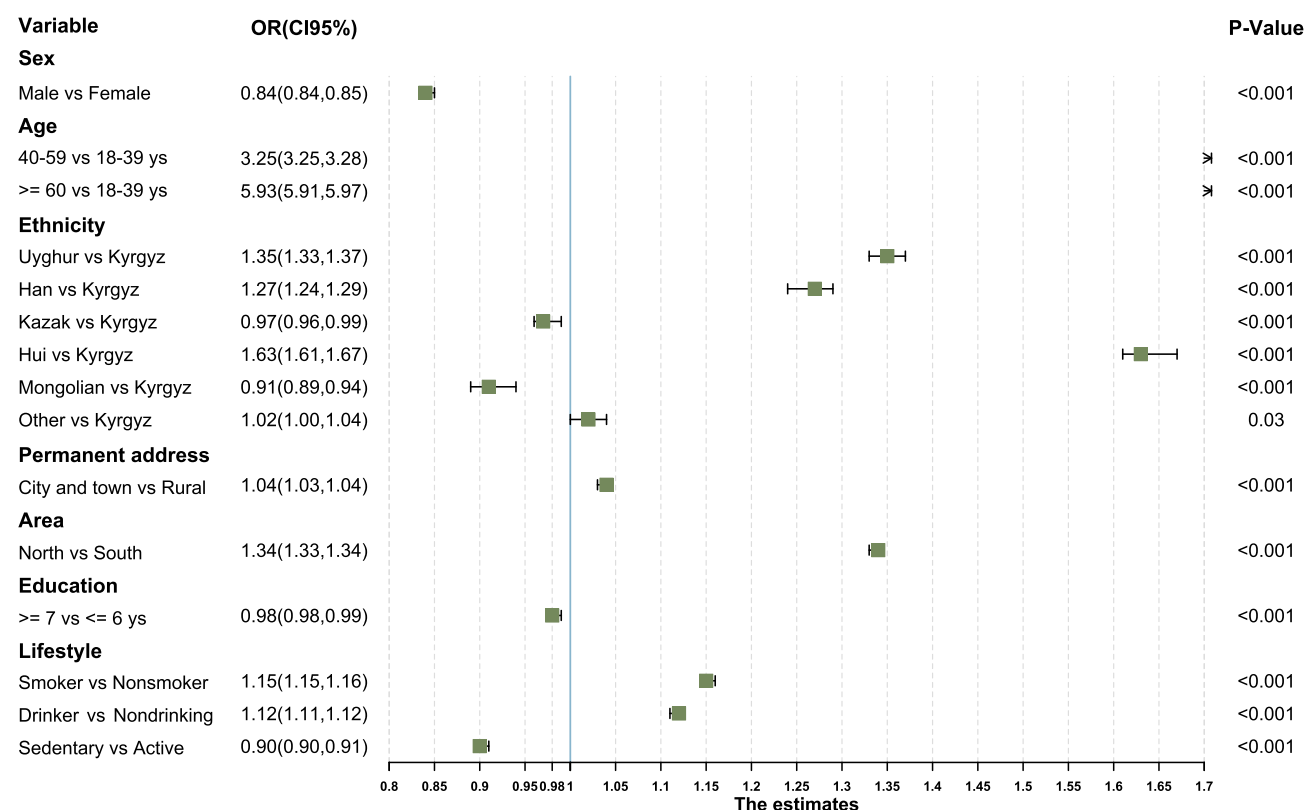| Variable	OR(CI95%)		P-Value
Sex			
Male vs Female	0.84(0.84,0.85)		<0.001
Age			
40-59 vs 18-39 ys	3.25(3.25,3.28)		<0.001
>= 60 vs 18-39 ys	5.93(5.91,5.97)		<0.001
Ethnicity			
Uyghur vs Kyrgyz	1.35(1.33,1.37)		<0.001
Han vs Kyrgyz	1.27(1.24,1.29)		<0.001
Kazak vs Kyrgyz	0.97(0.96,0.99)		<0.001
Hui vs Kyrgyz	1.63(1.61,1.67)		<0.001
Mongolian vs Kyrgyz	0.91(0.89,0.94)		<0.001
Other vs Kyrgyz	1.02(1.00,1.04)		0.03
Permanent address			
City and town vs Rural	1.04(1.03,1.04)		<0.001
Area			
North vs South	1.34(1.33,1.34)		<0.001
Education			
>= 7 vs <= 6 ys	0.98(0.98,0.99)		<0.001
Lifestyle			
Smoker vs Nonsmoker	1.15(1.15,1.16)		<0.001
Drinker vs Nondrinking	1.12(1.11,1.12)		<0.001
Sedentary vs Active	0.90(0.90,0.91)		<0.001

Figure 2 Odds ratios and 95% CIs for the associations of MetS with population and health behavior characteristics. The arrows in the figure indicate that the range of corresponding values exceed the plotting area.

(32.69%, 27.75% and 8.11%, *P*< 0.0001) than that in other ethnic groups. The prevalence of central obesity and high-BP of Mongolian were significantly higher (55.94% and 27.18%, *P*< 0.0001) than that in other ethnic groups.

The prevalence of MetS and its components were higher in smoking and drinking groups except for central obesity and high-BP. The prevalence of MetS and its components increased in participants with higher physical activity levels (Table 3).

