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Cardiometabolic risk factor clusters in older adults using latent class analysis on the Bushehr elderly health program

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Metabolic syndrome (MetS), comprising obesity, insulin resistance, hypertension, and dyslipidemia, increases the risk of type II diabetes mellitus and cardiovascular disease. This study aimed to identify the prevalence and determinants of specific clusters of the MetS components and tobacco consumption among older adults in Iran. The current study was conducted in the second stage of the Bushehr Elderly Health (BEH) program in southern Iran—a population-based cohort including 2424 subjects aged ≥ 60 years. Latent class analysis (LCA) was used to identify MetS and tobacco consumption patterns. Multinomial logistic regression was conducted to investigate factors associated with each MetS class, including sociodemographic and behavioral variables. Out of 2424 individuals, the overall percentage of people with one or more components of MetS or current tobacco use was 57.8% and 20.8%, respectively. The mean (SD) age of all participants was 69.3(6.4) years. LCA ascertained the presence of four latent classes: class 1 ("low risk"; with a prevalence of 35.3%), class 2 ("MetS with medication-controlled diabetes"; 11.1%), class 3 ("high risk of MetS and associated medication use"; 27.1%), and class 4 ("central obesity and treated hypertension"; 26.4%). Compared to participants with a body mass index (BMI) < 30, participants with BMI ≥ 30 were more likely to belong to class 3 (OR 1.91, 95% CI 1.31–2.79) and class 4 (OR 1.49, 95% CI 1.06–2.08). Polypharmacy was associated with membership in class 2 (OR 2.07, 95% CI 1.12–3.81), class 3 (OR 9.77, 95% CI 6.12–15.59), and class 4 (OR 1.76, 95% CI 1.07–2.91). The elevated triglyceride-glucose index was associated with membership in class 2 (OR 12.33, 95% CI 7.75–19.61) and class 3 (OR 12.04, 95% CI 8.31–17.45). Individuals with poor self-related health were more likely to belong to class 3 (OR 1.43; 95% CI 1.08–1.93). Four classes were identified among older adults in Iran with distinct patterns of cardiometabolic risk factors. Segmenting elderly individuals into these cardiometabolic categories has the potential to enhance the monitoring and management of cardiometabolic risk factors. This strategy may help reduce the severe outcomes of metabolic syndrome in this susceptible population.

Keywords Latent class analysis, Metabolic syndrome, Cardiometabolic, Older adults

Metabolic syndrome (MetS) is a major risk factor for the development of cardiovascular disease (CVD) and type 2 diabetes mellitus (T2DM)[1]. Mets, as defined by the International Diabetes Federation (IDF), comprises an increased waist circumference plus two or more of (i) hypertriglyceridemia, (ii) low high-density lipoprotein (HDL) cholesterol levels, (iii) high blood pressure, and (iv) elevated fasting blood glucose[2]. The risk of

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developing MetS increases with age, with the highest incidence in men during their sixth decade of life and women during their seventh decade[3]. MetS has been associated with a 1.5-fold increase in the risk of all-cause mortality[4]. A recent meta-analysis of 69 surveys in 2019 conducted in Iran has revealed a concerning prevalence rate of 51.7% for MetS over among older adults. The deleterious effects of MetS may be effectively mitigated by improved identification and management of the component risk factors[5]. It has been observed that there could be a possible association between the presence of nonalcoholic fatty liver disease (NAFLD), polycystic ovary syndrome (PCOS), or sleep apnea in an individual's medical history and an increased likelihood of developing metabolic syndrome[6–8]. Excess deep fat accumulation in the abdominal area, also known as visceral adiposity, can potentially disrupt the balance of adipokines in the body, leading to insulin resistance, impaired functioning of the endothelium, and a heightened risk of developing atherosclerosis[9].

Smoking cessation is beneficial in preventing MetS and reducing the risk of cardiovascular disease in individuals with established MetS[10]. Active smokers have a 26% higher risk of developing metabolic syndrome compared to individuals who do not smoke. Cigarette smoking can contribute to the development of various components of metabolic syndrome, which can lead to the onset and progression of the disease through multiple synergistic mechanisms[11].

