Journal of Diabetes & Metabolic Disorders (2022) 21:263–273
https://doi.org/10.1007/s40200-022-00969-6

RESEARCH ARTICLE

Sex-specific prevalence of metabolic syndrome in older adults: results from the Neyshabur longitudinal study on aging, Iran

Mohsen Azimi-Nezhad[1] · Nayyereh Aminisani[1] · Ahmad Ghasemi[1] · Azam Rezaei Farimani[1,2] · Fatemeh Khorashadizadeh[3] · Seyed Reza Mirhafez[4] · Martin Hyde[5] · Seyed Morteza Shamshirgaran[1]

Received: 25 July 2021 / Accepted: 31 December 2021 / Published online: 17 January 2022
© Springer Nature Switzerland AG 2022

Abstract

Purpose The prevalence of metabolic syndrome (MetS) and associated diseases grows as the population ages. This study aimed to investigate sex differences in the prevalence of MetS and its components among people aged 50 years and older in Iran.

Methods Data were drawn from the Neyshabur Longitudinal Study on Ageing (NeLSA), which is an ageing component of the Prospective Epidemiological Research Studies in IraAn (PERSIAN). The NCEP ATP III and IDF criteria were used to identify the prevalence of MetS among 3383 men and 3873 women aged 50 years and older. Sociodemographic information, lifestyle and clinical factors were collected via an interview-based questionnaire. Weight and height, waist circumferences and blood pressure were measured. Laboratory measures such as fasting blood sugar, triglycerides and high-density cholesterol were also assessed.

Results The overall prevalence of the MetS according to the NCEP ATP III and IDF definitions were 45% and 47%, respectively. The prevalence of the MetS in men and women was 37% and 63% according to the NCEP ATP III definition, 33% and 67% by the IDF definition, respectively**.** The prevalence of MetS components was significantly higher in women than in men.

Conclusion In the current study, the prevalence of MetS and its components was significantly higher among women than men. We also observed good concordance between IDF and NCEP ATP III criteria.

Keywords Metabolic syndrome · Gender · NCEP ATP III · IDF · Neyshabur longitudinal study on aging

Introduction

Metabolic Syndrome (MetS) is one of the most common non-communicable disorders worldwide [1]. It is characterized by a set of metabolic disorders that increase the risk of cardiovascular disease (CVD) and Type 2 Diabetes Mellitus (T2DM). Individuals with MetS are between five and three times more likely to develop T2DM and CVD than those without the problem [1]. The prevalence of MetS in the world's adult population is estimated to be between 20–25% [2]. This is influenced by definition used and by factors such as age, sex, race/ethnicity, lifestyle, genetic and environmental factors, endocrine dysfunction, specific medications, and oxidative stress [3].

There are various definitions and criteria for the diagnosis of MetS, including the World Health Organization (WHO), The National Cholesterol Education Program Adult Treatment III (NCEP ATP III), and the International Diabetes Federation (IDF). The major components such as obesity, hypertension, and dyslipidemia are similar in these definitions, although they differ in details and criteria [4]. While glucose tolerance and insulin resistance are essential elements of the WHO definition, clinicians prefer more straightforward definitions such as NCEP ATP III and IDF.

✉ Seyed Morteza Shamshirgaran
m.shamshirgaran@hotmail.com;
shamshirgaranm1@nums.ac.ir

1 Healthy Ageing Research Centre, Neyshabur University of Medical Sciences, 9329774448 Neyshabur, Iran

2 Cardiovascular Diseases Research Center, Birjand University of Medical Sciences, Birjand, Iran

3 Department of Epidemiology and Biostatistics, Neyshabur University of Medical Sciences, Neyshabur, Iran

4 Non-Communicable Diseases Research Center, Neyshabur University of Medical Sciences, Neyshabur, Iran

5 Centre for Innovative Ageing, College of Human and Health Sciences, Swansea University, Swansea, Wales, UK

Both definitions focus on central obesity rather than insulin resistance [4].

Iran is one of the countries with a high prevalence of MetS in the world [5]. A meta-analysis study found that high levels of triglycerides and low levels of high-density lipoprotein (HDL-C) were the leading causes of the high prevalence of MetS in adults in Iran [6]. Similar to various studies, a population study in Iran showed that the prevalence of MetS depends on the ethnicity of participants [7]. As the population ages, the prevalence of MetS and related diseases increases. The Tehran Lipid and Glucose study found that the prevalence of MetS in the age group of 60–69 years was six times higher than in the age group of 20–29 years [8].

Studies have shown that gender-related factors cause gender inequality in the prevalence of MetS [9]. In adults under 50 years of age, the prevalence of MetS is higher in men than in women, but this ratio is reversed after menopause. Hormonal changes, decreased HDL-c levels, and increased abdominal fat in menopause is associated with increased insulin resistance [10]. Recent studies confirm that the prevalence of MetS is lower in men than women [11]. Recently a meta analysis including 69 studies conducted in different regions of Iran showed that the prevalence of MetS is significantly higher among women than men (34.8% vs. 25.7%) [12]. Although the epidemiology of the MetS has been described in the general population, this would be the first large population-based study in older adults in Northeast of Iran to look at sex differences in details. The current study extends our understanding of this under-researched topic by looking at gender differences in non-Western middle-income countries. This study could also really add to our knowledge and be of immense practical use as it means that policymakers and healthcare practitioners could devise gender-specific (rather than gender blind) information/interventions to reduce Mets. Therefore, the aim of the study was to assess the MetS prevalence and its correlates by gender in older adults based on a large population-based study in Northeast of Iran; Nayshabur Longitudinal Study on Ageing (NeLSA).

Materials and methods

Study population

The PERSIAN Elderly Cohort is an ageing component of the Prospective Epidemiological Research Studies in Iran (PERSIAN) cohort [13]. It was conducted in 4 sites, including Neyshabur (Razavi Khorasan province, Northeast of Iran), Guilan (Northern Iran), Tabriz (Northwest of Iran), and Ardakan (central Iran) to include people from different ethnicity and geographical areas. The current study included people aged 50 -94 in Neyshabur, Northeast of Iran, during 2016–2018 (NeLSA). Participants were selected through stratified random sampling from the list of people registered with six health centers. A total of 9220 people met the eligibility criteria minimum 3-year residency in Neyshabur, Iranian citizens, without dementia, major depression, and disabilities, limiting their ability to participate in the study), of whom a total of 7462 individuals (4831 households) provided the written consent to participate in the study. The participation rate was 81%".Due to the two MetS criteria comparability, the study was restricted to 7256 participants, all of whom had waist circumference measurements recorded. Standard questionnaires were used to collect information such as demographics, current smoking, marital status, income status, and education level, physical activity, history of chronic disease, and medication use. Trained individuals conducted face-to-face interviews.. Blood pressure and anthropometrics were measured and glucose and lipid profile were also done.

