Original Article

The influence of diet and behaviour on metabolic syndrome and the prevalence of metabolic syndrome according to different definitions in west China

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Background and Objectives: This study investigated the updated prevalence of metabolic syndrome among adults in West China and the influence of diet and behaviour on metabolic syndrome. **Methods and Study Design:** A cross-sectional survey was conducted from 2013-2014, and multi-stage stratified clustering sampling was applied in 12 counties of Sichuan province. Data regarding metabolic syndrome and style risk factors were collected through interviewer-administered questionnaires, and physical measurements were recorded following a standardized protocol. Logistic regression models were used to explore the association between metabolic syndrome and its risk factors. **Results:** A total of 7,131 adults participated. The prevalence of metabolic syndrome was 16.9% and 23.8% according to the International Diabetes Federation criteria and the consensus definition, respectively. The International Diabetes Federation criteria failed to identify 28.8% of the participants identified by the consensus definition. The odds ratios (ORs) of suffering from Metabolic syndrome in people eating pork every week compared with at lower frequencies, people eating more than 100 g of red meat/day, people with more sedentary behaviour per day, and people consuming at least 20 cigarettes/day were 1.76 (1.09-2.84), 1.28 (1.01-1.62), 1.03 (0.99-1.07), and 1.46 (1.12-1.92), respectively, according to the consensus definition, and 1.51 (1.09-2.10), 1.4 (1.14-1.72), 1.07 (1.02-1.13), and 1.5 (1.16-1.94), respectively, based on the International Diabetes Federation criteria. **Conclusions:** The International Diabetes Federation criteria were less sensitive in identifying metabolic syndrome than the consensus definition. More sedentary behaviour, smoking ≥20 cigarettes per day, and a higher frequency of pork intake increased the risk of metabolic syndrome in this study.

Key Words: sedentary, smoking, dietary, prevalence and influencing factors, metabolic syndrome

INTRODUCTION

In 2012, the World Health Organization (WHO) reported that cardiovascular disease (CVD) was responsible for 17.5 million deaths, accounting for 31.3% of all deaths worldwide. In China, the incidence of CVD[1] as well as stroke[2] increased in 2013. The CVD mortality rate in Sichuan province, West China, increased from 2002 to 2012,[3] and CVD ranked first in years of life lost due to different types of disease.[4]

Metabolic syndrome (MS) is a cluster of the most dangerous risk factors for heart attack including diabetes (DB), elevated fasting plasma glucose (FPG) level, abdominal obesity, high cholesterol and high blood pressure (HBP).[5-8] However, different diagnostic criteria for MS have been proposed by various international institutions.[9-13] Currently, the two most widely used definitions are from the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) and the International Diabetes Federation (IDF). However, only the IDF definition included abdominal obesity as a requirement and incorporated waist circumference (WC) measurements with ethnicity/race-specific cut-offs. In contrast, the NCEP ATP III and the American Heart Association/National Heart, Lung, and Blood Institute (AHA/NHLBI) adopted WC as a simple screening measurement with fixed cut-off values. Some researchers believed that a consensus definition[14] that incorporated both the IDF and the AHA/NHLBI criteria might be the most appropriate for practical use in clinical medicine. Some

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studies have indicated that using different definitions might lead to a different prevalence.[15-17]

There is a lack of relevant research about the risk factors and prevalence of MS in West China. The current study investigated the updated prevalence of MS in 2013-2014 in West China, using the IDF criteria and the consensus definition separately; assessed the prevalence of related diseases (i.e., HBP, DB, dyslipidaemia (DY), and central obesity); and analysed the related dietary style and behavioural risk factors to explore positive measures for health policy planning.

METHODS

A cross-sectional survey with random samples was conducted from 2013-2014. This study applied a multi-stage, stratified cluster sampling method across 12 counties of Sichuan province. The sampling was based on the economic status and population density of the region. Data regarding MS and its risk factors were collected from adults (aged 18 years and above) via interviewer-administered questionnaires and physical (i.e., biochemical) measurements according to a standardized protocol. Nonresident, pregnant women, adults with hearing and visual impairments, other cognitive disorders were excluded.