Latent class analysis (LCA) is a statistical technique used to identify groups of individuals with similar patterns of attributes or characteristics that may not be directly observed. To date, LCA has offered valuable insights into the underlying mechanisms and can identify different risk profiles in the context of metabolic syndrome[12–14]. Based on the available evidence, the sedentary lifestyle, technological advancements, shifts in behavioral and dietary habits, and rapid urbanization in Iran have contributed to the emergence of metabolic syndrome as a significant health concern. This is particularly critical as cardio-metabolic risk factors play a pivotal role in the development of cardiovascular diseases[5,15].

Extensive research efforts have been dedicated to understanding MetS and its associated risk factors. However, significant gaps in knowledge persist, particularly regarding the heterogeneous nature of MetS. Traditional analyses often oversimplify MetS as a uniform condition, failing to capture its complex mechanisms. By contrast, LCA offers a more nuanced approach by identifying distinct subgroups within the MetS population, each characterized by unique patterns of risk factors. LCA methodology allows for a deeper understanding of the underlying mechanisms of MetS and facilitates the development of more personalized and effective interventions[16]. This is particularly crucial for older adults, among whom MetS prevalence is high. Our aim was to use LCA to derive subtypes of MetS and tobacco consumption behavior among community-dwelling older adults in Iran and to identify the key determinants of each MetS subtype. This may help us better comprehend the intricate physiological and behavioral factors that contribute to metabolic syndrome in this population and may lead to personalized interventions and healthcare strategies for older adults, improving their well-being and promoting healthier aging.

Methods

Study design and participants

The present study utilized cross-sectional data obtained from the second stage of the Bushehr Elderly Health (BEH) program, a prospective demographic cohort study conducted in Bushehr, Southern Iran. The study design and methodology for the BEH program have been previously detailed[7,17]. The first phase of BEH was initiated in March 2013 to examine the occurrence of cardiovascular risk factors and their association with adverse cardiovascular events in older persons. Using a stratified random sampling method, a total of 3000 individuals aged 60 and over were enlisted to participate in this study. Eligibility criteria for inclusion included (i) residing in Bushehr for a minimum of one year prior to recruitment, (ii) having no intention of leaving during the next two years, (iii) being capable of completing the study instruments, and (iv) providing written, informed consent. In 2018, the second stage of the initial study phase concluded, with an overall participation rate of 81%.

Questionnaires were utilized to gather data regarding demographic status, physical and mental health, functional status, lifestyle factors, and history of medication use by professional nurses through an interview. The study protocol was approved by the Ethics Research Committee of Bushehr University of Medical Sciences (IR.BPUMS.REC.1402.138) and the Endocrinology and Metabolism Research Institute of Tehran University of Medical Sciences.

Definition of metabolic syndrome

Metabolic syndrome was diagnosed in line with International Diabetes Federation (IDF) guidelines. MetS was diagnosed when an individual had central obesity in addition to at least two of the following criteria: (i)elevated blood triglyceride levels (≥ 150 mg/dl [1.7 mmol/L] or use of medication), (ii) reduced levels of high-density lipoprotein (< 40 mg/dl [1.03 mmol/L] in men and < 50 mg/dl [1.29 mmol/L] in women), (iii) elevated blood pressure (≥ 130 mmHg for systolic blood pressure and/or ≥ 85 mmHg for diastolic blood pressure or use of antihypertensive medication), and (iv) impaired fasting glucose (≥ 100 mg/dl [5.6 mmol/L] or use of drug therapy). In line with the IDF guidelines, waist circumference cut-off points appropriate for the BEH context were used: $\geq$ 80 cm for women and ≥ 94 cm for men[18].

Blood pressure

Systolic and diastolic blood pressures were measured twice using a standard mercury sphygmomanometer. The measurements were taken in the right arm after 15 min of rest in a sitting position, with a 10-min time interval between each measurement. The average of the two measurements was used[7,17].

Laboratory evaluations

Following a period of 8–10 h of fasting, trained nursing personnel collected venous blood samples amounting to 25 ml. Measurement of fasting blood glucose and the blood lipid profile (total cholesterol, HDL-c, LDL-c, and triglycerides) was performed by experienced and accredited clinical pathology professionals. The fasting blood glucose and lipid profile tests were measured using an enzymatic colorimetric method (Pars Azmun, Karaj, Iran).

