Prevalence and associated factors of metabolic syndrome in Chinese middle-aged and elderly population: a national cross-sectional study

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ABSTRACT

Background: Currently, China has an increasingly aging population. However, the prevalence of metabolic syndrome (MetS) in this high-risk population for metabolic diseases remains unknown. This study investigates the age- and gender-specific prevalence and associated factors of MetS in the middle-aged and elderly Chinese population.

Methods: Data were collected and subjected to descriptive statistics. Further, univariate logistic regression was used to evaluate the relevant factors, and then multivariate logistic regression was selected to construct the final model.

Results: A total of 10,834 participants were included in the present study. The overall prevalence of MetS is 32.97% as defined by International Diabetes Federation (IDF) and 29.75% under National Cholesterol Education Program-The Adult Treatment Panel III (NCEP-ATP III) criteria. With aging, the prevalence of MetS descends in males while ascends in females. In the >70 years old group, the prevalence of MetS is three times higher in females than that in males (50.43% versus 16.03%). Across all age groups and sexes, the prevalence of MetS in urban areas is significantly higher than in rural areas. Besides, regardless of gender, the prevalence of MetS is the highest for those living in the north region (28.41% for males and 51.74% for females) and the lowest for those living in the southwest region (13.91% for males and 31.58% for females). Finally, an afternoon nap has been identified as a positively associated factor, while blood urea nitrogen (BUN) has been identified as a negatively associated factor (p < 0.05).

Conclusion: The prevalence of MetS varies in different age groups, sexes, living areas, and regions. An afternoon nap is positively associated with the prevalence of MetS, while BUN is negatively associated with MetS.

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Background

Metabolic syndrome (MetS), also known as syndrome X, is composed of abdominal obesity, insulin resistance, dyslipidemia, and hypertension [1]. Currently, threats from communicable diseases have gradually declined, while hazards from metabolic diseases like MetS have surged [2,3]. Patients with MetS have higher odds of cancer [4,5], cardiovascular diseases [6,7], lower urinary tract symptoms [8], etc., affecting people’s daily lives heavily. Besides, these increased risks are much more evident for the aged than the young [1]. Therefore, exploring the prevalence and associated factors of MetS in the specific high-risk group, the middle-aged and elderly population in China, remains requisite.

There are diverse ways to construct MetS, such as definitions from National Cholesterol Education Program-The Adult Treatment Panel III (NCEP-ATP III) and International Diabetes Federation (IDF) [9]. In the United States, according to the definition of NCEP-ATP III, an overall prevalence of MetS was 33% from 2003 to 2012 [10], which slightly increased to 34.7% in 2011–2016 [11]. In Iran, a meta-analysis of 69 studies disclosed a prevalence of 30.4% [12]. The results show that the prevalence in women and the aged are significantly higher than men and the young. Similar conclusions are also seen in Bangladesh, Peru, Portugal,
etc. [13–17]. The literature has disclosed observational results in the overall population. However, no specific study targeting the middle-aged and elderly Chinese population is performed.

To date, some associated factors have been investigated, comprising age, living areas, educational levels, physical activities [9,18–20]. Although most previous studies indicated that risk factors and its negative effects in different ages and gender were different [18,21,22], a few studies showed the opposite conclusion [16], needing further exploration. Besides, risk factors identified previously were explored in the overall population. However, few studies were performed on the aged. There are 111 million people aged 65 years above who resided in China (8.2% of the country residents) [23]. Performing one specific study targeting the aged seems imminent.

In this study, the prevalence of MetS and associated factors was scanned, including depression, sleep duration, liver diseases, kidney diseases, digestive diseases, etc. These factors were reported elsewhere to be closely implicated with MetS but not investigated in the Chinese aging population [24]. This study enrolled these factors to describe MetS and its comorbidities better.