Sample

In total, 7,131 adults (2,937 men and 4,194 women) participated in this study. Figure 1 shows the population pyramid of the samples after being weighted.

The Medical Ethics Committee of the Chinese National Center for Chronic and Non-communicable Disease Control and Prevention (NCNCD) approved this study (ethical approval number 201307). Written informed consent was obtained from the participants.

Physical measures

The questionnaires addressed information about participants' demographic characteristics including smoking, alcohol consumption, diet, physical activity, blood pressure (BP), blood glucose, blood lipids and other health conditions. The physical examination measured participants' height, weight, WC, and BP. A biochemical test, using fasting blood samples typically drawn between 7 and 8 AM, and an oral glucose tolerance test (except among participants with DB) were performed. Dietary information was collected using a food-frequency questionnaire. All participants were asked to avoid vigorous exercise and any food intake other than water 10 to 12 hours before the examination. The blood glucose test samples were immediately centrifuged within 2 hours and analysed within 48 hours. The hexokinase, glucose oxidase or glucose dehydrogenase method was used to measure plasma glucose levels. BP was measured using the left arms of participants in a seated position. This recording was averaged and based on the China Hypertension Prevention Guidelines (2010 Edition). WC was measured according to the WHO's recommended method, using anthropometric tape to measure midway between the lowest rib and the iliac crest. Emergency doctors, equipment and related drugs were provided in the examination field.

Quality control

All of the investigators received strict and uniform training. All of the equipment was inspected. Designated staff members assayed all of the biochemical indices. Approximately 10% of the questionnaires in every county were extracted for quality control, and 5% of the BP values were extracted. All of the quality control results were input online and were managed by senior project staff members who could immediately correct any errors as needed.

Statistical analyses

The collected data were input using specially designed software and analysed via SAS Version 9.3 (SAS institute Inc. Cary, NC, USA). During the analysis, the complex sample data were adjusted by sampling weight, no-response weight and post-stratification weight according to the total population, as well as the sex ratio and age ratio of Sichuan province in 2013. As a result, the data

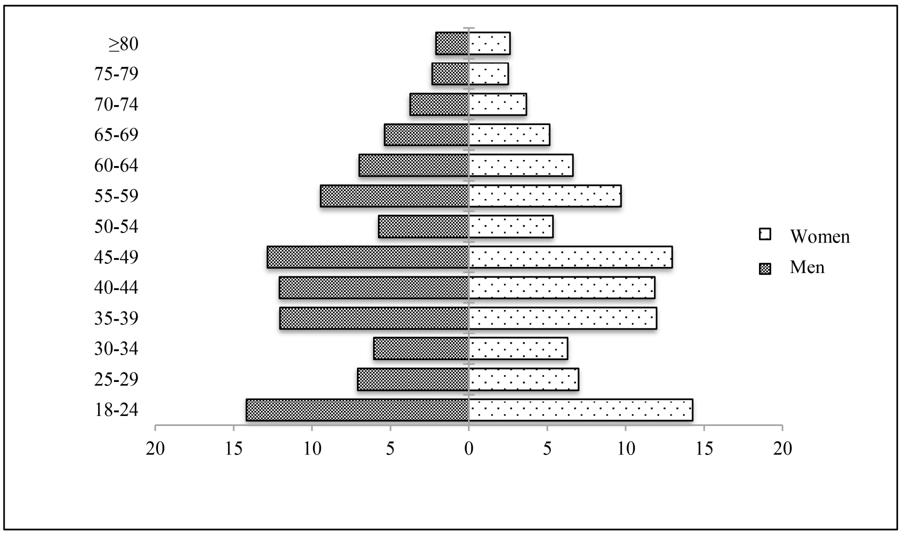

Figure 1. Population Pyramid of Sample after weighting. The weight process took account of sampling weight, no-response weight and the post-stratification weight according to the total population (sex and age ratio).

represented the demographics of Sichuan province in West China. Continuous variables were described with means (95% confidence intervals [CIs]). The relationships between the diseases and their risk factors were explored by logistic regression and were described as ORs and *p*-values. Rao-Scott χ^2 test was used to compare the rates between multiple groups. When building the models, adults with self-reported Hypertension, diabetes or dyslipidemia, plus dietary or action change were not excluded.