Influential Factors Associated with MetS and Its Components

The logistic regression analysis was performed to identify factors affecting MetS and its components in Figures 2–7. The risk to have MetS was 1.19 (1/0.84) times less in women relative to that in men (95% confidence interval [CI] 0.84–0.85, *P*< 0.0001). The risk was 3.25 and 5.93 times higher in 40- to 59-year group and ≥60-years group than that in 18–39-year group (95% CI: 3.25–3.38, 5.91–5.97, *P*<0.0001). The risk was 1.35, 1.27, 1.63 times higher in Uyghur, Han, Hui than that in Kyrgyz (95% CI: 1.33–1.37,

1.24–1.29, 1.61–1.67, *P*<0.001); it was 1/0.97, 1/0.91 time lower than that in Kazak, Mongolian (95% CI: 0.96–0.99, 0.89–0.94). The risk was 1.04 times higher in cities and towns than that in rural subjects (95% CI: 1.03–1.04, *P*<0.001), and 1.34 times higher in north Xinjiang residents than that in south residents (95% CI: 1.33–1.34, *P*<0.001). The risk was 1/0.98 times lower in ≥7-year education group than that in 6 years and less education subjects (95% CI: 0.98–0.99, *P*<0.001). The risk was 1.15, 1.12 times higher in smoking and drinking groups than that in non-smoking and non-drinking groups (95% CI: 1.15–1.16, 1.11–1.12, *P*<0.001) (Figure 2).

The risk of central obesity was 2.38 (1/0.42) times higher in women relative to that in men (95% CI: 0.42–0.42, *P*< 0.001). Among ethnic groups, Uyghur and Mongolian had higher risk to have central obesity [OR (95% CI): 1.27 (1.25–1.29), 1.16 (1.14, 1.18)], while Han had less risk than others [OR (95% CI): 0.79 (0.79–0.81)]. The risk of central obesity was 1/0.98 times lower in 7 year or above education group (95% CI: 0.98–0.99, *P*<0.001). Living in cities and towns, Northerners, smokers and drinkers were more at risk of central obesity (Figure 3).

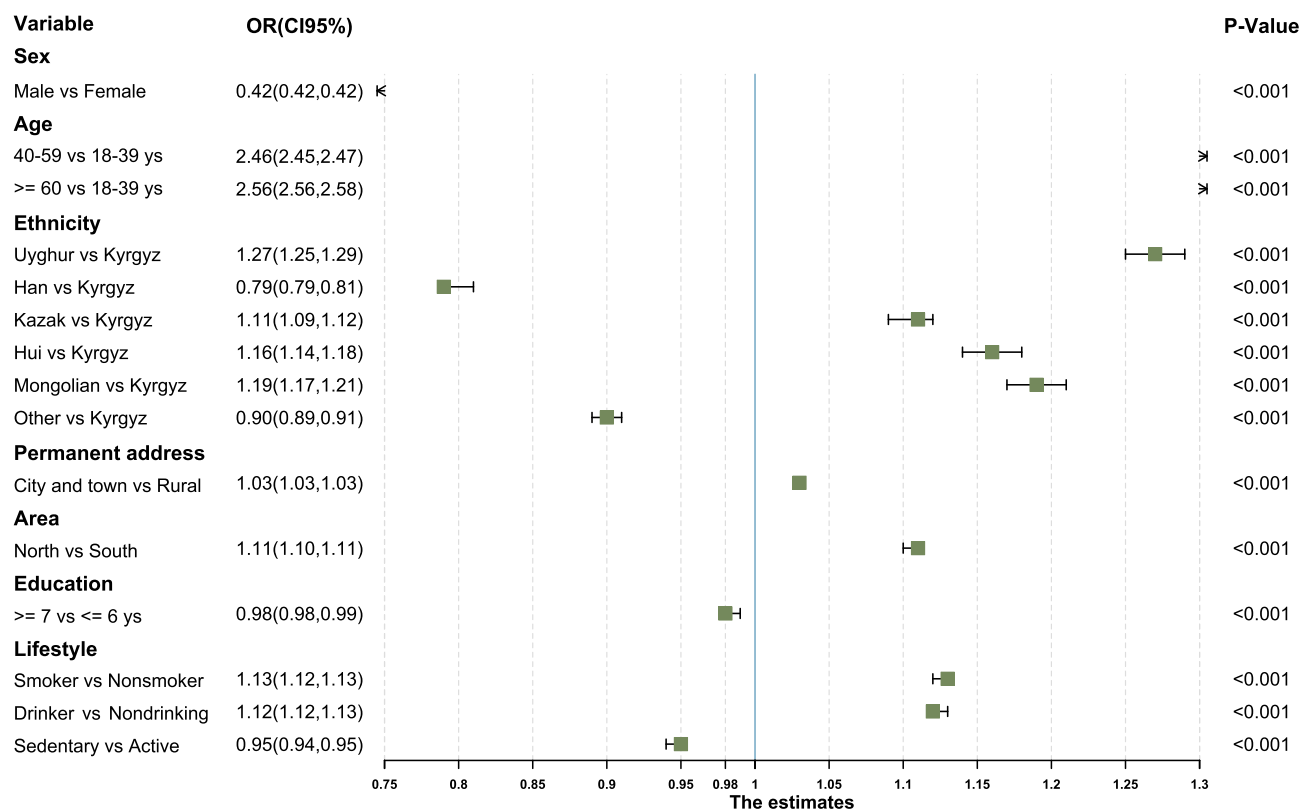| Variable	OR(CI95%)		P-Value
Sex			
Male vs Female	0.42(0.42,0.42)		<0.001
Age			
40-59 vs 18-39 ys	2.46(2.45,2.47)		<0.001
>= 60 vs 18-39 ys	2.56(2.56,2.58)		<0.001
Ethnicity			
Uyghur vs Kyrgyz	1.27(1.25,1.29)		<0.001
Han vs Kyrgyz	0.79(0.79,0.81)		<0.001
Kazak vs Kyrgyz	1.11(1.09,1.12)		<0.001
Hui vs Kyrgyz	1.16(1.14,1.18)		<0.001
Mongolian vs Kyrgyz	1.19(1.17,1.21)		<0.001
Other vs Kyrgyz	0.90(0.89,0.91)		<0.001
Permanent address			
City and town vs Rural	1.03(1.03,1.03)		<0.001
Area			
North vs South	1.11(1.10,1.11)		<0.001
Education			
>= 7 vs <= 6 ys	0.98(0.98,0.99)		<0.001
Lifestyle			
Smoker vs Nonsmoker	1.13(1.12,1.13)		<0.001
Drinker vs Nondrinking	1.12(1.12,1.13)		<0.001
Sedentary vs Active	0.95(0.94,0.95)		<0.001