Definition of MetS

In this analysis, NCEP ATP III and IDF criteria were used to identify MetS. According to the modified NCEP ATP III criteria (2005), having at least three of the following five criteria indicates metabolic disorder: 1) Waist Circumference (WC) ≥ 102 cm in men or ≥ 88 cm in women); 2) High- Density Lipoprotein Cholesterol (HDL-C) < 40 mg/dl in men or < 50 mg/dl in women; 3) Triglycerides (TG) ≥ 150 mg/dl; 4) Blood Pressure (BP) > 130/85 mmHg; 5) fasting plasma glucose ≥ 100 mg/dl, and pharmacologic treatment to control hyperglycemia, dyslipidemia and hypertension [4]. Abdominal obesity is a key criterion for diagnosing MetS based on the IDF definition, with at least two of the other four indices similar to the NCEP ATP III criteria, and pharmacologic treatment for dyslipidemia, and hypertension or previously diagnosed T2DM [14, 15]. According to NCEP ATP III criteria and IDF definition, the WC cut-off points for Middle Eastern men and women are 94 and 80 cm, respectively[15]. It is noteworthy that the National Iranian Committee on Obesity considers WC cut-off of ≥ 90 cm as diagnosis criteria of MetS in Iranian adults of both sexes [5, 16]. Thus, in the current study, WC cut-off of ≥ 90 cm was used for MetS diagnosis. Australian findings showed that Body Mass Index (BMI) > 30 kg/m2 is likely to be associated with increased waist circumference [15].

Anthropometric measures and blood pressure

Weight, BMI. and anthropometric parameters were measured using an InBody 770 connected to a BSM 370. BMI (kg/m2) was categorised as healthy weight (< 25), overweight (25–29.9), obese (≥ 30) based on WHO-defined standard cut-off points. WC was determined, in duplicate, at the midpoint between the lowest costal ridge and upper border of the iliac crest. BP was measured twice in a sitting position on both arms. Systolic and diastolic BP were measured by a nurse using a calibrated mercury sphygmomanometer (Riester diplomat, Australia). At least half an hour before measuring BP; coffee, alcohol, drugs, stimulant drinks, smoking, and heavy activity was banned.

Other epidemiological and clinical variables

The age was categorised as 50–59 years, 60–69 years. and 70 years and over for better presentation in the tables. Marital status was considered as two groups: 1) married/living with a partner; and 2) divorced/separated/single/widow. Socioeconomic status indicators included years of education categorized as 0, 1–8, ≥ 9 years. The Financial situation was based on the respondent's subjective evaluation of the adequacy of their income, (e.g. I don't have a problem, it is enough for basic needs, and it is not enough for basic needs). Smoking status was based on whether respondents identified themselves as regular smokers or not. The Physical Activity Scale for the Elderly (PASE) was used to estimate the level of physical activity. It has been validated in previous studies in Iran [17]. The PASE is a brief and specific instrument that has been designed to estimate physical activity for older adults for a one-week period. The frequency and time spent in a variety of activities including leisure time activities (walking, light activities, moderate, or strenuous intensity and muscle-conditioning activities) as well as work-related activities (in paid or volunteer work) and household activities such as light house-work, yard work, and caring for others were also recorded. After considering the weight according to the PASE Administration and Scoring Instruction Manual for each activity, the final PASE score for the week was calculated based on the sum of all activities, and the mean score was presented. The data were separated into tertile to categorize physical activity levels as high (≥ 106.5), medium (40.3–106.5), or low (< 40.3).

Hypertension was defined as: Self-report history of hypertension and/or using hypertension drugs and/or systolic blood pressure (SYS) > = 140 mmHg and/or diastolic blood pressure (DYS) > = 90 in a blood test. Diabetes was defined as Self-report history of diabetes and/or using diabetes drugs and/or FBS > = 126 in the blood test. Medical conditions were based on clinical assessments by a physician and the participant's response to the question 'Has a doctor ever told you that you have any of the following health problems? This study includes a list of different chronic diseases including gastrointestinal conditions, heart diseases, neurological diseases, musculoskeletal and endocrine conditions, respiratory diseases, and cancers. These were coded as (zero, one, two or more conditions. Participants had been asked to bring all medical records, laboratory results and medications that they were using on the interview day; they all checked by a general practitioner to verify the self-reported medical conditions as well.

Blood sampling and related tests

Venous blood samples were taken from 7:00 to 9:00 AM after 8–12 h of fasting. Blood tubes were centrifuged for 15 min at 3000 rpm to separate serum. Serum concentrations of glucose, and HDL-C were measured by enzymatic reactions using a chemistry analyzer (BT1500, Italy; Pars Azmun kits, Iran).

Statistical analysis

For continuous and categorical variables, descriptive statistical analyses were performed. Data were expressed as mean (SD) and median (interquartile range) for continuous variables due to the asymmetric nature of the variables. For categorical variables, numbers and percentages are presented. We used Neyshabur census data of residents 50 years and up to calculate the overall age-adjusted prevalence of MetS. Except for the overall prevalence of MetS, Because participants in the Neyshabur longitudinal study on Ageing were selected through stratified random sampling from residents of 50 years and up. Except for the overall prevalence of MetS, all prevalence in the current analysis is crude. The normality of distribution of continuous variables was checked by plots (histograms and Q-Q plots) and tested by a one-sample Kolmogorov–Smirnov test. Mann–Whitney tests for non-normally distributed variables and the Chi-square tests were used to examine differences between participants in terms of categorical variables. The prevalence of individual components of metabolic syndrome is described using sex-specific criteria. Multivariable logistic regression was used to identify risk factors associated with metabolic syndrome for both definitions (ATP and the IDF) by sex, including age categories, marital status, income status, education levels, smoking, physical activity, other medical conditions, and BMI). Crude and adjusted odds ratios (AORs) with 95% confidence intervals (CIs) were calculated. The agreement between the definitions of ATP and IDF was assessed with kappa statistics. The agreement level was rated as poor with $K \leq 0.20$, fair with $K = 0.21$ to 0.40, moderate with $K = 0.41$to 0.60, remarkable with $K = 0.61$ to 0.80, and excellent with $K > 0.80$. All statistical analyses were performed using R version 4.0.2 for Windows. A two-sided P-value of < 0.05 was considered statistically significant.