Definitions and components of MS

The IDF criteria (2006)[13] used central obesity as a prerequisite for MS and specified ethnicity-specific waist circumference values (Chinese people waist circumference: ≥90 centimetre (cm) for men and ≥80 cm for women). As the Chinese national "weight criteria for adults" standard (≥90 cm for men and ≥85 cm for women) was recently published in 2013 and was the first official Chinese definition, this study adopted the Chinese national standard. Furthermore, participants had to meet at least two of the following criteria to be considered to have MS: (a) elevated triglycerides ≥1.7 mmol/L or use of treatment specifically for triglycerides; (b) reduced high-density lipoprotein (HDL) cholesterol (<1.03 mmol/L in men or <1.29 mmol/L in women) or use of treatment specifically for HDL cholesterol; (c) elevated BP (systolic BP ≥130 mmHg or diastolic BP ≥85 mmHg) or treatment for HBP; or (d) elevated FPG (≥5.6 mmol/L) or previous diagnosis of type 2 DB. According to the consensus definition, abdominal obesity was considered a component of MS but not a precondition. Meeting any three of the following criteria constituted an MS diagnosis based on this definition: abdominal obesity or (a), (b), (c), or (d) from the criteria described above.

RESULTS

Population health status

In total, 7,131 adults (≥18 years old) were investigated between August 2013 and February 2014. The average age was 45.5 (95% CI=41.5-49.5) years. The average WC and HDL cholesterol level of men, representing two MS component values, were higher and lower than the corresponding values in women, respectively. The average triglyceride, systolic BP and diastolic BP values for both sexes were lower than MS defined values, while the average FPG level was a little higher than MS defined values (Table 1). Other indices of diet and behaviour in our study differed significantly by sex; for example, daily cigarette use among current smokers, daily intake of alcohol, and intake of red meat were 16.3 (95% CI=15.4-17.1), 11.8 g (95% CI=8.7-15), and 147.6 g (95% CI=119.6-175.7), respectively, among men and 9.3 (95% CI=6.7-11.9), 0.7 g (95% CI=0.5-0.9), and 103.6 g (95% CI=88.5-118.7), respectively, among women.

Prevalence

The age-sex-region-standardized prevalence rates of MS according to the consensus definition and the IDF criteria were 23.8% (95% CI=20.9%-26.7%) and 16.9% (95% CI=14.4%-19.4%), respectively. The test of consistency of MS prevalence based on the two definitions showed a Kappa value of 0.7808 (Figure 2). Although the definitions were highly consistent, a total of 8.1% of adults were diagnosed with MS according to the consensus definition but not according to the IDF criteria. This finding indicated that the IDF criteria failed to identify 28.9% of the participants who were identified using the consensus definition. In other words, of the cases identified by the consensus definition, 71.1% had central obesity. Of the cases not identified by the IDF criteria, 10.1% had more than 3 MS components that did not include central obesity. In contrast, the consensus definition agreed in all cases when a patient was diagnosed using the IDF criteria.

In addition, the prevalence of HBP, DB, DY, and central obesity was 27.7% (95% CI=21.7%-33.7%), 10.3% (95% CI=8.2%-12.4%), 26.2% (95% CI=21.4%-31.1%), and 26.5% (95% CI=21.6%-31.4%), respectively. Moreover, the prevalence of other possible risk factors such as current smoking, alcohol consumption over the past year, excessive consumption of red meat (>100 g/day), insufficient intake of vegetables and fruits (<400 g/day), and insufficient physical activity (exercise <3 times/week) was 27.4% (95% CI=22.9%-31.9%), 34.3% (95% CI=30.6%-38.1%), 53.9% (95% CI=45.3%-62.5%), 42.6% (95% CI=33.1%-52%), and 11.1% (95% CI=7.2%-14.9%), respectively (Figure 3).