**Methods**

**Study sample and data cleansing**

In order to scan the prevalence of MetS in the middle-aged and elderly Chinese population, data from China Health and Retirement Longitudinal Study (CHARLS) Follow-up Questionnaire 2015 were used. Further detailed description regarding this representative program could be accessed in their official website (http://charls.pku.edu.cn/) or publications [25]. In this national cross-sectional survey, a total of 21,095 participants aged 40 years old above were enrolled. Data cleansing was performed due to the missing values of covariates and unqualified blood samples. The study flowchart is displayed in Figure 1. Finally, 10,834 participants remained and were subjected to further analyses whose blood was collected under fasting status.

**Figure 1.** Flowchart of data cleansing. HDL: high-density lipoprotein.
Definition of MetS and data collection

Currently, there are diverse definitions to construct MetS, such as NCEP-ATP III, and IDF. Of note, the definition of IDF considers the ethnic characteristics of the Chinese and has lower cutoff values than other definitions, which benefits early diagnosis and intervention. Therefore, the definition of IDF was adopted to scan the prevalence of MetS. Besides, for comparing the results of this paper with those of other studies employing different definitions, the NCEP-ATP III definition was also used to scan the morbidity of MetS.

The definition of IDF requires abdominal obesity (waist circumference ≥90 cm for males and ≥80 cm for females) and two or more of the following: hyperglycemia, low HDL cholesterol, high blood triglycerides, and hypertension. Hyperglycemia is defined as blood glucose greater than 5.6 mmol/l (100 mg dℓ⁻¹) or diagnosed as diabetes. Low HDL cholesterol is defined as <1.0 mmol/l (40 mg dℓ⁻¹) in men or <1.3 mmol/l (50 mg dℓ⁻¹) in women or drug treatment for low HDL. High blood triglycerides are defined as blood triglycerides >1.7 mmol/l (150 mg dℓ⁻¹) or drug treatment for elevated triglycerides. Hypertension is defined as blood pressure >130/85 mmHg or drug treatment for hypertension. As for NCEP-ATP III, the presence of any three or more of the components stated above is sufficient to diagnose MetS. However, the cutoff of waist circumference to diagnose abdominal obesity is 102 cm for men or 88 cm for women. Detailed definitions of IDF and NCEP-ATP III can also be viewed in the previous literature [9].

Five components, including waistline, HDL, triglycerides, blood glucose, and blood pressure, are requisite to construct MetS. All the measurements of these five components were carried out by well-trained researchers from the Chinese Center for Disease Control and Prevention (CCDC). Tapes were placed over the clothing around the waist at the level of the navel to measure waistlines. Participants were asked to be relaxed and seated until three blood pressure measurements were completed. Final blood pressures were recorded using the average of three measurements. Before the blood collection, participants were asked to fast from the night until the next morning for assessing blood biomarkers. Venous blood of participants was collected and centrifuged into plasma, for assessing blood biomarkers. Venous blood of participants was also used to scan the morbidity of MetS.

Covariates

In this study, covariates comprising individual characteristics, blood biomarkers, and medical histories were collected. Individual behaviors include age, gender, marital status, depression, sleeping time, afternoon nap, geographic region, smoking, alcohol consumption, and body mass index (BMI). According to previous studies, age was divided into four groups: 40–50 years old, 50–60 years old, 60–70 years old, and >70 years old [26,27]. Marital status consisted of two groups. One included the married or cohabitated, and the other incorporated the divorced, widowed, married but not living with spouses. Participants with scores ≥10 assessed by the Center for Epidemiologic Studies Depression scale (CESD)-10 questionnaire were seen as depressed patients [28]. Sleeping time was stratified into 0–6 h, 6–8 h, and >8 h. An afternoon nap was gathered as 0 min, 1–30 min, 31–60 min, 61–90 min, and >90 min. The living regions were also divided into the rural region and urban region. The rural region only referred to villages, and other regions were unified as the urban region. Smoking and alcohol consumption were also collected and stratified according to their status. Smoking was reported as yes, no, and quitted. Alcohol consumption was divided as never, drunk but less than once a month, and drunk but more than once a month.