The estimates

Figure 3 Odds ratios and 95% CIs for the associations of central obesity with population and health behavior characteristics.

The risk of high-TG levels was 1.54 times higher in men than that in women (95% CI: 1.53–1.54, $P< 0.001$). Among ethnic groups, Hui and Han had higher risk to have high-TG than other ethnic groups [OR (95% CI):1.67 (1.64–1.70), 1.62 (1.58, 1.64)], while Mongolian and Kazak had lower risk than others. The risk of high-TG was 1/0.94 times lower in ≥7-year education group (95% CI: 0.94–0.94, $P<0.001$). Living in cities and town, Northerners, smokers and drinkers were more at risk of high-TG (Figure 4).

The risk of low-HDL-C was 1.93 times higher in men than that in women (95% CI: 1.92–1.94, $P< 0.001$). Among ethnic groups, Hui and Han had higher risk to have low-HDL-C than other ethnic groups [OR (95% CI): 1.11 (1.08–1.14), 1.07 (1.05–1.10)], while Mongolian and Kazak had remarkably lower risk than others. The risk of low-HDL-C was 1.09 times higher in ≥7 year education group (95% CI: 1.08–1.10, $P<0.001$). Living in cities and towns, drinkers had higher and Northerners, smokers had lower risk to have low-HDL-C (Figure 5).

The risk of high-FBG was 1.15 times higher in men than that in women (95% CI: 1.14–1.15, $P< 0.001$).

Among ethnic groups, Hui and Han had higher risk to high-FBG than other ethnic groups [OR (95% CI)]. The risk of high-FBG was 1.25 (1.23–1.26), 1.04 (1.02–1.05), while Mongolian and Kazak had lower risk than others (Figure 6).

The risk of high-BP was 1.23 times higher in men than that in women (95% CI: 1.23–1.24, $P< 0.001$). Among ethnic groups, Kazak and Mongolian had more risk to high-BP than other ethnic groups [OR (95% CI): 1.28 (1.26–1.31), 1.15 (1.12–1.17)], while Han and Hui had lower risk than others. The risk of high-BP was 1.19 times higher in ≥7-year education group than that in 6 year and less education subjects (95% CI: 1.18–1.19, $P<0.001$). Living in cities and towns, smokers have less and Northerners, drinkers had more risk to high-BP (Figure 7).