For self-reported patients of HBP, DB and DY, the rates of taking medication, diet or exercise therapy were 86.5%, 98.5%, 69.5% respectively. And the effective control rates were 19.1%, 37.5%, 34.3%. For self-reported patients of HBP, DB and DY, the average of Systolic blood pressure, diastolic blood pressure and fasting glucose in treatment group were 10 mmHg, 7 mmHg and 7.7

Table 1. Description of MS components in our sample after weighting

Variables	Mean†	95% CI
Waist circumference men, cm	82.3	81.1-83.5
Waist circumference women, cm	79.8	78.3-81.3
Triglyceride (TG), mmol/L	1.4	1.3-1.5
High-density lipoprotein cholesterol (HDL-C) men, mmol/L	1.4	1.3-1.5
High-density lipoprotein cholesterol (HDL-C) women, mmol/L	1.5	1.4-1.5
Systolic BP (SBP), mmHg	129	125-132
Diastolic BP (DBP), mmHg	77.3	75.4-79.2
Fasting plasma glucose (FPG), mmol/L	5.6	5.6-5.7

MS: metabolic syndrome.
†The mean analysis accounted for the sampling weight, no-response weight and the post-stratification weight according to the total population (sex and age ratio).

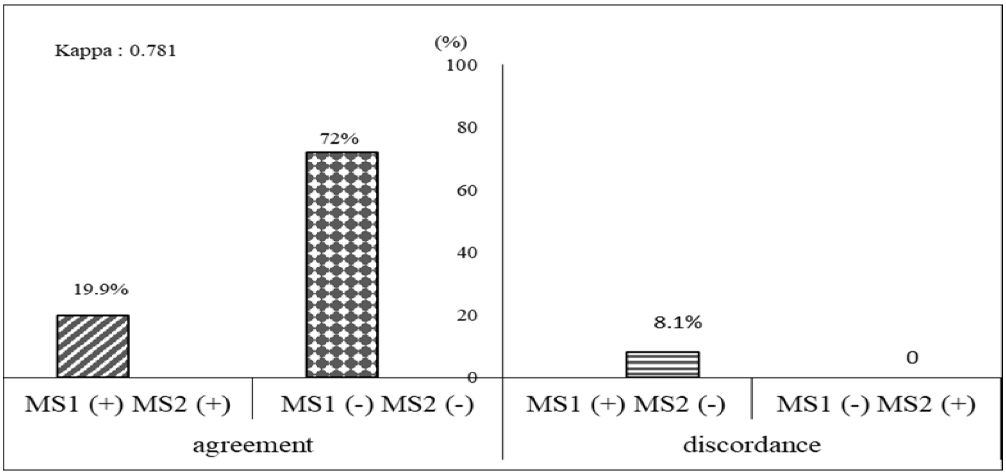

Figure 2. The consistency test of MS (defined by two different criteria). 1) MS1, Metabolic Syndrome (MS) by consensus definition; MS2, MS by International Diabetes Federation (IDF). 2) A total of 8.1% adults were diagnosed with MS according to the consensus definition but not according to the IDF criteria. Of the cases not identified using the IDF criteria, 10.1% had more than 3 MS components not including central obesity. In contrast, the consensus definition agreed in all cases when a patient was diagnosed using the IDF criteria.