Result

There were 3383 men and 3873 women aged ≥ 50 years evaluated in this study. The overall median age of the population was 59.3 (interquartile range (IQR) = 54.9–65.5) years, whereas the median age of men and women were 60.3 and women were 60.3 (IQR = 55.9–66.8) and 58.4 (IQR = 54.2–64.4), respectively. The categorical baseline characteristics of the study subjects according to the status of the MetS are shown in **Table 1**. In general, the frequency of MetS was higher in older people, women, illiterate, those with higher BMI and less physical activity, and those who were living alone or had hypertension, diabetes, or other medical conditions compared to those without MetS. However, the prevalence of MetS was lower in those in less income category and smokers.,All variables were significantly different between the two groups ($P < 0.05$). According to the ATP and IDF definitions, the overall crude and age-adjusted prevalence of the MetS were similar (45.8% and 47.1%, respectively). The prevalence of the MetS in men and women was 36.8% and 53.5% by the ATP definition, 33.1% and 59.4% by the IDF definition, respectively. The Prevalence of individual components of MetS in older adults according to NCEP ATP III and IDF criteria was presented in Fig. 1. As shown in Fig. 1, by both the ATP and the IDF definitions, prevalence of individual components in women was higher than men (prevalence of abnormal obesity in women was more than twice). Tables 2 and 3 illustrate the multivariable logistic regression findings for MetS indicators for both criteria (ATP and the IDF) by gender. In the fully adjusted model, according to both definitions, those with MetS were more likely to be in the age range of 70 years and above, have at least one disease, and a higher BMI.

After fully adjusting, according to ATP criteria, other gender-specific metabolic syndrome risk factors in men included smoking, income, physical activity, whereas in women, those who had a higher education level were less likely to have MetS. According to IDF criteria, other gender-specific metabolic syndrome risk factors in men included physical activity, and in women, it was education level.

On the other hand, in men, smoking had an associated reduction in odds of MetS. There was an interaction between smoking and BMI. Therefore, a composition variable was defined to include both smoking and BMI in the model (Table 4). Accordingly, based on the ATP criteria among men, nonsmokers with an abnormal level of BMI were significantly four times more (AOR 4.74, 95% CI: 3.84–5.86, p-value < 0.001) likely to have MetS compared to those with a normal level of BMI. Moreover, smokers with an abnormal level of BMI were four times more (AOR 4.17, 95% CI: 3.08–5.63, p-value < 0.001) likely to have MetS compared to nonsmokers with a normal level of BMI. Besides, smokers with a normal level of BMI were 52% (AOR 0.48, 95% CI: 0.31–0.74, p-value < 0.001) less likely to have MetS than nonsmokers with normal BMI levels. The same pattern was true for women. In addition, in ATP III criteria and women's results, nonsmokers with an abnormal level of BMI were significantly three times more likely to have MetS compared to those with a normal level of BMI (AOR 2.99, 95% CI: 2.46–3.63, p-value < 0.001). Smokers with an abnormal level of BMI were 63% more likely to have MetS than to nonsmokers with a normal level of BMI (AOR 1.63, 95% CI: 0.83–3.20, p-value = 0.157).

The degree of agreement (kappa statistic) between ATPIII and IDF definition was nearly perfect (Kappa = 0.79, 95% CI 0.72–0.80, p-value < 0.001).

Discussion

The present study investigated the associations between gender and the prevalence of MetS components in adults 50 years and up based on IDF and NCEP: ATP III definitions. Our findings showed that the overall prevalence of MetS by the ATP III and IDF definitions was 45.76% and 47.13%, respectively. There was no significant difference between IDF and ATP III diagnosis for individuals with MetS.

Iran in the Middle- East has been reported as a country with a high prevalence of MetS [18, 19]. A meta-analysis of cross-sectional studies on the population of the Middle-East reported that the overall prevalence of MetS in Iran is 6–42%,.[18]. Various Iranian studies indicate a high prevalence of MetS in adults, suggesting an increased risk of this syndrome with increasing age. In a meta-analysis study in Iran, the overall prevalence of MetS was 30.4%; this value increases to 51.7% in those over 60 years of age [12]. In another meta-analysis study in Iran, the prevalence of MetS was 36.9% for ATP III and 34.6% for IDF in adults [19].

In our study, the prevalence of MetS was higher in women than in men, 53.6% vs 36.8% by the definition of ATP III and 59.4% vs. 33.1% by IDF. Furthermore, the prevalence of all components of MetS among women was higher (Fig. 1). These results were in line with the other studies carried out in Iran. A longitudinal study in people aged 40–70 found that the prevalence of MetS and its components was more in women than in men [20]. The Tehran Lipid and Glucose Study showed that MetS prevalence increased with age in both sexes with a significantly higher prevalence in the age group above 50 years, especially in women (Men; ≥ 33.9%, and women; ≥ 64.1%) [21]. The findings of a meta-analysis study in Iran showed that MetS prevalence was higher in women than men; 35.4% versus 24.1% by the ATPIII definition, and 36.0% versus 29.9% by the IDF definition (32).

Based on ATP III and IDF criteria, our results revealed a higher prevalence of all the MetS components in women than in men. The highest prevalence among the components was low HDL-C and high WC. The prevalence of other components, including high TG level, high BP, and elevated BS levels, were also higher in women than in

Table 1 Socio-demographic and clinical profile of the study participants according to the status of Metabolic Syndrome (MetS), Neyshabur Longitudinal Study on Ageing