Discussion

This study was carried out in Xinjiang, a typical multi-ethnic province in the world. Xinjiang is the largest province in China, with an area of 1.66 million square kilometers, accounting for 1/6 of China's total land area. There are 55 ethnic groups well mixed in Xinjiang, with
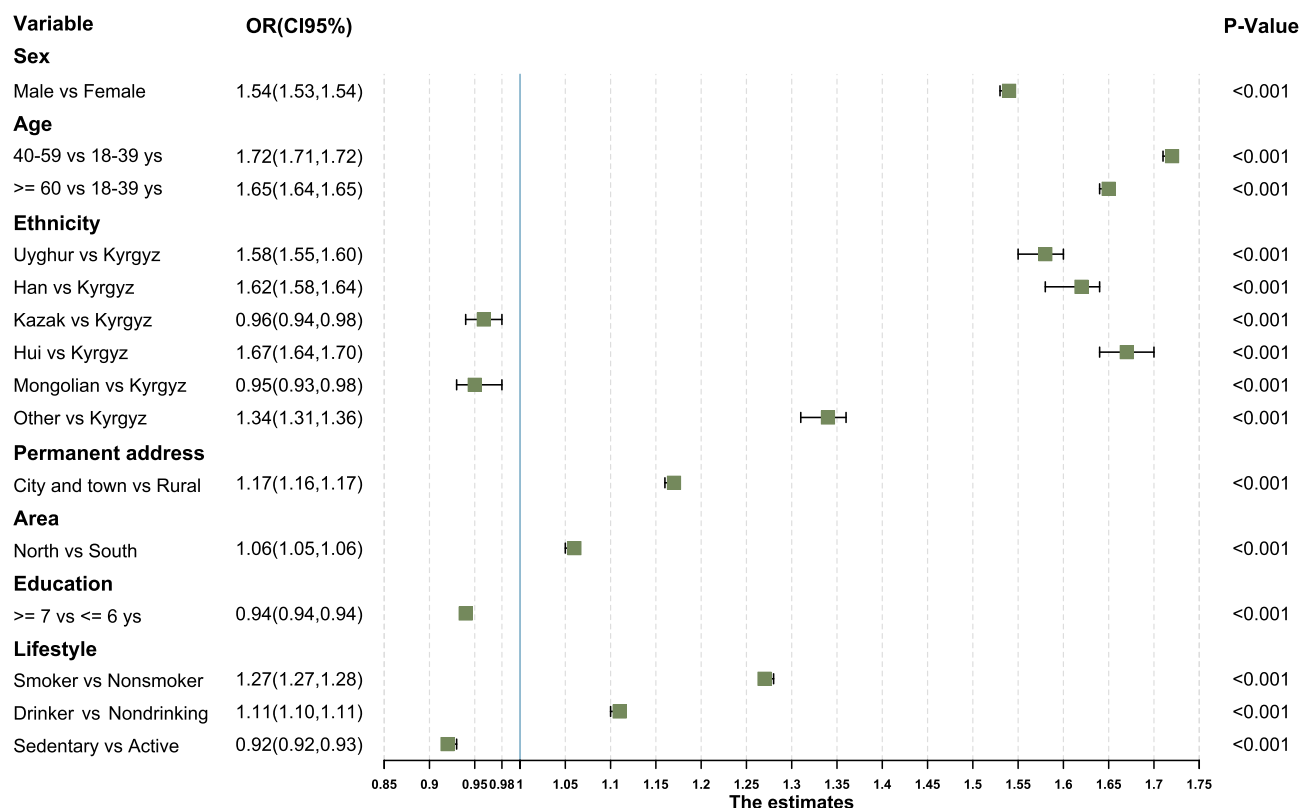
Variable	OR(CI95%)		P-Value
Sex			
Male vs Female	1.54(1.53,1.54)		<0.001
Age			
40-59 vs 18-39 ys	1.72(1.71,1.72)		<0.001
>= 60 vs 18-39 ys	1.65(1.64,1.65)		<0.001
Ethnicity			
Uyghur vs Kyrgyz	1.58(1.55,1.60)		<0.001
Han vs Kyrgyz	1.62(1.58,1.64)		<0.001
Kazak vs Kyrgyz	0.96(0.94,0.98)		<0.001
Hui vs Kyrgyz	1.67(1.64,1.70)		<0.001
Mongolian vs Kyrgyz	0.95(0.93,0.98)		<0.001
Other vs Kyrgyz	1.34(1.31,1.36)		<0.001
Permanent address			
City and town vs Rural	1.17(1.16,1.17)		<0.001
Area			
North vs South	1.06(1.05,1.06)		<0.001
Education			
>= 7 vs <= 6 ys	0.94(0.94,0.94)		<0.001
Lifestyle			
Smoker vs Nonsmoker	1.27(1.27,1.28)		<0.001
Drinker vs Nondrinking	1.11(1.10,1.11)		<0.001
Sedentary vs Active	0.92(0.92,0.93)		<0.001

The estimates

Figure 4 Odds ratios and 95% CIs for the associations of high-TG with population and health behavior characteristics. The arrows in the figure indicate that the range of corresponding values exceed the plotting area.

a resident population of 24.8676 million. The top 6 ethnic groups in Xinjiang are Uygur, Han, Kazakh, Hui, Mongolian and Kyrgyz. Xinjiang is divided into Northern and Southern Xinjiang because of Tianshan Mountain in the middle. Due to the geographical location and the topography of the Taklimakan Desert, which is the second largest desert in the world in southern Xinjiang, the climates of north and south Xinjiang are very different with temperate continental semi-arid in Northern and arid climate in Southern Xinjiang respectively. Geographical environment and ethnic origin may affect the occurrence and development of metabolic diseases. Therefore, this study not only analyzed the common demographic characteristics for people to live in, but also performed analysis of six ethnic groups in both Northern and Southern Xinjiang. Although the objects of this study were one comprehensive and multi-ethnic population in Xinjiang, considering the huge number of the sampling size, the analysis of each individual subgroup would still be valid to reflect true statistical outcome.

This study showed the prevalence of MetS in this large comprehensive multi-ethnic population in Xinjiang was 20.85%, which was consistent with that of the world population.[28] This rate is lower than those of Western countries, United States,[6] other Asian countries, and Chinese studied on other area of China; but higher than that in rural areas in Xinjiang reported in a study conducted previously in multi-ethnic adults in 2017 (14.43%).[12] It is worth noting that results of previous studies demonstrated that the prevalence of MetS in mono-ethnic population was always higher than that in mixed or multi-ethnic population. Reason for such difference may be that prevalence of MetS is always low in certain minority ethnic groups to contribute to the average prevalence of multi-ethnic population. This study demonstrated that Kazakh, Mongolian and Kyrgyz had lower prevalence of MetS.