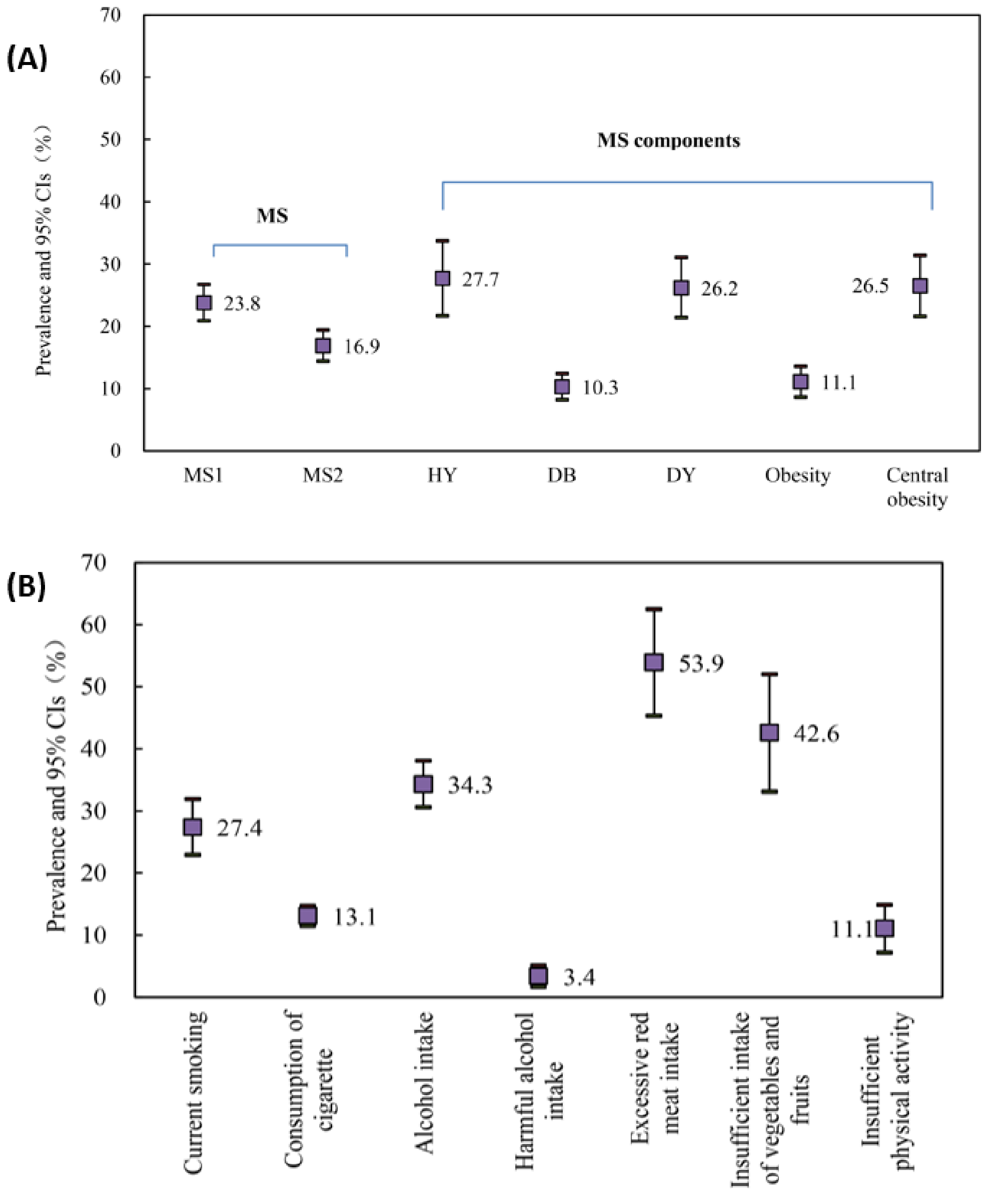

Figure 3. The prevalence of MS and other related factors. 1) MS1, Metabolic Syndrome (MS) by consensus definition; MS2, MS by International Diabetes Federation. 2) The prevalence calculating process took account of sampling weight, no-response weight and the post-stratification weight according to the total population (sex and age ratio).

gram lower than no-treatment group respectively.

When comparing the correlation of MS1 (by the consensus definition) and MS2 (by IDF criteria) to CVD and DB, there were 14 more CVD and 183 more DB patients by self-reported in the objects with MS1 than the objects with MS2.