Blood biomarkers consist of uric acid, LDL, total cholesterol, and blood urea nitrogen (BUN). Hyperuricemia is defined as a blood uric acid concentration higher than 420 μmol/l in men and 357 μmol/l in women. LDL is classified into two groups ≥120 mg/dl and <120 mg/dl. Total cholesterol is classified into ≥200 mg/dl and <200 mg/dl. According to the previous study, BMI was split into <18.5 kg/m², <24 kg/m², <28 kg/m², and ≥28 kg/m² [29]. After referring to Arihan’s research [30], BUN was divided as 0–20 mg/dl and >20 mg/dl. Furthermore, medical histories including liver diseases, kidney diseases, digestive diseases, arthritis were recorded. Digestive diseases included digestive ulcer, gastritis, etc. except for tumor or cancer. Renal disorders included kidney stones, chronic kidney diseases, etc. except for tumor or cancer. Hepatic disorders included hepatitis, liver cyst, hepatic aneurism, etc. excluding fatty liver, tumors, and cancer. Due to the different living and cultural habits, living localities of the participants were also categorized into six regions as the previous study did [27], which were East (Jiangsu, Fujian, Shanghai, Shandong, Zhejiang, Jiangxi, and Anhui), North (Shanxi, Hebei, Beijing, Tianjin, and Inner Mongolia), North-East (Jilin, Liaoning, and Heilongjiang), North-West (Qinghai,
Statistical analysis

Data, composed of continuous and categorical data in this study, were presented as mean ± SD and proportions (%), respectively. Descriptive statistics were performed to investigate the prevalence and distribution of MetS in different subgroups. Further, univariate logistic regression was adopted to evaluate the associated factors with MetS under the IDF criteria. Covariates with p values < 0.05 were enrolled into the final model assessed by multivariate logistic regression. Considering that LDL, total cholesterol, uric acid and BMI may be correlated with the components of MetS, the four variables were not enrolled into further multivariate testing. Besides, restricted cubic spline regression (RCS) was used to test the relationship between MetS and the duration of the afternoon nap. All the analyses were made by R 3.6.3, and all the figures were drawn by R 3.6.0 and GraphPad Prism 8.0 (GraphPad Software Inc., San Diego, CA). p < 0.05 (two-sided) was considered statistically significant.

Results

Baseline characteristics and prevalence of MetS in grouped population

In total, 10,834 participants aged 40 years old above were enrolled and 18 covariates were collected in this study. The distribution of participants in these covariates is shown in Table 1. The overall prevalence of MetS is 32.97% (95% CI = 32.09–33.86) under IDF definition and 29.75% (95% CI = 28.90–30.62) under NCEP-ATP III definition. The specific prevalence among different variables is displayed in Table 1.

Age- and gender-specific prevalence of MetS and its components

With aging, the prevalence of MetS under IDF definition in males descends while ascends in females (Figure 2(A)). In the >70 years old group, the prevalence of MetS in females is three times higher than that in males (50.43%, 95% CI = 46.98–53.88 versus 16.03%, 95% CI = 13.76–18.59). With aging, the increasing and decreasing trend for the prevalence of abdominal obesity remain identical in females and males, respectively (Figure 2(B)). As for hyperglycemia, the prevalence in both the overall population and females increases. However, this increasing trend in males has not been observed in the >70 years old group (Figure 2(C)). Besides, the prevalence of low HDL in females is nearly the same in all four age groups and thereof in males increases from 40–50 years old to 60–70 years, but decreases in the >70 years old group (Figure 2(D)). In Figure 2(E), the prevalence of high triglycerides in the overall population and females fluctuates, but this prevalence in males remains its downward trend in all four age groups. In Figure 2(F), the increasing trend of hypertensive patients is obvious in males, females, and the overall population.