Interestingly, the results showed the lowest prevalence of MetS in Kyrgyz with the highest smoking and drinking rates and the lowest physical activity rate. Lifestyle here did not play a major role in determining the prevalence of MetS in Kyrgyz. Similar phenomenon was observed in Kazak and Mongolian too. Compared with other ethnic groups, these groups had higher BMI, WC, SBP but lower TC and TG. It is speculated that genetic background of these ethnic groups may play
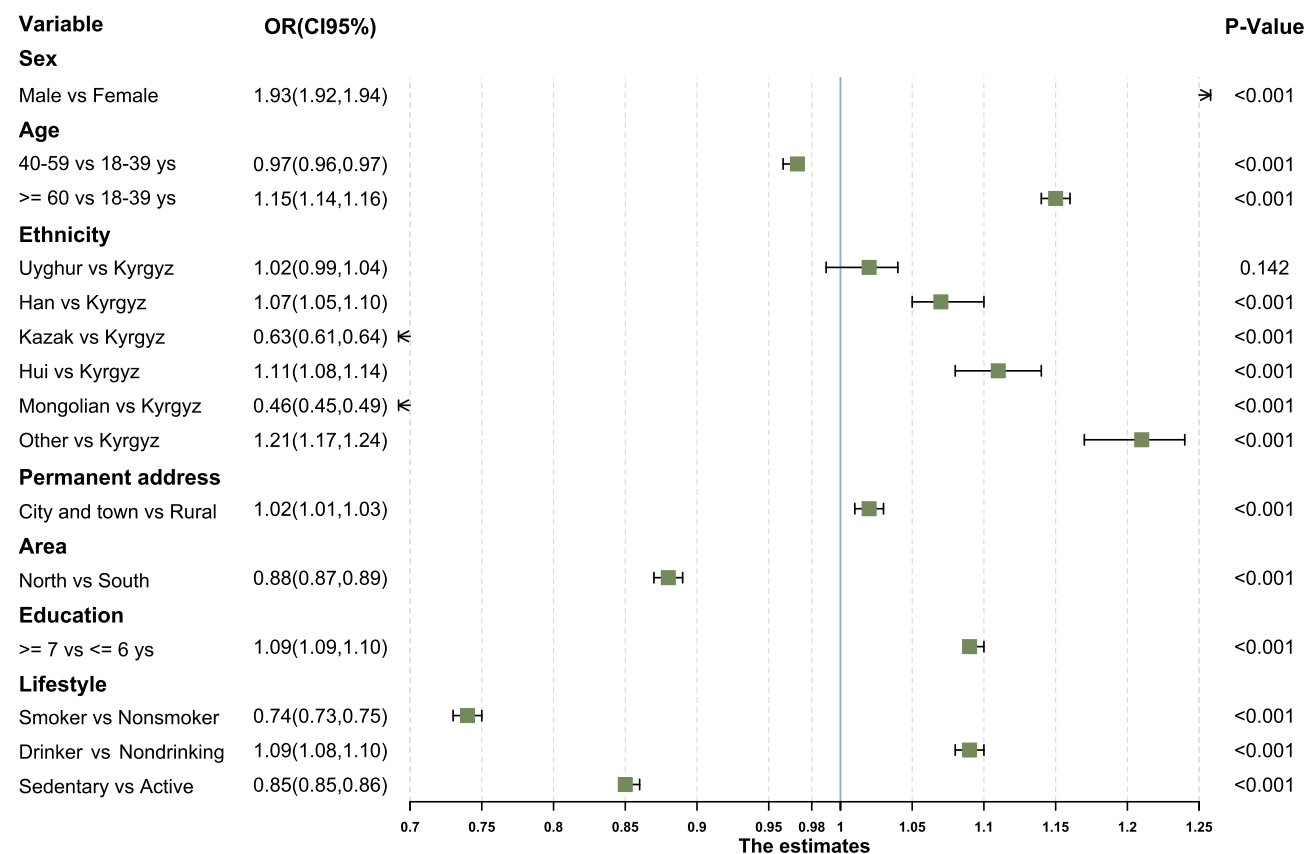
Variable	OR(CI95%)		P-Value
Sex			
Male vs Female	1.93(1.92,1.94)		<0.001
Age			
40-59 vs 18-39 ys	0.97(0.96,0.97)		<0.001
>= 60 vs 18-39 ys	1.15(1.14,1.16)		<0.001
Ethnicity			
Uyghur vs Kyrgyz	1.02(0.99,1.04)		0.142
Han vs Kyrgyz	1.07(1.05,1.10)		<0.001
Kazak vs Kyrgyz	0.63(0.61,0.64)		<0.001
Hui vs Kyrgyz	1.11(1.08,1.14)		<0.001
Mongolian vs Kyrgyz	0.46(0.45,0.49)		<0.001
Other vs Kyrgyz	1.21(1.17,1.24)		<0.001
Permanent address			
City and town vs Rural	1.02(1.01,1.03)		<0.001
Area			
North vs South	0.88(0.87,0.89)		<0.001
Education			
>= 7 vs <= 6 ys	1.09(1.09,1.10)		<0.001
Lifestyle			
Smoker vs Nonsmoker	0.74(0.73,0.75)		<0.001
Drinker vs Nondrinking	1.09(1.08,1.10)		<0.001
Sedentary vs Active	0.85(0.85,0.86)		<0.001