Exploration of related factors

We created two logistic regression models (samples 7043) to explore the factors related to MS. MS was separately specified as the dependent variable according to the consensus definition (first model) and the IDF criteria (second model). Moreover, the independent variables were divided into continuous and categorical variables. Age, daily hours of sedentary behaviour, heart rate, and LDL-CH were considered continuous variables. The frequency of intake of pork, beef, mutton, poultry and alcoholic drinks was analysed as a categorical variable. In the first model, basic demographic characteristics (i.e., age, sex, nationality and region), physiological features (i.e., heart rate, LDL cholesterol), and dietary and other behavioural factors (i.e., sedentary time, regular exercise, cigarette use, and the intake of wine, red meat, salt, fruit juice, pork, beef or mutton, and poultry) were significantly associated with MS. In the second model, the intake of wine was not included.

After adjusting for basic demographic characteristics, physiological features and other related behavioural factors, we found the following relationship between diet and MS. In both model 1 and model 2, the ORs of the dietary factors had the same direction of effect (Table 2). For people eating pork every week (1-7 days/week) compared with lower frequencies (1-3 days/month or 1-11 days/year), the ORs of suffering from MS were 1.76 (1.09-2.84) and 1.51 (1.09-2.10) in the first and second models, respectively. A completely pork-free diet was associated with an increased risk of MS compared with a diet including pork. Meat consumption affected people's health not only because of the frequency of consumption but also because of the amount consumed. Excessive red meat intake (>100 g/day) elevated the risk of MS by 28% when applying the consensus definition and by 40% when applying the IDF criteria. A lower frequency of juice/fruit-flavoured drink consumption (1-6 days/week) was more likely to lead to MS than daily consumption.

Second, more time spent on sedentary behaviour per day and higher exercise frequency showed negative and positive effects on MS, respectively. The former factor elevated the risk of MS by 3%-7% for each additional hour. If a person exercised for 3 days or more per week, then the risk of MS was reduced by 31%-39%. We also found that the risk of MS increased by 46%-50% when participants smoked at least 20 cigarettes per day.

The models also revealed that women were 1.48-1.56 times more likely to suffer from MS than men, and every 10 years of age elevated this risk by 33%-36%. Interestingly, differences were found between the Han, Yi, and Zang ethnicities. According to the models, Yi participants were more likely to suffer from MS than Han participants. Additional results are presented in Table 2.

DISCUSSION

MS components

The prevalence of MS components differs around the world. According to the latest reports (i.e., "World Health Statistics 2015" and "Global Status Report on Non-communicable Diseases 2014"),[18,19] in the Americas, the prevalence of HBP, DB and obesity was found to be 20.8%, 9.3%, and 24.0% in men and 15.6%, 8.1%, and 29.6% in women, respectively. In Europe, these values were 27.1%, 9.0%, and 21.5% for men and 19.7%, 7.6%, and 24.5% for women, respectively. In Southeast Asia, these values were 25.3%, 9.4%, and 3.2% for men and 24.2%, 9.1%, and 6.8% for women, respectively.[18,19] According to the "2015 Report on Chinese Nutrition and Chronic Disease,"[20] the prevalence of HBP was 25.2% (26.2% for men and 24.1% for women); of DB, 9.7% (10.2% for men and 9.0% for women); and of obesity, 11.9% (12.1% for men and 11.7% for women) among Chinese adults in 2012. All three rates were higher than those recorded in 2002. Among the adults from West China in our study, the rates of HBP, DB, and obesity in 2013 were 27.9%, 10.3%, and 9.5% for men and 27.5%, 10.3%, and 12.8% for women, respectively.

Additionally, in the latest report,[18] the age-standardized prevalence rates of HBP and DB for both sexes and of obesity among women were higher in upper-middle-income countries than high-income countries in 2014. As China has been classified as an upper-middle-income country since 2010 by the World Bank, the statistics above were consistent with this study's results that the prevalence of HBP and DB among adults in West China was higher than the rates in the Americas and Europe. However, these statistics differed from the current results in that the prevalence of obesity in both sexes was lower among adults in West China than in adults in America and Europe.