Age- and gender-specific prevalence of MetS in urban and rural areas

In Figure 3(A), the prevalence of MetS in urban areas increases from 30.94% (95% CI = 27.22–34.92) to 43.37% (95% CI = 40.09–46.72) and then fluctuates (45.54% in 60–70 years old group and 44.16% in > 70 years old group). In females, the prevalence of MetS ascends in all four age groups (30.86% in 40–50 years old group, 50.21% in 50–60 years old group, 56.55% in 60–70 years old group, and 61.66% in > 70 years old group). In males, the prevalence of MetS fluctuates in all the four age groups (31.05% in 40–50 years old group, 34.74% in 50–60 years old group, 34.40% in 60–70 years old group, and 27.36% in >70 years old group).

In rural and urban areas, the female and overall population show the same increasing and fluctuating trends (Figure 3(B)). However, in the male population, the prevalence of MetS has revealed a fluctuating trend in urban areas in contrast to a decreasing trend in rural areas. Among the male population in rural areas, the prevalence of MetS is 21.70% in the 40–50 age group, 20.97% in the 50–60 age group, 18.55% in the 60–70 age group, and 12.76% in >70 age group.

Gender-specific prevalence in different regions

The gender-specific prevalence in different regions is displayed in Figure 4. In Figure 4(A), people living in north region have the highest prevalence (40.91%, 95% CI = 38.44–43.42) and people living in southwest region have the lowest prevalence (23.06%, 95% CI = 21.14–25.11). In Figure 4(B,C), the difference between the south and north still exists in both males and females (13.91% [95% CI = 11.72–16.43] for males in south-west region, 28.41% [95% CI = 25.17–31.88] for females).
| Characteristics                     | Total participants (%) | IDF | NCEP-ATP III |
|------------------------------------|------------------------|-----|--------------|
|                                    | Total                  |     |              |
|                                    | 10834 (100.00)         |     |              |
| Total age groups                   |                        |     |              |
| 40–50                              | 2202 (22.32)           |     |              |
| 50–60                              | 3472 (32.05)           |     |              |
| 60–70                              | 3459 (31.93)           |     |              |
| >70                                | 1701 (15.70)           |     |              |
| Gender                             |                        |     |              |
| Male                               | 4977 (45.94)           |     |              |
| Female                             | 5857 (54.06)           |     |              |
| Marital status                     |                        |     |              |
| Married/cohabitated                | 9002 (83.09)           |     |              |
| Others                             | 1832 (16.91)           |     |              |
| Depression                         |                        |     |              |
| <10                                | 6595 (66.77)           |     |              |
| ≥10                                | 3282 (33.23)           |     |              |
| Smoking                            |                        |     |              |
| Yes                                | 2937 (27.14)           |     |              |
| No                                 | 6504 (60.11)           |     |              |
| QUITTED                            | 1380 (12.75)           |     |              |
| Alcohol consumption                |                        |     |              |
| Never                              | 6998 (64.66)           |     |              |
| Less than once a month             | 965 (8.92)             |     |              |
| More than once a month             | 2859 (26.42)           |     |              |
| Afternoon napping (minutes)        |                        |     |              |
| 0                                  | 4371 (41.27)           |     |              |
| 1–3                                | 1649 (15.57)           |     |              |
| 31–60                              | 2565 (24.22)           |     |              |
| 61–90                              | 527 (4.98)             |     |              |
| >90                                | 1478 (13.96)           |     |              |
| Uric acid                          |                        |     |              |
| Hyperuricemia                      | 1241 (11.45)           |     |              |
| Non-hyperuricemia                  | 9593 (88.55)           |     |              |
| Low-density lipoprotein            |                        |     |              |
| ≥120 mg/dl                         | 2673 (24.67)           |     |              |
| <120 mg/dl                         | 8160 (75.33)           |     |              |
| Total cholesterol                  |                        |     |              |
| ≥200 mg/dl                         | 3183 (29.38)           |     |              |
| <200 mg/dl                         | 7651 (70.62)           |     |              |
| Body mass index, (BMI)             |                        |     |              |
| 18.5 kg/m²                         | 600 (5.55)             |     |              |
| <24 kg/m²                          | 5096 (47.14)           |     |              |
| <28 kg/m²                          | 3656 (33.82)           |     |              |
| >28 kg/m²                          | 1459 (13.50)           |     |              |
| Blood urea nitrogen, (BUN)         |                        |     |              |
| 0–20 mg/dl                         | 9356 (86.36)           |     |              |
| >20 mg/dl                          | 1478 (13.64)           |     |              |
| Liver diseases                      |                        |     |              |
| Yes                                | 428 (3.95)             |     |              |
| No                                 | 10406 (96.05)          |     |              |
| Kidney diseases                     |                        |     |              |
| Yes                                | 687 (6.34)             |     |              |
| No                                 | 10147 (93.66)          |     |              |
| Digestive system diseases          |                        |     |              |
| Yes                                | 2463 (22.73)           |     |              |
| No                                 | 8371 (77.27)           |     |              |
| Arthritis                          |                        |     |              |
| Yes                                | 3589 (33.13)           |     |              |
| No                                 | 7245 (66.87)           |     |              |