Figure 5 Odds ratios and 95% CIs for the associations of low-HDL-C with population and health behavior characteristics. The arrows in the figure indicate that the range of corresponding values exceed the plotting area.

a dominant role in determining prevalence of MetS. In this study, higher HDL-C and less high-TG risk were found in these three ethnic groups, suggesting that hereditary factors might facilitate the production of HDL-C and metabolism of TG to reduce MetS occurrence. Coincidentally, in 2018, Zhang et al[29] identified a rare frame shift variant in the LIMA1 (also known as EPLIN or SREBP3) gene in Kazakh ethnicity with inherited low LDL-C and reduced cholesterol absorption. Several other studies proved that Kazak, Mongolian and Kyrgyz had closer genetic background among them than that in other ethnic groups.[30–33] Therefore, it is possible that Mongolian and Kyrgyz people may have this unique genetic background too. This is worthy of further study to clarify this issue.

In terms of gender, the prevalence of MetS in women was lower than that in men, but multivariate regression analysis showed that the risk of MetS was higher in women than that in men under adjusting age, ethnic group, region and lifestyle. It is consistent with previous research.[12,14,34] Postmenopausal status of women increased the prevalence of MetS because of IR and central obesity.[35]

From living in urban or rural area, the prevalence and risk of MetS in urban residents were higher than that in rural residents. With rapid development of urbanization, people's lifestyle and diet are changing too. From the univariate and multivariate analysis of the influencing factors and MetS components in this study, although there were more people doing physical activity in urban area and less smoking population, the rate of MetS was significantly higher in urban than that in rural residents. High-drinking population in urban residents contributed to the high prevalence of MetS as drinking may cause high-TC, low-HDL-C, which promoted MetS.[36–38] Alcohol restriction should be considered in the health education of urban residents.

Based on the geographical location, the prevalence of MetS in Northern Xinjiang was much higher than that in Southern Xinjiang, and the risk for MetS was also higher in Northern than that in Southern Xinjiang residents. Northerners were more likely to suffer from central obesity, high-TG, high-BP and high-BFG, but had a lower risk of pathological high- and low-density lipoproteins. In fact, residents in Northern Xinjiang ate high-calorie food and drank more alcohol than residents in Southern Xinjiang
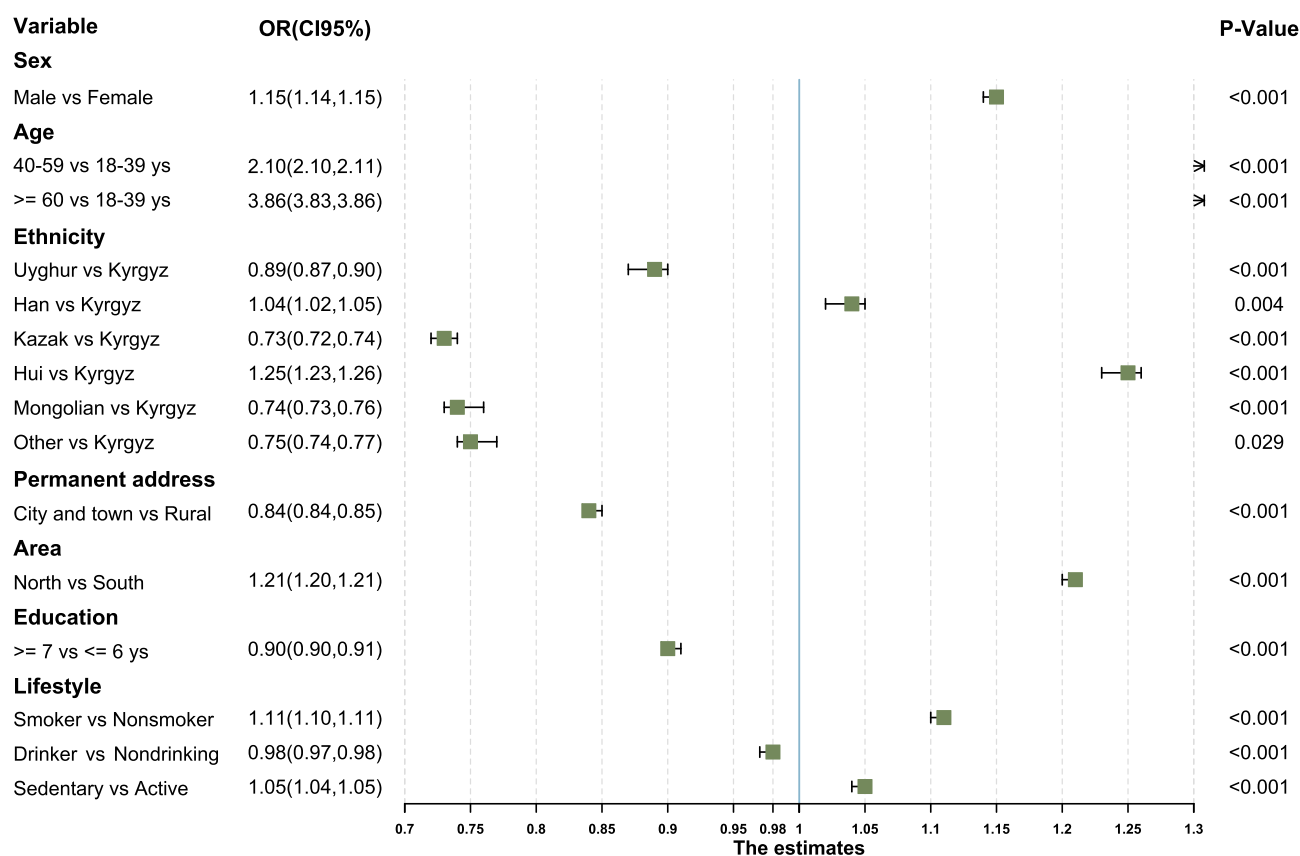
Variable	OR(CI95%)		P-Value
Sex			
Male vs Female	1.15(1.14,1.15)		<0.001
Age			
40-59 vs 18-39 ys	2.10(2.10,2.11)		<0.001
>= 60 vs 18-39 ys	3.86(3.83,3.86)		<0.001
Ethnicity			
Uyghur vs Kyrgyz	0.89(0.87,0.90)		<0.001
Han vs Kyrgyz	1.04(1.02,1.05)		0.004
Kazak vs Kyrgyz	0.73(0.72,0.74)		<0.001
Hui vs Kyrgyz	1.25(1.23,1.26)		<0.001
Mongolian vs Kyrgyz	0.74(0.73,0.76)		<0.001
Other vs Kyrgyz	0.75(0.74,0.77)		0.029
Permanent address			
City and town vs Rural	0.84(0.84,0.85)		<0.001
Area			
North vs South	1.21(1.20,1.21)		<0.001
Education			
>= 7 vs <= 6 ys	0.90(0.90,0.91)		<0.001
Lifestyle			
Smoker vs Nonsmoker	1.11(1.10,1.11)		<0.001
Drinker vs Nondrinking	0.98(0.97,0.98)		<0.001
Sedentary vs Active	1.05(1.04,1.05)		<0.001