Anthropometric and clinical assessments

Height and weight were measured using a fixed stadiometer and digital scale. Neck, waist, and hip circumferences were measured using a flexible, constant tension tape at the level of the umbilicus and the widest part over the buttocks. Body mass index (BMI) was calculated by dividing weight (in kilograms) by height squared (in meters).

Other covariates

Interviews were conducted to gather sociodemographic information, including age, gender, marital status, physical activity, income levels, education, occupation, smoking history (never used, past history of use, current user), medical history, and drug use. In order to assess the average physical activity level, the International Physical Activity Questionnaire (IPAQ) was employed to evaluate the metabolic equivalent of tasks within a 24-h timeframe. This self-report tool is commonly used to assess an individual's physical activity levels in the Iranian population. It has been validated and classified into three categories: no activity and sedentary (≤ 1.39), low active (1.4–1.59), and active (≥ 1.6 MET/24 h)[17,19]. Polypharmacy was defined as the administration of more than five medications within a 24-h period. Triglyceride-glucose index (TyG) was calculated using the formula Ln [fasting triglycerides (mg/dl) × fasting glucose (mg/dl)/2][20].

Individuals reported their perception of their overall health using a five-point scale, ranging from excellent to poor. For the purposes of this study, this was dichotomized into good self-rated health (excellent, very good, and good) vs. poor self-rated health (fair and poor)[21,22].

Statistical analysis

The LCA model was used to identify subgroups of metabolic syndrome components and tobacco consumption. In order to select the most appropriate number of latent classes, the likelihood-ratio statistic, G^2 statistic, Akaike information criterion (AIC), Bayesian information criterion (BIC), entropy, and the log-likelihood value were calculated for models ranging from one to seven classes. When selecting the best model, lower log-likelihood values, AIC, BIC, G2, and higher entropy values were considered. Finally, the four-class model was chosen due to clinical interpretability and model parsimony. We used nine variables to evaluate the latent classes: waist circumference (high, normal), fasting blood glucose (high, normal), triglycerides (high, normal), high-density lipoprotein (high, normal), blood pressure (high, normal), diabetes drugs (yes, no), antihypertensive drugs (yes, no), lipid-lowering drugs (yes, no), and tobacco (no, past, current). Each study participant was allocated to a single class with the greatest probability of membership. Multinomial logistic regression was performed to identify determinants of class membership, including age, gender, education, socioeconomic status, marital status, occupation, physical activity, self-related health, polypharmacy, and triglyceride-glucose index. LCA was performed using R version 4.1.1. In all analyses, a significance level of 0.05 was considered statistically significant.

Results

The current study included a total of 2424 individuals (Fig. 1), of which 52.1% were women. The mean (standard deviation, SD) age of all participants was 69.3 ± 6.4 years (69.5 ± 6.4 for men and 69.2 ± 6.4 for women). Overall, 77% of participants reported being sedentary or not engaging in regular physical activity. Additionally, 23.4% of men and 18.4% of women were current smokers. The prevalence of metabolic syndrome in women and men was 45.3 (95% confidence intervals, CI 42.4–48.2) and 69.4 (95% CI 66.7–71.9), respectively ($P < 0.001$). The prevalence of central obesity, low HDL, and hypertriglyceridemia were more common in women than men ($P < 0.001$; Table 1).

Latent class analysis

A four-class LCA model achieved the best compromise between model fit, parsimony, and clinical interpretability (Table 2). Although a five-class solution resulted in a slightly better model fit, this did not further improve clinical interpretability, so the four-class solution was used. These classes were labeled: "low risk" (class 1; 35.3%), "MetS with medication-controlled diabetes" (class 2; 11.1%), "high risk of MetS and related medication use" (class 3; 27.1%), and "central obesity and treated hypertension" (class 4; 26.4%).

Table 3 shows the prevalence of MetS components, medication use, and tobacco smoking among each latent class. Participants identified as Class 1, the "low risk" group, did not meet the criteria for a metabolic syndrome diagnosis. They were determined to be relatively metabolically healthy, except for elevated WC and BP measurements. The second class, classified as "MetS with administrating diabetes control medication," demonstrated the lowest prevalence at 11.1%. Individuals within this group exhibited a high probability of elevated FBS, high WC, and low HDL levels, as well as using glucose-lowering medications. The third group (high risk of MetS using associated medications), which accounted for 27.1% of the individuals, was identified by a high prevalence of MetS components, except for high triglycerides. This group of people was taking medications for diabetes, hypertension, and high cholesterol. The fourth category, comprising 26.4% of the study population, consisted of individuals with a high likelihood of hypertension, elevated WC, and using antihypertensive medications.