Variables	Total (N = 7256)	Metabolic Syndrome (ATP definition)			Metabolic Syndrome (IDF definition)		
		With MetS (n = 3320) (% row)	without MetS (n = 3936) (% row)	p-value	With Met S (n = 3420) (% row)	without MetS (n = 3836) (% row)	p-value
Age in years Mean (Interquartile Range)	59.3 (54.9–65.5)	60.2 (55.7–66.4)	58.6 (54.3–64.6)	< 0.001	59.59 (55.2–65.8)	58.92 (54.6–65.1)	0.009
Age groups (years)							
50–59	3716	1546 (41.6)	2170 (58.4)	< 0.001	1691(45.5)	2025 (54.5)	< 0.001
60–69	2399	1218 (50.8)	1181(49.2)		1214 (50.6)	1185 (49.4)	
70 +	1141	556 (48.7)	585 (51.3)		515 (45.1)	626 (54.9)	
Sex							
Men	3383	1246(36.83)	2137(63.17)	< 0.001	1120(33.11)	2263(66.89)	< 0.001
Women	3873	2074(53.55)	1799(46.45)		2300(59.39)	1573(40.61)	
Years of education							
0	1892	960 (50.7)	932 (49.3)	< 0.001	996 (52.6)	896 (47.4)	< 0.001
1–8	3121	1379 (44.2)	1742 (55.8)		1430 (45.8)	1691(54.2)	
> =9	2185	957 (43.8)	1228 (56.2)		967 (44.3)	1218 (55.7)	
Marital status							
Living alone	727	398 (54.8)	329 (45.2)	< 0.001	418 (57.5)	309 (42.5)	< 0.001
Living with spouse	6454	2887 (44.73)	3567 (55.3)		2965 (45.9)	3489 (54.1)	
Income status							
Have difficulties	1456	615 (42.2)	841(57.8)	0.008	641 (44.0)	815 (56.0)	0.026
Sufficient	4363	2024 (46.4)	2339 (53.6)		2082 (47.7)	2281 (52.3)	
No problem	1388	659 (47.5)	729 (52.5)		673 (48.5)	715 (51.5)	
Current smoking							
Nonsmoker	6075	2970 (48.9)	3105 (51.1)	< 0.001	3048 (50.2)	3027 (49.8)	< 0.001
Smoker	717	194 (27.1)	523 (72.9)		187 (26.1)	530 (73.9)	
Diabetes							
Yes	1887	1597 (84.6)	290 (15.4)	< 0.001	1410 (74.7)	477 (25.3)	< 0.001
No	5289	1722 (32. 6)	3567 (67.4)		2009 (38.0)	3280 (62.0)	
Hypertension							
Yes	2832	2197 (77.6)	635 (22.4)	< 0.001	2063 (72.8)	769 (27.2)	< 0.001
No	3740	910 (24.3)	2830(75.7)		1114 (29.8)	2626 (70.2)	
Other medical conditions*							
0	2696	856 (31.7)	1840 (68.3)	< 0.001	928 (34.4)	1768 (65.6)	< 0.001
1	2051	869(42.4)	1182 (57.6)		915 (44.6)	1136 (55.4)	
+2	2509	1595 (63.6)	914 (36.4)		1577 (62.8)	932 (37.2)	
BMI							
< 25	1949	408 (20.9)	1541(79.1)	< 0.001	247 (12.7)	1702 (87.3)	< 0.001
25–29.9	3100	1517 (48.9)	1583 (51.1)		1609 (51.9)	1491 (48.1)	
> =30	2158	1371 (63.5)	787 (36.5)		1538 (71.3)	620 (28.7)	
Physical activity (PASE score)** Mean (interquartile Range)	63.5 (35.3–141.7)	57.5 (33.9–117.1)	67.6 (35.8–153.4)	< 0.001	57.46 (35.3–114.9)	70.75 (35.3–155.1)	< 0.001
Physical activity (PASE score)							

Table 1 (continued)

Variables	Total (N = 7256)	Metabolic Syndrome (ATP definition)			Metabolic Syndrome (IDF definition)		
		With MetS (n = 3320) (% row)	without MetS (n = 3936) (% row)	p-value	With Met S (n = 3420) (% row)	without MetS (n = 3836) (% row)	p-value
Low (= < 40.3)	2537	1280 (50.5)	1257 (49.5)	< 0.001	1299 (51.20	1238 (48.8)	< 0.001
Moderate)40.3–106.5)	2263	1097 (48.5)	1166 (51.5)		1181 (52.2)	1082 (47.8)	
High (> = 106.5)	2400	920 (38.3)	1480 (61.7)		915 (38.1)	1485 (61.9)	
WHR (Waist to Hip Ratio)***				< 0.001			
Normal	1023	153 (15.0)	870 (85.0)		34 (3.3)	989 (96.7)	< 0.001
Abnormal	6232	3166 (50.8)	3066 (49.2)		3386 (54.3)	2846 (45.7)	

*Other medical conditions: a list of different chronic diseases including gastrointestinal conditions, heart diseases, neurological diseases, musculoskeletal and endocrine conditions, respiratory diseases, and cancers have been included

**PASE: Physical Activity Scale for Elderly

***WHR: Waist to Hip Ratio

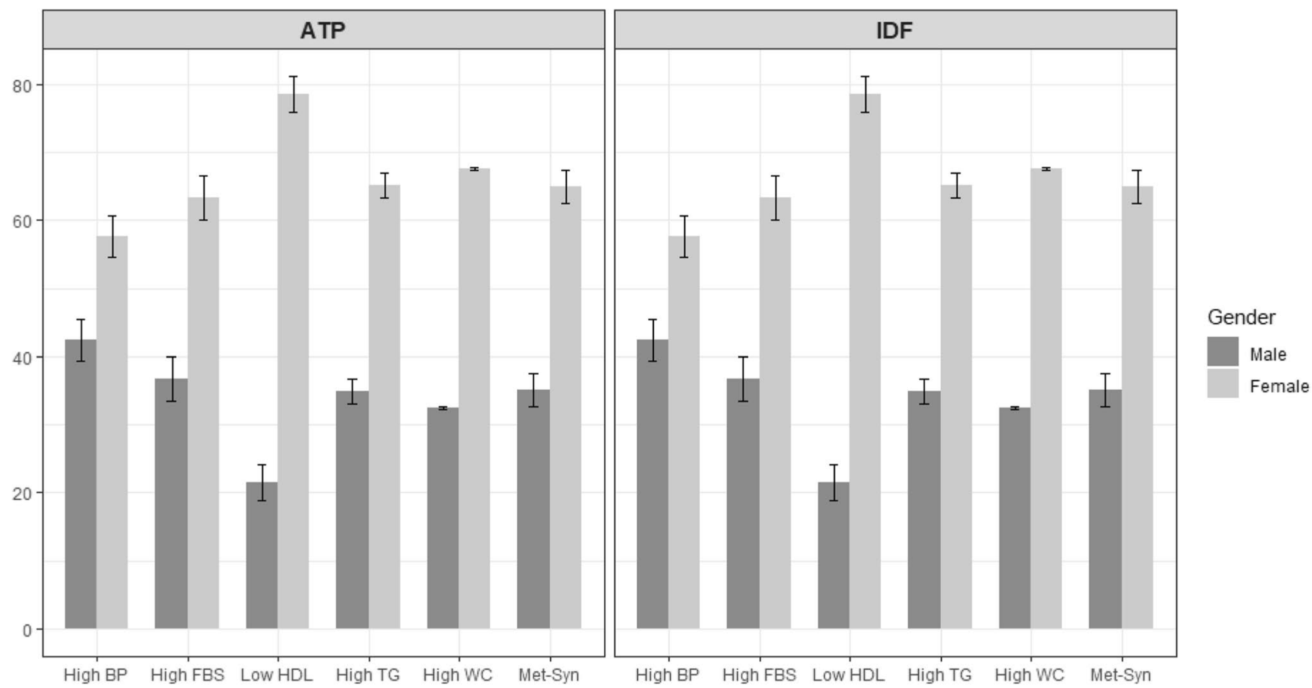

Fig. 1 Prevalence of individual components of Metabolic Syndrome in older adults according different definitions; The National Cholesterol Education Program Adult Treatment III (NCEP ATP III), and the International Diabetes Federation (IDF) criteria, Neyshabur Longitudinal Study on Ageing