The estimates

Figure 6 Odds Ratios and 95% CIs for the Associations of Elevated-FBG with population and health behavior characteristics. The arrows in the figure indicate that the range of corresponding values exceed the plotting area.

due to the cold climate in the north. Outdoor exercise was less in the North than in the South, which was consistent with the results of previous studies on MetS of North and South residents.[11] Southerners were more likely to develop low-HDL-C than Northern residents. Kazakh, Mongolian with probably anti-lipid genes are mostly living in northern Xinjiang to contribute to the above results.

From the perspective of educational background, the prevalence of MetS in group with ≥ 7 years of educational experience was higher than that in those ≤ 6 years of education. However, after adjusting for ages, ethnic areas and living habits, the risk was lower in ≥ 7 years of education than that in ≤ 6 years education group. Previous studies showed that higher level of education had a higher score of health literacy.[39] The results of this study showed that the rate of smoking and drinking was higher, and the rate of regular exercise was lower in ≥ 7 years of education group. Through the analysis of various components of metabolic diseases, the risk of Low-HDL-C, Elevated-BP was higher in subjects of ≤ 6 years education, and the risk of central obesity, high-TG and high-FBG was

lower in ≥ 7 years of education group. The possible reasons are still unknown.

Interestingly, in this study, there were inconsistencies among the results of this big data analysis of unhealthy lifestyles such as smoking, drinking and lack of exercise. People who smoked, drank, and took regular exercise had a lower prevalence of MetS than that in non-smoking, non-drinking people, and those who did not take regular exercise . Through the multivariate analysis, the risk of MetS in the smoking and drinking populations was higher than that in non-smokers and non-drinkers, indicating that the risk of MetS was greatly affected by other factors, such as gender, ages, exercise, etc. In summary, the relationship between lifestyle and MetS is not fully established yet. This may be caused by the complex compositions of subgroups within the big comprehensive population.