IDF: International Diabetes Federation; NCEP-ATP III: National Cholesterol Education Program (Adult Treatment Panel III); CI: confidence interval; BUN: blood urea nitrogen; BMI: Body Mass Index.
for males in north region, 31.58% [95% CI = 28.62–34.71] for females in south-west region, 51.74% [95% CI = 48.28–55.19] for females in north region).

**Associated factors of MetS in the Middle-aged and elderly population**

In Table 2, results from univariate logistic regression revealed that participants who have higher age, afternoon nap, and arthritis are found to have higher odds of MetS ($p < 0.05$). Moreover, this increased risks of MetS are also found in females and participants who are not married or cohabitated ($p < 0.05$). In univariate testing, subjects who have cigarette consumption or quitted, alcohol consumption, higher BUN or digestive system diseases or live in rural areas display lower risks of MetS than their counterparts ($p < 0.05$).

In multivariate testing, this increased risk of MetS is observed in participants who have higher age, afternoon nap ($p < 0.05$). For females and those living in urban areas, smoked or quitted now, the elevated risk of MetS still exists ($p < 0.05$). Additionally, the results of RCS regression reveal a nonlinear relationship between the duration of afternoon naps and MetS ($p < 0.05$, Supplemental Figure 1). A decreased risk of MetS is observed in participant with elevated BUN or living in rural areas ($p < 0.05$).

**Discussion**

In the present study, the prevalence of MetS in the participants aged 40 years and older is 32.97%, according to the IDF definition. Under the NCEP-ATP III definition, the prevalence of MetS is 29.75%. According to Li’s report, the prevalence of MetS in Chinese adults aged 18 years and older was 24.2% under the NCEP-ATP III definition in 2010–2012 [22]. According to He’s study, the prevalence of MetS in the overall population was 9.5% in 2002 and 18.7% in 2010–2012 [31]. The figures revealed that the aged had higher odds of MetS, which were in line with other studies [9,32]. According to IDF criteria, the prevalence of MetS was 45.5% in Tunisia, 37.4% in Iran, and 53.9% in Gwalior, a city in India [33,34]. Compared with studies in other countries, the prevalence reported in the present study seems lower than in these countries, which was
probably attributed to different races, lifestyles, etc. In the aging population, the prevalence was 35% in the 40-59 years group and 46.7% in the >60 years group in the United States [10]. The prevalence of MetS in the aging population was high in the United States but still lower than developed countries. Besides, in 2009, this number was 31.5% among people over 35 years old in Jiangsu province, China [35], indicating...
that the trend of MetS in the aging population did not vary wildly.