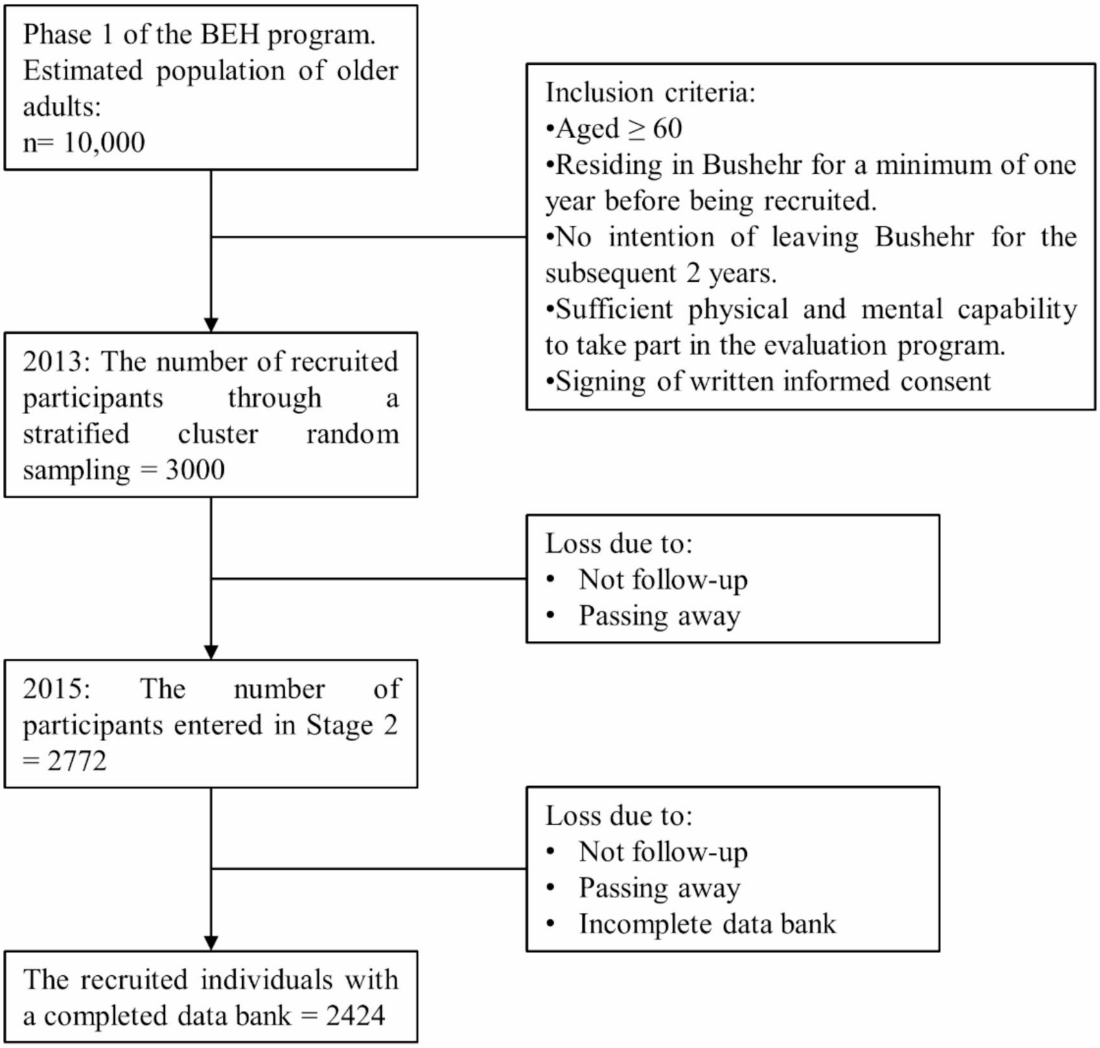

Fig. 1. Flow chart of enrolment in the Bushehr Elderly Health (BEH) program.