Some ethnic groups, such as Kyrgyz, Mongolian and Kazak may have the ability to resist risk factors of MetS due probably to specific genetic factors. Further exploration of genetic contribution to MetS is warranted to clarify the relationship between MetS and genetic background of Kazakh, Mongolian and Kyrgyz in order to
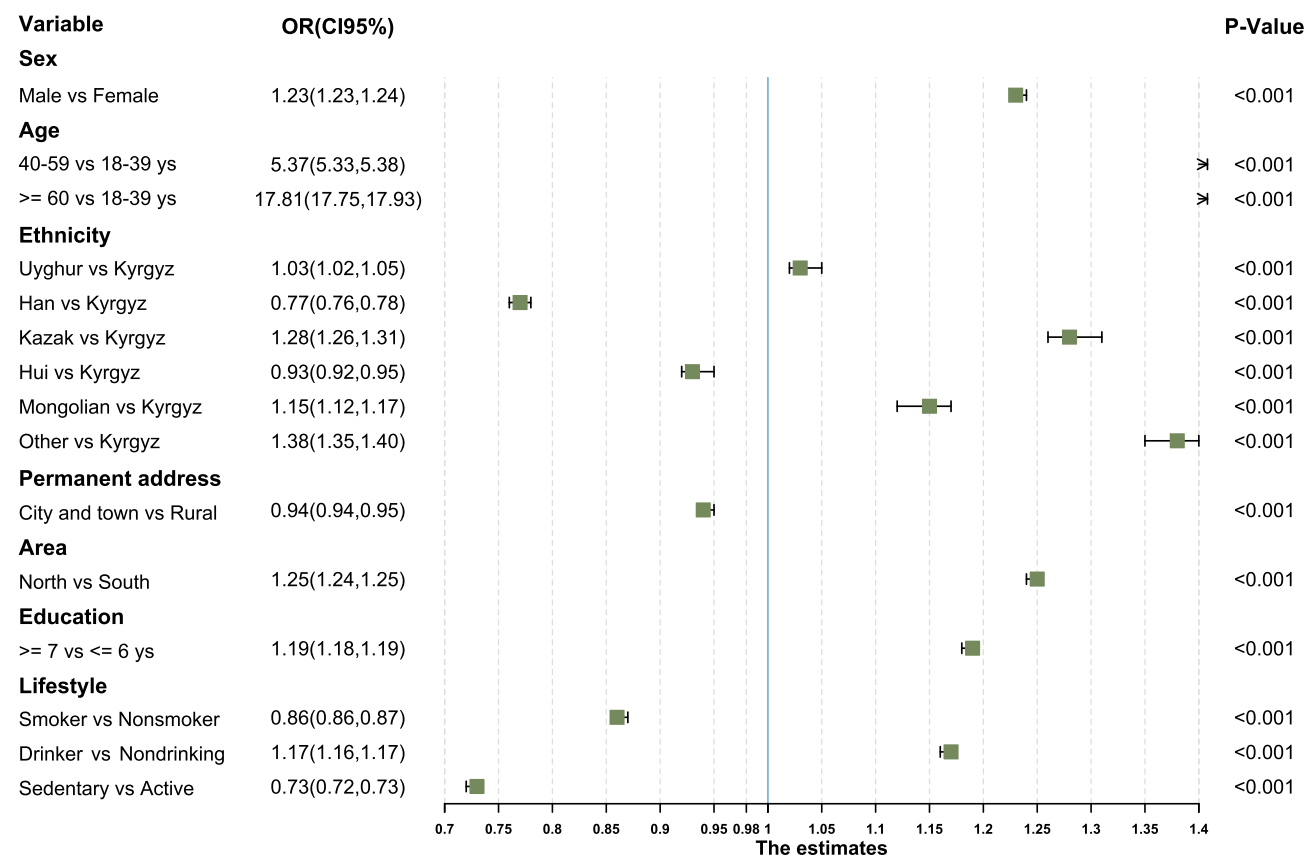
Variable	OR(CI95%)		P-Value
Sex			
Male vs Female	1.23(1.23,1.24)		<0.001
Age			
40-59 vs 18-39 ys	5.37(5.33,5.38)		<0.001
>= 60 vs 18-39 ys	17.81(17.75,17.93)		<0.001
Ethnicity			
Uyghur vs Kyrgyz	1.03(1.02,1.05)		<0.001
Han vs Kyrgyz	0.77(0.76,0.78)		<0.001
Kazak vs Kyrgyz	1.28(1.26,1.31)		<0.001
Hui vs Kyrgyz	0.93(0.92,0.95)		<0.001
Mongolian vs Kyrgyz	1.15(1.12,1.17)		<0.001
Other vs Kyrgyz	1.38(1.35,1.40)		<0.001
Permanent address			
City and town vs Rural	0.94(0.94,0.95)		<0.001
Area			
North vs South	1.25(1.24,1.25)		<0.001
Education			
>= 7 vs <= 6 ys	1.19(1.18,1.19)		<0.001
Lifestyle			
Smoker vs Nonsmoker	0.86(0.86,0.87)		<0.001
Drinker vs Nondrinking	1.17(1.16,1.17)		<0.001
Sedentary vs Active	0.73(0.72,0.73)		<0.001

The estimates: 0.7 0.75 0.8 0.85 0.9 0.95 0.98 1 1.05 1.1 1.15 1.2 1.25 1.3 1.35 1.4

Figure 7 Odds Ratios and 95% CIs for the Associations of Elevated-BP with population and health behavior characteristics. The arrows in the figure indicate that the range of corresponding values exceed the plotting area.

explore the mechanism of MetS occurrence and development.

Conclusion

Both genetic and environmental factors affect the prevalence and development of MetS. The prevalence of MetS in Kazakh, Mongolian and Kyrgyz was less even though the proportion of risk factors and the rate of unhealthy lifestyles were higher. The regular relationship between lifestyle and common risk factors was established in this large-scale comprehensive multiethnic population analysis. In addition, the prevention of central obesity was strongly recommended, especially in ≥ middle-aged women. Han and Hui should pay particular attention to hyperglycemia; northern Xinjiang residents should be specially encouraged to take more exercise, and urban residents should carefully restrict their alcohol consumption.

Abbreviations

MetS, metabolic syndrome; WC, waist circumference; SBP, DBP, systolic-diastolic blood pressure; TC, total cholesterol; TG, triglyceride; HDL-C, high-density lipoprotein; LDL-C, low-density lipoprotein; FBG, fasting blood glucose; ATP III, modified Adults Treatment Panel.

Acknowledgments

Disclosure

The authors report no conflicts of interest in this work.

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