men. The gender-specific differences in the prevalence of MetS components were reported in several previous studies [22–26]. Although, the findings of these studies are not consistent in terms of gender differences characteristics. For instance, an analysis of the Turkish and Kurdish populations showed the most common components of MetS were hypertension, abdominal obesity, elevated FBS, and TG but not low HDL-C in both sexes [27]. In Chain, it was revealed that older adult women had higher TG, lower HDL-C, and larger WC than older men [25]. In another study in older adults in Turkey, it has been shown that the prevalence of systolic BP, WC, and HDL-C in women is more than the prevalence in men [28]. In addition, the prevalence of TG and BP was higher in Korean women than in men aged 60

Table 2 Factors related to the prevalence of metabolic syndrome in men and women aged 50 years and up according to the National Cholesterol Education Program Adult Treatment III (NCEP ATP III) definition, Neyshabur Longitudinal Study on Aging

Variables	Men		Women	
	Univariate OR[¥] (95% Confidence Interval (CI))	Full Model AOR[#] (95% CI)	Univariate OR (95% CI)	Full Model AOR (95% CI)
Age, years				
50–59 years	1	1	1	1
60–69 years	1.34 (1.14–1.56)***	1.36 (1.13–1.64)**	1.79 (1.55–2.07)***	1.77 (1.50–2.08)***
70 years and above	1.28 (1.06–1.55)*	1.43 (1.11–1.84)**	1.71 (1.41–2.09)***	2.05 (1.59–2.64)***
Marital status				
Separated	1	1	1	1
Married	1.14 (0.67–2.01)	1.46 (0.76–2.83)	0.86 (0.73–1.02)	1.01 (0.82–1.23)
Income status				
Have difficulties	1	1	1	1
Sufficient for basic needs	1.34 (1.11–1.62)**	1.22 (0.97–1.53)	1.06 (0.90–1.25)	1.02 (0.85–1.23)
No problem	1.72 (1.38–2.15)***	1.40 (1.05–1.86)*	0.99 (0.80–1.22)	1.07 (0.83–1.39)
Years of education				
0	1	1	1	1
1–8	0.95 (0.77–1.17)	0.94 (0.73–1.21)	0.85 (0.74–0.99)*	0.87 (0.73–1.03)
9 = <	1.29 (1.05–1.58)*	1.13 (0.85–1.48)	0.69 (0.58–0.81)***	0.75 (0.60–0.94)*
Current Smoking				
Nonsmoker	1	1	1	1
Smoker	0.51 (0.42–0.62)***	0.49 (0.32–0.75)**	0.59 (0.33–1.02)	0.40 (0.08–1.97)
Physical activity (PASE score)				
Low (= < 40.3)	1	1	1	1
Moderate)40.3–106.5)	0.95 (0.78–1.15)	0.82 (0.65–1.04)	0.79 (0.69–0.92)**	0.88 (0.75–1.04)
High (> = 106.5)	0.73 (0.63–0.86)***	0.73 (0.60–0.89)**	0.68(0.57–0.81)***	0.82 (0.67–1.01)
Other medical conditions****				
0	1	1	1	1
1	1.66 (1.40–1.97)***	1.55 (1.28–1.88)***	1.36 (1.15–1.61)***	1.29 (1.07–1.55)**
+ 2	3.83 (3.21–4.58)***	3.31 (2.69–4.06)***	3.01 (2.57–3.52)***	2.64 (2.22–3.13)***
BMI				
< 25	1	1	1	1
25–29.9	4.40 (3.67–5.31)***	3.72 (2.98–4.64)***	2.50 (2.07–3.02)***	2.48 (2.01–3.05)***
> = 30	10.78 (8.58–13.59)***	9.09 (6.91–11.97)***	3.63 (3.01–4.40)***	3.67 (2.97–4.54)***

Full Model: Fully adjusted for all of variables (Adjusting for age categories, education levels, marital status, income status, current smoking, physical activity, other medical conditions and BMI)

Significance level, *** p < 0.001, ** p < 0.01, * p < 0.05

**** Other medical conditions: a list of different chronic diseases including gastrointestinal conditions, heart diseases, neurological diseases, musculoskeletal and endocrine conditions, respiratory diseases, and cancers have been included

[¥] OR: Odds Ratio, [#]AOR: adjusted odds ratio

and over, whereas in individuals with 20 to 59 years old, the prevalence of TG and BP in men was higher than in women [23]. It seems that differences in age [23, 29], genetic traits [30], dietary habits [31, 32], level of physical activity [22], and socioeconomic status [33] in the study populations are possible explanations for inconsistent findings regarding gender difference in various studies.

Menopause can be one of the reasons for the difference in the prevalence of MetS in women over 50 years of age compared to men. It has been found that MetS can occur in 40% of postmenopausal women due to obesity and weight gain [34]. Evidence suggests that reducing estrogen levels is associated with an increased risk of MetS during menopause. Reduced estrogen is associated with increased central fat, weight gain, insulin resistance, and increased levels of total cholesterol, LDL-C, TG, and decreased HDL-C[35, 36]. A study in Iran showed that the prevalence of MetS in postmenopausal women was 53.5% compared to

Table 3 Factors related to the prevalence of metabolic syndrome in men and women aged 50 years and up according to the International Diabetes Federation (IDF)definition, Neyshabur Longitudinal Study on Aging