Thus, these regional differences in obesity indicated that the sensitivity may differ when using obesity as a diagnostic component of MS. In this study, the IDF criteria showed a lower sensitivity with regard to identifying MS than the consensus definition. Especially in the prediction of the risk of CVD and DB, it is more likely to choose consensus definition diagnostic target. However, the two definitions showed high consistency.

Influence of diet

The frequency and amount of intake of meat products affected people's health. A higher frequency of pork intake (every week compared with every month or year) and a completely pork-free diet both increased the risk of MS. The association strengths were larger when identifying MS by the consensus definition than by the IDF criteria. Excessive red meat intake elevated the risk of MS, and the strength of the association was smaller when identifying MS by the consensus definition than by the IDF criteria. Both the IDF criteria and the consensus definition showed an elevated risk of MS with a reduced frequency of consuming beef or mutton, poultry and juice/fruit-flavoured drinks.

We speculated that the differences in the ORs of MS between the different meat product intake frequencies were associated with their nutrient differences, as beef

Table 2. The logistic regression models of metabolic syndrome (MS) (defined using two criteria)

Type	Variable names†	Model 1‡				Model 2§			
		β	STD	*p*	OR (95% CI)	β	STD	*p*	OR (95% CI)
	Intercept	-9.06	0.89	<0.0001		-9.92	1.22	<0.0001	
Continuous	Age, unit: 10 years	0.03	0.00	<0.0001	1.36 (1.27-1.45)	0.03	0.00	<0.0001	1.33 (1.24-1.43)
	Total daily sedentary behaviour	0.03	0.02	0.13	1.03 (0.99-1.07)	0.07	0.03	0.01	1.07 (1.02-1.13)
	Heart rate	0.02	0.00	<0.0001	1.02 (1.01-1.03)	0.02	0.00	<0.0001	1.02 (1.01-1.02)
	Low-density lipoprotein cholesterol, unit: 0.5 mmol/L	0.24	0.07	0.00	1.13 (1.06-1.20)	0.28	0.08	0.00	1.15 (1.07-1.24)
Categorical	Women (men)	0.39	0.09	<0.0001	1.48 (1.24-1.75)	0.44	0.13	0.00	1.56 (1.20-2.02)
	Yi nationality (Han nationality)	0.70	0.08	<0.0001	2.02 (1.71-2.38)	0.78	0.14	<0.0001	2.18 (1.64-2.90)
	Zang nationality (Han nationality)	0.32	0.10	0.00	1.38 (1.13-1.68)	-0.11	0.10	0.28	0.90 (0.73-1.09)
	Other (Han nationality)	0.21	0.51	0.69	1.23 (0.45-3.36)	0.71	0.49	0.15	2.03 (0.78-5.28)
	Rural (urban)	-0.48	0.10	<0.0001	0.62 (0.51-0.75)	-0.45	0.13	0.00	0.64 (0.49-0.83)
	Consumption of cigarettes ≥ 20/day (<20)	0.38	0.14	0.01	1.46 (1.12-1.92)	0.40	0.13	0.00	1.50 (1.16-1.94)
	Wine intake (never)	0.37	0.23	0.10	1.45 (0.93-2.25)				
	Excessive red meat intake >100 g/day (≤ 100)	0.25	0.12	0.04	1.28 (1.01-1.62)	0.34	0.11	0.00	1.40 (1.14-1.72)
	Pork intake every week (eat but not every week)	0.57	0.24	0.02	1.76 (1.09-2.84)	0.41	0.17	0.01	1.51 (1.09-2.10)
	Pork intake: never (eat but not every week)	1.65	0.32	<0.0001	5.22 (2.78-9.78)	1.46	0.53	0.01	4.28 (1.50-12.2)
	Beef or mutton intake: eat but not every day (every day)	1.44	0.72	0.05	4.21 (1.03-17.2)	1.01	0.73	0.17	2.74 (0.65-11.6)
	Beef or mutton intake: never (every day)	1.27	0.72	0.08	3.57 (0.87-14.7)	0.92	0.78	0.24	2.51 (0.55-11.5)
	Poultry intake: eat but not every day (every day)	1.14	0.40	0.00	3.13 (1.42-6.91)	1.66	0.74	0.02	5.25 (1.24-22.2)
	Poultry intake: never (every day)	0.99	0.52	0.06	2.68 (0.96-7.49)	1.58	0.81	0.05	4.83 (0.99-23.5)
	Juice/fruit-flavoured drinks intake: drink but not every day (every day)	0.64	0.34	0.06	1.89 (0.98-3.67)	1.14	0.31	0.00	3.13 (1.72-5.69)
	Juice/fruit-flavoured drinks intake: never (every day)	0.82	0.35	0.02	2.28 (1.16-4.49)	1.28	0.40	0.00	3.58 (1.65-7.77)
	Salt intake >6 g/day (≤6)	0.12	0.06	0.03	1.13 (1.01-1.26)	0.16	0.06	0.01	1.17 (1.03-1.33)
	Exercise ≥3 days/week (<3)	-0.37	0.15	0.01	0.69 (0.52-0.93)	-0.50	0.18	0.01	0.61 (0.42-0.87)