With aging, the prevalence of MetS descends in males while ascends in females. This trend has also been observed in Korean [36], Indian [34], Spanish [37], etc., which is probably partly attributed to hormone secretion. According to Jeenduang’s study, the prevalence of MetS was 29.37% in postmenopausal women, while it was 16.97% in premenopausal women [38]. Hormones hidden behind menopause probably lead to this alteration [39]. However, one previous article performed in the U.S. presented an opposite observational result that males had a higher prevalence of MetS than females [40]. Due to the limited samples, this finding is probably biased, which still needs more evidence.

This study also found that the prevalence of MetS in urban areas was significantly higher than one in rural areas due to the sedentary lifestyles in modern cities possibly [41]. Of note, with aging, this upward

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**Table 2. The associated factors and adjusted ORs for MetS.**

| Characteristics                      | Crude OR (95% CI) | p value | Adjusted OR (95% CI) | p value |
|--------------------------------------|-------------------|---------|----------------------|---------|
| Age group                            |                   |         |                      |         |
| 40–50                                | 1.00 (reference)  | –       | 1.00 (reference)     | –       |
| 50–60                                | 1.40 (1.25–1.58)  | <0.001  | 1.58 (1.39–1.79)     | <0.001  |
| 60–70                                | 1.46 (1.30–1.65)  | <0.001  | 1.71 (1.50–1.95)     | <0.001  |
| >70                                  | 1.28 (1.11–1.47)  | <0.001  | 1.52 (1.30–1.78)     | <0.001  |
| Gender                               |                   |         |                      |         |
| Male                                 | 1.00 (reference)  | –       | 1.00 (reference)     | –       |
| Female                               | 2.54 (2.33–2.76)  | <0.001  | 2.54 (2.22–2.90)     | <0.001  |
| Marital status                       |                   |         |                      |         |
| Married/cohabitated                  | 1.00 (reference)  | –       | 1.00 (reference)     | –       |
| Others                               | 1.11 (1.00–1.24)  | <0.05   | 1.01 (0.90–1.14)     | 0.839   |
| Depression                           |                   |         |                      |         |
| <10                                  | 1.00 (reference)  | –       | –                    | –       |
| ≥10                                  | 1.05 (0.96–1.14)  | 0.316   | –                    | –       |
| Sleeping time                        |                   |         |                      |         |
| 0–6 h                                | 0.94 (0.86–1.02)  | 0.133   | –                    | –       |
| 6–8 h                                | 1.00 (reference)  | –       | –                    | –       |
| >8 h                                 | 0.99 (0.85–1.14)  | 0.844   | –                    | –       |
| Geographical area                    |                   |         |                      |         |
| Urban                                | 1.00 (reference)  | –       | 1.00 (reference)     | –       |
| Rural                                | 0.61 (0.56–0.67)  | <0.001  | 0.60 (0.54–0.66)     | <0.001  |
| Smoking                              |                   |         |                      |         |
| Yes                                  | 0.41 (0.37–0.45)  | <0.01   | 0.79 (0.68–0.91)     | <0.01   |
| No                                   | 1.00 (reference)  | –       | 1.00 (reference)     | –       |
| Quitting                             | 0.67 (0.59–0.76)  | <0.001  | 1.24 (1.06–1.46)     | <0.01   |
| Alcohol consumption                  |                   |         |                      |         |
| Never                                | 1.00 (reference)  | –       | 1.00 (reference)     | –       |
| Less than once a month               | 0.71 (0.62–0.83)  | <0.001  | 0.90 (0.80–1.01)     | 0.083   |
| More than once a month               | 0.56 (0.51–0.62)  | <0.001  | 0.90 (0.77–1.05)     | 0.188   |
| Afternoon nap (minutes)              |                   |         |                      |         |
| 0                                    | 1.00 (reference)  | –       | 1.00 (reference)     | –       |
| 1–30                                 | 1.27 (1.13–1.43)  | <0.001  | 1.31 (1.16–1.49)     | <0.001  |
| 31–60                                | 1.20 (1.09–1.34)  | <0.001  | 1.38 (1.23–1.54)     | <0.001  |
| 61–90                                | 1.30 (1.07–1.57)  | <0.01   | 1.61 (1.32–1.97)     | <0.001  |
| >90                                  | 1.28 (1.13–1.45)  | <0.001  | 1.54 (1.35–1.76)     | <0.001  |
| Blood urea nitrogen (BUN)            |                   |         |                      |         |
| 0–20 mg/dl                           | 1.00 (reference)  | –       | 1.00 (reference)     | –       |
| >20 mg/dl                            | 0.77 (0.68–0.87)  | <0.001  | 0.82 (0.72–0.94)     | <0.01   |
| Liver disease                        |                   |         |                      |         |
| Yes                                  | 1.20 (0.98–1.46)  | 0.077   | –                    | –       |
| No                                   | 1.00 (reference)  | –       | –                    | –       |
| Kidney diseases                      |                   |         |                      |         |
| Yes                                  | 1.02 (0.87–1.21)  | 0.770   | –                    | –       |
| No                                   | 1.00 (reference)  | –       | –                    | –       |
| Digestive system diseases            |                   |         |                      |         |
| Yes                                  | 0.91 (0.82–1.00)  | <0.05   | 0.83 (0.75–0.92)     | 0.745   |
| No                                   | 1.00 (reference)  | –       | 1.00 (reference)     | –       |
| Arthritis                            |                   |         |                      |         |
| Yes                                  | 1.14 (1.04–1.24)  | <0.01   | 1.08 (0.98–1.19)     | 0.102   |
| No                                   | 1.00 (reference)  | –       | 1.00 (reference)     | –       |