Factors associated with latent class membership

Multinomial logistic regression was performed to identify associations between sociodemographic and lifestyle factors and membership of each class (Table 4). Older age increased the odds of membership in class 4 (OR 1.61, CI 1.09–2.38, $P=0.016$) compared to latent class 1. Those who were unemployed and retired were less likely to be a member of class 2 than those who were in employment (OR 0.38, 95% CI 0.18–0.77, $P=0.007$ and OR 0.41, 95% CI 0.20–0.84, $P=0.16$, respectively). In addition, those with low physical activity levels were less likely to be a member of class 3 than those with no activity (OR 0.66, 95% CI 0.44–0.93, $P=0.020$). Individuals with obesity were most likely to be included in class 3 (OR 1.91, 95% CI 1.31–2.79, $P=0.001$), and class 4 (OR 1.49, 95% CI 1.06–2.08, $P=0.019$). Polypharmacy was associated with membership in class 2 (OR 2.07, 95% CI 1.12–3.81, $P=0.020$), class 3 (OR 9.77, 95% CI 6.12–15.59, $P<0.001$) and class 4 (OR 1.76, 95% CI 1.07–2.91, $P=0.026$) compared to class 1. A triglyceride-glucose index in tertile 3 (8.9–11.9) was associated with membership in class 2 (OR 12.33, 95% CI 7.75–19.61, $P<0.001$) and class 3 (OR 12.04, 95% CI 8.31–17.45, $P<0.001$).

Characteristics	Categories	Men ($n=1161$) Mean (SD) or proportion	Women ($n=1263$) Mean (SD) or proportion	*P*-value
Age n (%)	60–64 year	285(24.50)	313(24.80)	0.016
	65–69 year	422(36.30)	529(41.90)	
	70-74year	198(17.10)	180(14.30)	
	> =75 year	256(22.00)	241(19.10)	
Education (year)		7.17 ± 5.15	3.38 ± 4.15	< 0.001
Marital status n (%)	Married	1104(95.10)	758(60.00)	< 0.001
	Single	57(4.90)	505(40.00)	
Occupation	Employed	112(9.60)	23(1.80)	< 0.001
	Retired	952(82.00)	126(10.00)	
	Unemployed	97(8.40)	1114(88.20)	
Physical activity n (%)	No active and sedentary	893(76.90)	976(77.30)	0.086
	Low active	180(15.50)	217(17.20)	
	Active	88(7.60)	70(5.50)	
Household income n (%)	Low	168(14.50)	345(27.30)	< 0.001
	Moderate	641(55.20)	721(57.10)	
	High	352(30.30)	197(15.60)	
Tobacco n (%)	No	321(27.60)	414(32.80)	< 0.001
	Past-cigarette or Hookah	568(48.90)	617(48.90)	
	current-cigarette or Hookah	272(23.40)	232(18.40)	
BMI n (%)	Underweight and normal	434(37.4)	317(25.10)	< 0.001
	Overweight	539(46.40)	488(38.60)	
	Obesity	188(16.20)	458(36.30)	
Triglyceride-glucose index n (%)	T1(6.96–8.41)	435(37.50)	373(29.50)	< 0.001
	T2(8.42–8.93)	371(32.00)	437(34.50)	
	T3(8.94–11.92)	355(30.60)	453(35.90)	
Polypharmacy n (%)	Yes	88(9.80)	251(22.80)	< 0.001
	No	806(90.20)	848(77.20)	
Self-rated health n (%)	Good	792(68.20)	602(47.70)	< 0.001
	Poor	369(31.80)	661(52.30)	
Glucose (mmol/dl)		104.06 ± 40.69	107.13 ± 45.07	0.080
Systolic blood pressure (mm Hg)		140.00 ± 19.45	139.34 ± 19.20	0.398
Diastolic blood pressure (mm Hg)		82.39 ± 8.73	80.78 ± 8.54	< 0.001
HDL cholesterol (mmol/dl)		42.80 ± 10.40	48.37 ± 12.14	< 0.001
Triglycerides (mmol/dl)		129.85 ± 67.66	140.73 ± 78.84	< 0.001
Waist circumference (cm)		97.04 ± 11.43	100.26 ± 12.33	< 0.001
Binary variables related to metabolic syndrome				
High glucose n (%)		440(37.90)	589(46.60)	< 0.001
High triglyceride n (%)		339(29.20)	429(34.00)	0.013
Low HDL n (%)		471(40.60)	711(56.30)	< 0.001
High waist circumference n (%)		770(66.30)	1196(94.70)	< 0.001
High blood pressure n (%)		953(82.10)	1059(83.80)	0.266
Antihypertensive medication n (%)		523(45.00)	759(60.10)	< 0.001
Lipid-lowering drugs n (%)		274(23.60)	495(39.20)	< 0.001
Diabetes drugs n (%)		294(25.30)	419(33.20)	< 0.001
Metabolic syndrome		526(45.30)	876(69.40)	< 0.001