†The values in the brackets represents the reference values for categorical variables.
‡In Model 1, the dependent variable was MS by the consensus definition.
§In Model 2, the dependent variable was MS by the International Diabetes Federation.

(mutton) and poultry are rich in high-quality proteins and contain less fat than pork. The World Cancer Research Fund recommended consuming only 100 g or less of red meat per day. Considering that pork, beef (mutton) and poultry are the major types of meat consumed in China,[20] increasing the frequency of beef (mutton) or poultry consumption might decrease the intake frequency of pork. Improving the dietary patterns of people in West China and reducing the accumulation of fat might be beneficial in preventing and controlling obesity and dyslipidaemia.

Influence of behaviour

Growing evidence indicates that sedentary behaviour is an important risk factor for various serious and chronic diseases.[21-23] The amount of physical activity most likely directly influences health. The current study found that an additional hour of sedentary behaviour was linked to a 3%-7% increase in the risk of MS. Exercising at least 3 days a week was related to a 31%-39% decrease in the risk of MS. It is not easy to keep balance between energy intake (eating) and energy expenditure (physical activity/sedentary behaviour). The major causes of obesity are an unhealthy diet, sedentary behaviour and low levels of physical activity[24] (i.e., unhealthy energy balance-related behaviours; EBRBs).[25]

In addition, we found that smoking at least 20 cigarettes per day increased the risk of MS by 46%-50%. Moreover, men were more likely to suffer from MS than women. Although this study observed differences in the prevalence of MS by ethnicity, a more thorough exploration of this influence requires a greater sample size and one that includes minorities.

The prevalence of MS and its components (HBP, DB, and HY) remained high in this study. In addition, for self-reported patients of HY, the treatment rate was relatively low. And for those who had carried out blood pressure, blood sugar or dyslipidemia treatment, the control situations were not good, especially for blood pressure. As a result, innovative and effective strategies are needed to prevent further increases in MS. Dietary style and behavioural risk factors should receive more attention through surveys and monitoring. Furthermore, health education and medical treatment should be enhanced among patients with HBP, DB, overweight, and central obesity, especially those in urban areas. Intervention measures should emphasize the significance of a healthy dietary style (reducing smoking and pork intake) and behaviours. A limitation of this study was that it conducted a cross-sectional survey. The results could only indicate associations between diet and behaviour on MS. We are currently building a follow-up cohort based on this study and will conduct intervention studies in the next steps. Emerging technologies such as panel computer interviews will be used to improve the efficiency and quality.

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AUTHOR DISCLOSURES

The authors have no conflicts of interest to declare. The central and local governments of China funded the present study.

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