Variables	Men		Women	
	Univariate OR¥ (95% Confidence Interval (CI))	Full Model AOR# (95% CI)	Univariate OR (95% CI)	Full Model AOR (95% CI)
Age, years				
50–59 years	1	1	1	1
60–69 years	1.12(0.95–1.31)	1.23(1.00–1.51)*	1.66(1.44–1.93)***	1.64(1.39–1.94)***
70 years and above	0.93(0.76–1.14)	1.19(0.90–1.59)	1.39(1.14–1.70)**	1.83(1.41–2.38)***
Marital status				
Separated	1	1	1	1
Married	1.77(0.98–3.43)	1.98(0.90–4.37)	0.94(0.79–1.11)	1.07(0.88–1.32)
Income status				
Have difficulties	1	1	1	1
Sufficient for basic needs	1.27(1.05–1.55)*	1.10(0.85–1.43)	1.06(0.90–1.25)	0.99(0.82–1.21)
No problem	1.66(1.32–2.07)***	1.23(0.89–1.69)	1.02(0.83–1.26)	1.05(0.81–1.37)
Years of education				
0	1	1	1	1
1–8	1.00(0.81–1.24)	0.93(0.70–1.24)	0.91(0.78–1.05)	0.84(0.70–1.00)
9 = <	1.38(1.12–1.71)**	1.20(0.88–1.64)	0.73(0.62–0.87)***	0.69(0.55–0.87)**
Current Smoking				
Nonsmoker	1	1	1	1
Smoker	0.57(0.47–0.70)***	0.68(0.31–1.51)	0.68(0.40–1.18)	0.47(0.10–2.26)
Physical activity (PASE score)				
Low (= < 40.321)	1	1	1	1
Moderate)40.322–106.548)	0.90(0.74–1.10)	0.73(0.56–0.95)*	0.89(0.77–1.04)	0.99(0.84–1.18)
High (> = 106.549)	0.72(0.61–0.85)***	0.65(0.52–0.81)***	0.74(0.63–0.89)**	0.89(0.73–1.10)
Other medical conditions				
0	1	1	1	1
1	1.56(1.31–1.85)***	1.41(1.13–1.75)**	1.30(1.10–1.54)**	1.24(1.03–1.49)*
+2	2.65(2.22–3.17)***	2.29(1.82–2.88)***	2.63(2.25–3.08)***	2.27(1.91–2.71)***
BMI				
< 25	1	1	1	1
[25–29.9]	19.93(14.68–27.75)***	18.61(12.71–27.26)***	3.79(3.13–4.60)***	3.85(3.12–4.75)***
> = 30	81.62(57.89–117.62)***	79.19(51.83–120.98)***	5.55(4.57–6.77)***	5.55(4.47–6.89)***

Full Model: Fully adjusted for all of variables (Adjusting for age categories, education levels, marital status, income status, current smoking, physical activity, other medical conditions and BMI)

Significance level, *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

**** Other medical conditions: a list of different chronic diseases including gastrointestinal conditions, heart diseases, neurological diseases, musculoskeletal and endocrine conditions, respiratory diseases, and cancers have been included

¥ OR: Odds Ratio, #AOR: adjusted odds ratio

premenopausal women (18.3%) [37]. One of the reasons for the high prevalence rate of MetS in our study population was a large percentage of postmenopausal women. One study in the elderly women population showed that the prevalence of MetS was 45.7%; they found WC to be the most appropriate indicator for MetS detection in this group [38]. Abdominal obesity is an index of dysfunctional adipose tissue, which is crucial in clinical diagnosis. Adipose tissue plays a prominent role in insulin resistance and MetS by producing and secreting various biological molecules called adipokines. One study in older adults showed that the prevalence of MetS is associated with high levels of adipokines, including leptin, IL-6, TNF-α and low adiponectin levels [39]. It is known that MetS is associated with glucose intolerance, hypertension, and dyslipidemia. This study also found that FBS, TG, and BP levels increased with increasing abdominal obesity. Also, the use of anti-diabetic, anti-hypertensive, and anti-hyperlipidaemia drugs was higher in women than in

Table 4 Association between smoking and metabolic syndrome by gender; interaction between smoking and BMI, Neyshabur Longitudinal Study on Ageing

Criteria	Gender	Level	OR (Odds Ratio)	% 95 CI (Confidence Interval)	p-value
ATP	Male	Nonsmoker& BMI* < 25	Reference	………	………
		Nonsmokers& BMI > = 25	4.74	(3.84–5.86)	< 0.001
		Smoker& BMI < 25	0.48	(0.31–0.74)	< 0.001
		Smoker& BMI ≥ 25	4.17	(3.08–5.63)	< 0.001
	Female	Nonsmoker& BMI < 25	1	………	………
		Nonsmokers& BMI > = 25	2.99	(2.46–3.63)	< 0.001
		Smoker& BMI < 25	0.40	(0.08–1.96)	0.258
		Smoker& BMI ≥ 25	1.63	(0.83–3.20)	0.157
IDF	Male	Nonsmoker& BMI* < 25	1	………	………
		Nonsmokers& BMI > = 25	27.19	(18.67–39.61)	< 0.001
		Smoker& BMI < 25	0.67	(0.30–1.49)	0.327
		Smoker& BMI ≥ 25	24.94	(16.19–38.42)	< 0.001
	Female	Nonsmoker& BMI* < 25	1	………	………
		Nonsmokers& BMI > = 25	4.57	(3.75–5.57)	< 0.001
		Smoker& BMI < 25	0.47	(0.10–2.25)	0.343
		Smoker& BMI ≥ 25	3.17	(1.59–6.30)	0.001

Fully adjusted for all of variables (Adjusting for age categories, education levels, marital status, income status, current smoking, physical activity, other medical conditions)

*BMI: Body Mass Index (< 25; normal, ≥ 25; overweight and obesity

men (Women: 14.8%, and 40.4, 19.5%; men: 11.3%, 29.2%, and 14.2%, respectively).

Our results also show that the odds of MetS are affected by some conditions such as income status, current smoking, education level, physical activity, medical conditions, and BMI. Among these conditions, the effect of BMI is more significant than other factors. So, the abnormality in BMI (≥ 25) versus normal BMI (< 25) increased the odds of MetS more than 9 and 3,5 times in men and women, respectively. These results are inconsistent with other studies reporting the significant effects of BMI on odds of MetS [40–42]. In this regard, our results about the effect of smoking on the odds of MetS should be considered with caution. Although numerous studies have been indicated that smoking has an inductive effect on MetS [43–45], our results show that smoking has a protective role against MetS. Onat et al. reported that the protective role of smoking against MetS is due to the fact that smoking has a "protective" effect against abdominal obesity in both sexes, independent of waist circumference [46]. Compelling evidence implicated that smokers tended to have lower BMI than non-smokers, which is due to the fact that nicotine could suppress appetite by acting on the brain, and extend inter-meal interval; thus less food intake resulted in weight loss [47]. Although our result is consistent with the study performed by Onat [46], it seems that the protective effect of smoking is more due to the interaction between smoking and normal BMI, not to only smoking. Thus, it can be concluded that BMI is a strong determining factor that removes the inductive effect of smoking on MetS odds in smoker subjects with normal BMI. This effect might be due to the low number of smokers in this study and that most of them have normal BMI. Therefore, more studies on the high population of older smokers are necessary to reveal the pure effect of smoking on MetS.