Table 1. Study characteristics, stratified by gender in the Bushehr Elderly Health (BEH) program.($N=2424$). *BMI* Body mass index, *HDL* High-density lipoprotein.

Discussion

Having a comprehensive understanding of how the elements of metabolic syndrome come together is valuable in identifying and tackling common cardiometabolic risk factors, as well as in devising specific approaches to prevent the development of coronary artery disease and diabetes[23,24].

In this study, we used a person-centered analytical approach to identify latent classes based on the components of metabolic syndrome and smoking behavior. This analysis led to the discovery of four classes:[1] low-risk[2], metabolic syndrome with medication-controlled diabetes[3], high-risk metabolic syndrome with associated

Number of latent classses	Number of parameters estimated	G^2	df	AIC	BIC	CAIC	ABIC	X^2	Entropy	Maximum log-likelihood
1	10	4282.6	757	28622.5	28680.4	28690.4	28648.6	6867.6	5.89	− 14301.2
2	21	1713.7	746	27118.0	26857.7	26878.7	26790.9	2162.9	5.50	− 13347.0
3	32	1193.3	735	26237.6	26423.0	26455.0	26321.3	1381.8	5.40	− 13086.8
4	43	790.7	724	25854.0	26106.1	26149.1	25969.5	796.3	5.31	− 12855.5
5	54	649.9	713	25738.1	26051.0	26105.0	25879.4	635.3	5.28	− 12815.0
6	65	566.9	702	25677.2	26053.8	26118.8	25847.2	560.4	5.27	− 12773.6
7	76	487.4	691	25619.7	26053.8	26136.0	25818.5	481.8	5.25	− 12733.8

Table 2. Comparison of latent class analysis models with different numbers of latent classes based on model selection statistics in the Bushehr Elderly Health (BEH) program ($N = 2424$). *LCA* latent class analysis, *AIC* Akaike information criterion, *BIC* Bayesian information criterion, Consistent Akaike Information Criterion (CAIC), *df* degree of freedom, G^2 the likelihood-ratio statistic.

Items	Latent class			
	Class 1 (low risk)	Class 2 (MetS with medication-controlled diabetes)	Class 3 (High Risk of MetS and associated medication use)	Class 4 (Central obesity and treated hypertension)
Latent class prevalence	0.353	0.111	0.271	0.264
Item-response probabilities				
High fasting blood glucose	0.101	**0.989**	**0.996**	0.054
High waist circumference	**0.694**	**0.813**	**0.924**	**0.828**
High triglycerides	0.219	0.399	0.427	0.289
Low high-density lipoprotein	0.368	**0.555**	**0.601**	0.484
High blood pressure	**0.605**	**0.566**	**1.000**	**1.000**
Diabetes drugs	0.005	**0.782**	**0.747**	0.018
Antihypertensive drugs	0.000	0.000	**0.963**	**0.868**
Lipid-lowering drugs	0.118	0.296	**0.552**	0.319
Tobacco				
No	0.291	0.253	0.340	0.298
Past-cigarette or Hookah	0.434	0.461	**0.543**	**0.505**
Current-cigarette or Hookah	0.274	0.283	0.115	0.195

Table 3. The four latent class model of components of MetS, Tobacco in in the Bushehr Elderly Health (BEH) program. ($N = 2424$) The probability of a "No" response can be calculated by subtracting the item-response probabilities shown above from 1. *Item-response probabilities > 0.5 in bold to facilitate interpretation. Item-response probabilities: Probability of reporting components of MetS and tobacco given membership in various classes. Latent class prevalence: probability of membership in various classes.

medication use, and[4] central obesity and treated hypertension. Individuals in class 1 had fewer than three of the MetS components, while members of classes 2, 3, and 4 typically had at least three or more MetS components.