Logistic regression was adopted to identify the independent associated factors of MetS. All plausible variables with p < 0.05 in univariate testing were subjected to further multivariate testing. The crude ORs were calculated in univariate regression and the adjusted ORs were recorded using multivariate regression. OR: Odds Ratio; CI: confidence interval; BUN: blood urea nitrogen.
trend of MetS prevalence in females was not observed in males, especially for those settling in rural areas who displayed a downward trend. This result was in line with previous studies performed in China [17], India [42], sub-Saharan Africa [43], and Mexico [44] but contrary to Lee’s study in the middle-aged Koreans [45]. The study from Javier concluded that men were more susceptible to the urbanization-associated worsening of cardiometabolic health [44], which clarified this disparity partly. Notwithstanding, the specific reasons remain hazy. Besides hormones and lifestyles stated above, some other potential factors may contribute to this difference, including household income, educational levels, the annual cost of healthcare, etc. [46,47].

This disparity of MetS prevalence has been detected in different regions. Regardless of gender, participants have the highest prevalence in the north region and the lowest in the southwest region, which is linked to dietary nutrient intake according to previous reports [48]. Residents in the north region mainly eat food made of flour, such as noodles, which are rich in carbohydrates. The intake of carbohydrates and sodium is closely associated with the increased risk of MetS [45]. Besides, a diet rich in carbohydrates is a principal reason for aggravation glucose intolerance [49] and dyslipidemia [50]. Therefore, improving the diet structure seems sensible for those participants. Another possible reason for interpreting the disparity of the prevalence of MetS is the different income levels. According to the China Statistical Yearbook issued by the National Bureau of Statistics of China in 2020, the north regions (e.g. Beijing, Shanghai) have the highest per-capita disposable income than all other regions (39,438.9 RMB versus 27,370.6 RMB versus 26,025.3 RMB versus 23,986.1 RMB) [51]. Multiple epidemiological studies have disclosed the pandemic of obesity in developing countries, with better GDP performance and consequently more food consumption (e.g. sugar) than ever [52]. Hence, suppressing the rising trend of excessive food consumption in regions with higher GDP can decrease the prevalence of MetS.