There are few epidemiologic studies regarding sex- specific MetS prevalence in older adults. In the current study, a large number of men and women aged over 50 years in a cohort study were analysed. Our study was the first cohort study in Iran to reveal the prevalence of MetS in older subjects 50 years and older. Given the relatively high sample size, this study could provide a good estimation of the prevalence of MetS in older adults and provide insights for the management and reduction of MetS in older adults targeting women specifically. However, because of the cross-sectional design of the current study, we do not permit to evaluation of the cause-effect relationship between MetS and its components. In addition, few subjects of patients suffering from chronic illness were eliminated from the study and, few subjects not accepted our invitation for contribution to the study.

Conclusion

The current study was done based on the data from 7256 older individuals (50 years old and up) with MetS to explore the sex-specific prevalence of MetS and its components according to IDF and the NCEP ATP III definitions. Our results showed that the prevalence of MetS in older adults increased in both sexes, the prevalence of almost double in women. An almost perfect agreement was found between the IDF and the NCEP ATP III definitions in the present study. Our study also revealed that women had a higher prevalence of all the components of MetS contributed to the definition of MetS than did men. The findings showed that lowering HDL and increasing abdominal obesity could be good diagnostic factors for examining the prevalence of MetS in women over the age of 50. Sex-specific public health strategies and management policies for preventing and management of MetS and its components among the older adult population should be developed to reduce social and medical burden.

Author's contribution The author's contributions were as follows: NA, MSH, MA, and MH were involved in design of the protocol and reviewed all drafts of the manuscript. NA, MSH, and FK were responsible for data preparation and analysis. AZ, AGH, contributed in developing the current research question and prepared the manuscript draft. All authors reviewed and contributed to all drafts of the manuscript.

Funding Funding for the NeLSA has been partly provided by Neyshabur University of Medical Sciences. The Iranian Ministry of Health and Medical education has also contributed to the funding used in the PERSIAN Cohorts through Grant no 700/534.

Data availability The datasets used and analysed during the current study available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate NeLSA has been approved by the Ethical Committee of Neyshabur University of Medical Sciences (record number IR.NUMS.REC, 1394.35) and the PERSIAN cohort study ethics approval by Tehran University of Medical Sciences (record number IR.TUMS.DDRI.REC.1396.1). The Written informed consent was obtained from all participants and they were free to leave the study at any time and for any reason, without any consequences. The current study received an approval from Neyshabur University of Medical Sciences (record number IR.NUMS.REC.1398.040).

Consent for publication Not applicable.

Competing interests The authors declare that they have no competing interests.

References

1. Younis A, Younis A, Tzur B, Peled Y, Shlomo N, Goldenberg I, et al. Metabolic syndrome is independently associated with increased 20-year mortality in patients with stable coronary artery disease. Cardiovasc Diabetol. 2016;15(1):149.
2. O'neill S, O'driscoll L. Metabolic syndrome: a closer look at the growing epidemic and its associated pathologies. Obesity reviews. 2015;16(1):1–12.
3. Eckel RH, Alberti KG, Grundy SM, Zimmet PZ. The metabolic syndrome. The lancet. 2010;375(9710):181–3.
4. Eckel RH, Grundy SM, Zimmet PZ. The metabolic syndrome. The lancet. 2005;365(9468):1415–28.
5. Azizi F, Hadaegh F, Khalili D, Esteghamati A, Hosseinpanah F, Delavari A, et al. Appropriate definition of metabolic syndrome among Iranian adults: report of the Iranian National Committee of Obesity. Arch Iran Med. 2010;13(5):426.
6. Mazloomzadeh S, Khazaghi ZR, Mousavinasab N. The Prevalence of Metabolic Syndrome in Iran: A Systematic Review and Meta-analysis. Iran J Public Health. 2018;47(4):473.
7. Jahangiry L, Khosravi-far L, Sarbakhsh P, Kousha A, EntezarMahdi R, Ponnet K. Prevalence of metabolic syndrome and its determinants among Iranian adults: evidence of IraPEN survey on a bi-ethnic population. Sci Rep. 2019;9(1):7937.
8. Azizi F, Hadaegh F, Khalili D, Esteghamati A, Hosseinpanah F, Delavari A, et al. Appropriate definition of metabolic syndrome among Iranian adults: report of the Iranian National Committee of Obesity. 2010;13(5):426.
9. Pucci G, Alcidi R, Tap L, Battista F, Mattace-Raso F, Schillaci G. Sex-and gender-related prevalence, cardiovascular risk and therapeutic approach in metabolic syndrome: A review of the literature. Pharmacol Res. 2017;120:34–42.
10. Pradhan AD. Sex differences in the metabolic syndrome: implications for cardiovascular health in women. Clin Chem. 2014;60(1):44–52.
11. Ostovar R, Kiani F, Sayehmiri F, Yasemi M, Mohsenzadeh Y, Mohsenzadeh Y. Prevalence of metabolic syndrome in Iran: A meta-analysis. Electron Physician. 2017;9(10):5402.
12. Farmanfarma KK, Kaykhaei MA, Adineh HA, Mohammadi M, Dabiri S, Ansari-Moghaddam A. Prevalence of metabolic syndrome in Iran: A meta-analysis of 69 studies. Diabetes Metab Syndr. 2019;13(1):792–9.
13. Poustchi H, Eghtesad S, Kamangar F, Etemadi A, Keshtkar A-A, Hekmatdoost A, et al. Prospective epidemiological research studies in Iran (the PERSIAN Cohort Study): rationale, objectives, and design. Am J Epidemiol. 2018;187(4):647–55.
14. Zimmet P. A new IDF worldwide definition of the metabolic syndrome: the rationale and the results. Diabetes Voice. 2005;23:469–80.
15. Alberti KGM, Zimmet P, Shaw J. The metabolic syndrome—a new worldwide definition. The Lancet. 2005;366(9491):1059–62.
16. Azizi F, Khalili D, Aghajani H, Esteghamati A, Hosseinpanah F, Delavari A, et al. Appropriate waist circumference cut-off points among Iranian adults: the first report of the Iranian National Committee of Obesity. Arch Iran Med. 2010;13(3):243.
17. Ahmadi B, Sanii NA, Allahverdipour H, Bani F, Bakhtari F. Predictors of physical activity in older adults in Northwest of Iran. Elderly Health Journal. 2018.
18. Ansarimoghaddam A, Adineh HA, Zareban I, Iranpour S, HosseinZadeh A, Kh F. Prevalence of metabolic syndrome in Middle-East countries: Meta-analysis of cross-sectional studies. Diabetes Metab Syndr. 2018;12(2):195–201.
19. Amirkalali B, Fakhrzadeh H, Sharifi F, Kelishadi R, Zamani F, Asayesh H, et al. Prevalence of metabolic syndrome and its components in the Iranian adult population: a systematic review and meta-analysis. Iranian red crescent medical journal. 2015;17(12).
20. Ebtekar F, Dalvand S, Gheshlagh RG. The prevalence of metabolic syndrome in postmenopausal women: a systematic review and meta-analysis in Iran. Diabetes Metab Syndr. 2018;12(6):955–60.
21. Azizi F, Salehi P, Etemadi A, Zahedi-Asl S. Prevalence of metabolic syndrome in an urban population: Tehran Lipid and Glucose Study. Diabetes Res Clin Pract. 2003;61(1):29–37.
22. Kuk JL, Ardern CI. Age and sex differences in the clustering of metabolic syndrome factors: association with mortality risk. Diabetes Care. 2010;33(11):2457–61.
23. Park E, Kim J. Gender-and age-specific prevalence of metabolic syndrome among Korean adults: analysis of the fifth Korean