Obesity, especially visceral obesity, can lead to insulin resistance, which increases the risk of developing type 2 diabetes, endothelial dysfunction, an abnormal lipid profile, high blood pressure, and vascular inflammation, all of which contribute to the development of cardiovascular disease[25]. Previous studies have reported a relationship between obesity and MetS[26,27]. The incidence of high WC was high among all study participants, but the link between abdominal obesity and being a member of class 3 and 4 was stronger than in other classes. Additionally, the prevalence of obesity and high waist circumference was significantly higher in women than in men. Some studies on MetS have also reported similar findings regarding obesity[28,29] and high waist circumference[29] in women compared to men. This may be explained, in part, by the lower levels of physical activity observed in this study among women. Also, smoking acts as a risk factor for metabolic syndrome and cardiovascular disease through several mechanisms[30]. For example, Weitzman et al. reported that tobacco smoking is associated with dyslipidemia, including increased LDL and decreased HDL, as well as endothelial dysfunction and dysregulated coagulation, all of which are observed in metabolic syndrome[31]. In the present study, tobacco use was more prevalent in men than in women. LCA suggested that individuals with a history of tobacco were more likely to be in the High Risk of MetS class (Class 3), which demonstrated correlation between tobacco use and low HDL.

We observed a greater prevalence of low HDL among men and a greater prevalence of high triglyceride among women. The prevalence of Low HDL—the most common metabolic abnormality in Iran—has decreased in recent years, particularly in women[32,33]. Possible reasons for this include decreased carbohydrate consumption and increased unsaturated fat consumption[34]. Low HDL and elevated triglycerides are two interrelated metabolic

Characteristics	Categories	Low risk	MetS with medication-controlled diabetes OR (95% CI)	High risk of MetS and associated medication use OR (95% CI)	Central obesity and treated hypertension OR (95% CI)
Age	60–64 year	1	REF	REF	REF
	65–69 year	1	0.84 (0.56 to 1.26)	1.30 (0.91 to 1.85)	1.14 (0.82 to 1.57)
	70–74year	1	0.77 (0.45 to 1.30)	1.29 (0.83 to 2.00)	1.28 (0.86 to 1.91)
	> =75 year	1	0.64 (0.37 to 1.11)	1.45 (0.93 to 2.26)	1.61 (1.09 to 2.38)
Sex	Male	1	REF	REF	REF
	Female	1	NA	NA	NA
Marital status	Married	1	REF	REF	REF
	Single	1	NA	NA	NA
Education (year)		1	0.97 (0.93 to 1.01)	0.99 (0.96 to 1.03)	0.99 (0.96 to 1.02)
Occupation	Employed	1	REF	REF	REF
	Retired	1	0.38 (0.18 to 0.77)	0.79 (0.38 to 1.62)	0.65 (0.36 to 1.17)
	Unemployed	1	0.41 (0.20 to 0.84)	1.23 (0.59 to 2.54)	0.97 (0.53 to 1.78)
Physical activity	No active and sedentary	1	REF	REF	REF
	Low active	1	0.85 (0.55 to 1.32)	0.64 (0.44 to 0.93)	0.74 (0.53 to 1.03)
	Active	1	0.95 (0.51 to 1.78)	0.69 (0.39 to 1.20)	0.75 (0.46 to 1.22)
Household income	Low	1	REF	REF	REF
	Moderate	1	1.23 (0.79 to 1.89)	1.52 (1.06 to 2.17)	1.27 (0.92 to 1.76)
	High	1	1.16 (0.66 to 2.03)	1.40 (0.88 to 2.24)	1.62 (1.07 to 2.46f)
BMI	Underweight and normal	1	REF	REF	REF
	Overweight	1	1.34 (0.90 to 1.98)	1.59 (1.13 to 2.22)	1.25 (0.94 to 1.66)
	Obesity	1	1.03 (0.64 to 1.64)	1.91 (1.31 to 2.79)	1.49 (1.06 to 2.08)
TyG index	Tertile 1 (6.96–8.41)	1	REF	REF	REF
	Tertile 2 (8.42–8.93)	1	2.71 (1.70 to 4.30)	2.49 (1.76 to 3.52)	1.18 (0.90 to 1.55)
	Tertile 3 (8.94–11.92)	1	12.33 (7.75 to 19.61)	12.04 (8.31 to 17.45)	1.40 (0.99 to 1.98)
Polypharmacy	No	1	REF	REF	REF
	Yes	1	2.07 (1.12 to 3.81)	9.77 (6.12 to 15.59)	1.76 (1.07 to 2.91)
Self-rated health	Good	1	REF	REF	REF
	Poor	1	1.36 (0.97 to 1.92)	1.43 (1.08 to 1.89)	1.10 (0.85 to 1.41)