In this special aging population, some relevant factors, including age, gender, living areas, etc., were identified as revealed by previous literature [53]. Among them, marital status and arthritis were found not to be associated with MetS. Jung et al. [54] revealed that the widowed tended to have a higher risk of MetS in middle-aged Korean women. However, in Jordan, Ajlouni et al. [55] disclosed that the married had a significantly higher prevalence of MetS in both men and women. The results were concluded in different countries, races, and habits which were inconsistent with our study due to different socioeconomic factors and health behaviors. The different conclusions also highlighted the importance of performing studies in different countries, races, and economic levels. As for arthritis, Müller et al. revealed that the prevalence of MetS did not differ between the patients with early rheumatoid arthritis and the control group (35.2% versus 34.1%) [56]. Even restricted to the middle-aged and elderly population in Germany, the compound MetS showed no association with osteoarthritis, in line with our conclusion [57]. However, one multi-center study by Pan et al. [58] indicated that MetS and low HDL were associated with medial compartment cartilage volume loss and the increase of bone marrow lesion size, indicating that although MetS were not associated with arthritis, the damage to the cartilage also should be noted. Patients with MetS should take notice of their joint health.

In addition, two pivotal factors (afternoon nap and BUN) are little reported elsewhere. Maria’s study [59] showed that participants with an afternoon nap (<30 min/day) had lower risks of suffering MetS in the overall population, contrary to what we reported. This discrepancy is probably due to the different definitions of an afternoon nap. According to Cao’s study of 27,009 participants (mean age of 63.6 years), nappers with longer nap duration had a fairly higher rate of hypertension [60]. Maria’s study was limited to the <30 min/day group, constraining this conclusion. More importantly, BUN >20 mg dl⁻¹ was also determined to be a negative correlate. In Arora’s study, both metabolically healthy obesity and metabolically unhealthy obesity displayed normal kidney function [61]. However, their target population was children and adolescents. This varied risk in different populations reminded of renal function in these particular middle-aged and elderly MetS patients.

This study has several defects. First, although some associated factors have been identified, this association still awaits further cohort study to demonstrate in this specific population. Among the associated factors, it should be specifically noted that the negative association between BUN and MetS is mainly based on the cross-sectional design. No causal link between them can be provided. Additionally, given the price of monitoring devices in a large cohort, it is hard to collect the sleep duration using objective equipment. Therefore, a simplified approach relying on the participants’ self-reports has been used in this study, which may bring bias.
Conclusion

In the middle-aged and elderly Chinese population, the overall prevalence of MetS is 32.97% as defined by IDF and 29.75% under NCEP-ATP III criteria. The prevalence varies in different age groups, sexes, living areas, and regions. An afternoon nap is positively associated with MetS, while BUN is negatively associated with MetS.

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Author contributions

Conceptualization: Y. X. and Y. C. Z. Data curation: Y. X., Y. C. Z., and F. X. Z. Formal analysis: Y. X. and Y. C. Z. Funding acquisition: J. H. Y. Investigation: Y. C. Z., F. X. Z., and C. J. W. Methodology: Y. X. and F. Q. Project administration: J. H. Y. and F. Q. Resources: Y. X. and S. W. Supervision: J. H. Y. and F. Q. Validation: Y. X. and F. Q. Visualization: Y. C. Z. Writing – original draft: Y. X. Writing – review and editing: J. H. Y. and F. Q.

Ethics approval and consent to participate

The CHARLS study was approved by research ethics committees of Peking University (IRB00001052-13074). All participants provided written informed consent. No experimental interventions were performed.

Disclosure statement

The authors declare no conflict of interest.

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Data availability statement

The data that support the findings of this study are available from China Health and Retirement Longitudinal Study (CHARLS) website (http://charls.pku.edu.cn/). The full datasets used in this analysis are available from the corresponding author upon reasonable request.

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