National Health and Nutrition Examination Survey. J Cardiovasc Nurs. 2015;30(3):256–66.
24. Hari P, Nerusu K, Veeranna V, Sudhakar R, Zalawadiya S, Ramesh K, et al. A gender-stratified comparative analysis of various definitions of metabolic syndrome and cardiovascular risk in a multiethnic US population. Metab Syndr Relat Disord. 2012;10(1):47–55.
25. He Y, Jiang B, Wang J, Feng K, Chang Q, Fan L, et al. Prevalence of the metabolic syndrome and its relation to cardiovascular disease in an elderly Chinese population. J Am Coll Cardiol. 2006;47(8):1588–94.
26. Lee S, Ko Y, Kwak C, Yim E-s. Gender differences in metabolic syndrome components among the Korean 66-year-old population with metabolic syndrome. BMC geriatrics. 2016;16(1):27.
27. Jahangiry L, Khosravi-far L, Sarbakhsh P, Kousha A, EntezarMahdi R, Ponnet K. Prevalence of metabolic syndrome and its determinants among Iranian adults: evidence of IraPEN survey on a bi-ethnic population. Sci Rep. 2019;9(1):1–7.
28. Akbulut G, Köksal E, Bilici S, Tek NA, Yildiran H, Karadag MG, et al. Metabolic syndrome (MS) in elderly: a cross sectional survey. Arch Gerontol Geriatr. 2011;53(3):e263–6.
29. Arai H, Yamamoto A, Matsuzawa Y, Saito Y, Yamada N, Oikawa S, et al. Prevalence of the metabolic syndrome in elderly and middle-aged Japanese. Journal of Clinical Gerontology and Geriatrics. 2010;1(2):42–7.
30. Lim ES, Ko YK, Ban KO. Prevalence and risk factors of metabolic syndrome in the K orean population–K orean N ational H ealth I nsurance C orporation S urvey 2008. J Adv Nurs. 2013;69(7):1549–61.
31. Song S, Lee JE, Song WO, Paik H-Y, Song Y. Carbohydrate intake and refined-grain consumption are associated with metabolic syndrome in the Korean adult population. J Acad Nutr Diet. 2014;114(1):54–62.
32. Jung H-J, Song W-O, Paik H-Y, Joung H-J. Dietary characteristics of macronutrient intake and the status of metabolic syndrome among Koreans. Journal of Nutrition and Health. 2011;44(2):119–30.
33. Park MJ, Yun KE, Lee GE, Cho HJ, Park HS. The relationship between socioeconomic status and metabolic syndrome among Korean adults. The Korean Journal of Obesity. 2006;15(1):10–7.
34. Lobo RA. Metabolic syndrome after menopause and the role of hormones. Maturitas. 2008;60(1):10–8.
35. Toth M, Tchernof A, Sites C, Poehlman E. Effect of menopausal status on body composition and abdominal fat distribution. Int J Obes. 2000;24(2):226–31.
36. Jensen J, Nilas L, Christiansen C. Influence of menopause on serum lipids and lipoproteins. Maturitas. 1990;12(4):321–31.
37. Eshtiaghi R, Esteghamati A, Nakhjavani M. Menopause is an independent predictor of metabolic syndrome in Iranian women. Maturitas. 2010;65(3):262–6.
38. Bakhtiari A, Hajian-Tilaki K, Ghanbarpour A. Metabolic syndrome and different obesity phenotypes in the elderly women population: Iran's Health System on aging. Caspian J Intern Med. 2018;9(3):252.
39. You T, Nicklas BJ, Ding J, Penninx BW, Goodpaster BH, Bauer DC, et al. The metabolic syndrome is associated with circulating adipokines in older adults across a wide range of adiposity. J Gerontol A Biol Sci Med Sci. 2008;63(4):414–9.
40. He Y, Jiang B, Wang J, Feng K, Chang Q, Zhu S, et al. BMI versus the metabolic syndrome in relation to cardiovascular risk in elderly Chinese individuals. Diabetes Care. 2007;30(8):2128–34.
41. Sen Y, Kandemir N, Alikasifoglu A, Gonc N, Ozon A. Prevalence and risk factors of metabolic syndrome in obese children and adolescents: the role of the severity of obesity. Eur J Pediatr. 2008;167(10):1183–9.
42. Bradshaw PT, Monda KL, Stevens J. Metabolic syndrome in healthy obese, overweight, and normal weight individuals: the Atherosclerosis Risk in Communities Study. Obesity. 2013;21(1):203–9.
43. Bermudez V, Olivar LC, Wheeler Torres CN, Gonzalez R, Espinoza C, Morocho A, et al. Cigarette smoking and metabolic syndrome components: a cross-sectional study from Maracaibo City, Venezuela. F1000Research. 2018;7.
44. Jia WP. The impact of cigarette smoking on metabolic syndrome. Biomed Environ Sci. 2013;26(12):947–52.
45. Yu M, Xu C-X, Zhu H-H, Hu R-Y, Zhang J, Wang H, et al. Associations of cigarette smoking and alcohol consumption with metabolic syndrome in a male Chinese population: a cross-sectional study. Journal of epidemiology. 2014:JE20130112.
46. Onat A, Özhan H, Esen AM, Albayrak S, Karabulut A, Can G, et al. Prospective epidemiologic evidence of a "protective" effect of smoking on metabolic syndrome and diabetes among Turkish women—without associated overall health benefit. Atherosclerosis. 2007;193(2):380–8.
47. Lv J, Chen W, Sun D, Li S, Millwood IY, Smith M, et al. Gender-specific association between tobacco smoking and central obesity among 0.5 million Chinese people: the China Kadoorie Biobank Study. PloS one. 2015;10(4):e0124586.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.