Table 4. Associations between latent class memberships with some of its risk factors in the Bushehr Elderly Health (BEH) program ($N = 2424$). *BMI* body mass index, Triglyceride-glucose index (TyG), Multinomial logistic regression, *REF* References group, *NA* Not applicable.

abnormalities that increase the risk of developing cardiovascular disease[35]. Our study did not identify this association: membership of classes 3 and 4 was associated with low HDL levels, but elevated triglycerides were observed equally across all four classes.

High fasting blood glucose is one of the key components of metabolic syndrome but was not always observed to co-occur with abdominal obesity in this study (for example, in class 4). However, high fasting blood glucose, which is suggestive of insulin resistance and can lead to a diagnosis of type 2 diabetes, was seen to be associated with other components of metabolic syndrome, such as high blood pressure, abnormal cholesterol levels[36], and obesity[37].

Older participants were more likely to belong to class 4, although this relationship was not significant in other classes; however, as reported in some studies, the prevalence of components of metabolic syndrome increases with age[38–41]. Therefore, when examining metabolic syndrome, it is possible to focus on the increase in age and older age of individuals.

In the present study, sedentary people were more likely to belong to the high-risk group for metabolic syndrome. Sedentary behavior is strongly associated with metabolic syndrome, as shown by Russ et al., and regular exercise can effectively reduce the risk of cardiovascular disease[42]. This study showed that people with poor self-related health are 42% more likely to be in the high-risk group for metabolic syndrome. In line with these results, Xiangfeng et al.'s study showed that people with poor self-related health face an increased risk of 68% and 47%, respectively, for stroke and ischemic stroke compared to people with good self-related health. The triglyceride-glucose index, associated with metabolic syndrome, can evaluate insulin resistance and forecast cardiovascular disease risk. Also, women exhibit a higher index than men, corresponding to their elevated fasting blood glucose and triglyceride levels[43–46].

Strengths and limitations

The study's cross-sectional design prevents us from making any inferences regarding causality. Given the relatively large sample size, we expect that our findings are representative of older people in Iran. For future studies, longitudinal and multi-region studies with a broader age distribution are required to determine and monitor the incidence rate of MetS in the older population and, more importantly, its impact on long-term outcomes.

Conclusion

Among older adults in Iran, the use of LCA identified four distinct subgroups of individuals with different patterns of cardiometabolic risk factors. Stratifying elderly individuals into these different cardiometabolic categories could lead to better monitoring and treatment of cardiometabolic risk factors, ultimately reducing the severe outcomes of metabolic syndrome in this susceptible group. Subsequent research should concentrate on developing targeted approaches for managing subgroups to customize therapeutic plans aimed at reducing risk.

Data availability

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

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Author contributions
S.A., A.F., and Z.J. conceived the study, performed data analysis and interpretation. N.D., A.J., and H.M. performed data analysis and interpretation and drafted the manuscript performed data analysis. J.B. and H.M. critically reviewed the manuscript. I.N. and B.L. revised the manuscript.All authors reviewed the manuscript.

Declarations

Competing interests
The authors declare no competing interests.

Ethics approval and consent to participate
Ethics approval and consent to participate The Ethics Committee of Bushehr University of Medical Sciences granted ethical permission for this study (Ethical Code: IR.BPUMS.REC.1402.138) in compliance with the Helsinki Declaration and national guidelines for research ethics. Before research enrollment, all participants gave their informed consent after being informed about procedures involved in the study.

Consent for publication
The authors confirm that human research participants provided informed consent for publication of their data.

Informed consent
The participants provided their written informed consent to take part in this study. Participation was entirely optional, and any participant could withdraw consent at any moment with no repercussions.

Additional information
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