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ORIGINAL RESEARCH

Age-Related Differences in Anthropometric and Lifestyle Factors Linked to Metabolic Syndrome in Women with Overweight and Obesity: A Cross-Sectional Study

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Purpose: The aim of this cross-sectional study was to examine the relationship between age, degree of overweight and obesity, and the prevalence of metabolic syndrome (MetS) in women with excess body weight. The study also examined age-related differences in anthropometric parameters, body composition, and lifestyle factors. To our knowledge, this is the first study in Poland to investigate the relationship between dietary patterns and MetS in women with overweight and obesity.

Patients and Methods: A total of 141 women aged 23–85 years with overweight or obesity were included. The study was conducted in 2023 in south-eastern Poland. Participants were divided into two age groups: under 65 years and 65 years and older. Anthropometric, biochemical and blood pressure measurements were taken. The lifestyle analysis included frequency of food consumption, physical activity and sedentary behaviours, sleep duration, smoking and alcohol consumption.

Results: The prevalence of MetS was higher in women with obesity, especially in women aged 65 years and older. Older women had a higher waist-to-hip ratio (WHR) and a lower fat-free mass (FFM) with no significant differences in body fat percentage. The younger women were more physically active. Women aged 65 years and older consumed honey more frequently. They were less likely than younger women to consume fresh legumes and canned vegetables, nuts and seeds, wholemeal bread, as well as sugar-sweetened beverages, energy drinks, and mayonnaise and dressings. No significant age-related differences were found in smoking, alcohol consumption, or sleep duration.

Conclusion: The study suggests that obesity has a stronger impact on MetS prevalence than age alone. Differences in body composition and lifestyle patterns between age groups highlight the need for early, targeted interventions aimed at weight management and healthy behaviours, especially in younger women. Preventive strategies should be tailored to age-specific needs to effectively address metabolic risk.

Keywords: abdominal obesity, lifestyle, metabolic syndrome, nutrition, obesity, overweight

Introduction

Metabolic syndrome (MetS) is a cluster of metabolic dysregulation that includes central obesity, insulin resistance, atherogenic dyslipidemia, and hypertension.[1,2] The global prevalence of MetS and obesity is a growing public health concern worldwide.[3,4] Depending on the definition used, MetS affects 12.5% to 31.4% of the population, with the highest rates observed in the Eastern Mediterranean region and the Americas.[5] In Poland, according to the WOBASZ II study, MetS was found that 32.8% of women and 39% of men had MetS.[6] There is also a growing problem of excessive body weight among the adult population in Poland. In 2022, 62% of men and 43% of women (aged 20 years and over) had overweight or obesity, with obesity diagnosed in 16% of men and 12% of women.[7] Projections indicate that by 2035, the

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percentage of people with obesity in Poland could reach 33%.[8] However, it is worth emphasising that obesity and MetS are not the same concepts - although obesity, particularly central obesity, is a key component of MetS, not all individuals with obesity fulfill the diagnostic criteria for the syndrome. MetS can also be present in individuals with a normal body weight.[9] This distinction has important implications for clinical diagnosis and the development of effective prevention strategies.

MetS significantly increases the risk of type 2 diabetes and cardiovascular disease (CVD), the leading cause of morbidity and mortality worldwide.[1] A growing body of research shows that factors such as age, degree of overweight and obesity, as well as lifestyle, have a significant impact on the risk of MetS.[10,11] Although genetic determinants also play a role, environmental factors - in particular diet, physical activity and other lifestyle elements - appear to be key and modifiable.[12–14] In the context of women's health, this issue is of particular importance, as metabolic health plays a crucial role in fertility and can significantly affect a woman's ability to conceive.[15] Furthermore, obesity and MetS are associated with an increased risk of developing cancers such as endometrial and breast cancer.[16,17] Women with MetS also have a higher risk of colon and rectal cancer than women without MetS.[18] Therefore, early intervention to improve metabolic health can not only promote reproductive health, but also significantly reduce the risk of serious diseases later in life.

One of the main factors that differentiates metabolic health is age. Ageing processes lead to changes in body composition - an increase in fat mass while fat-free mass (FFM) decreases.[19,20] This is important, because the world's population is ageing rapidly, posing significant challenges to societies around the world. The number of people aged 65 years and older has almost doubled since 2000 and represents 10% of the world's population.[21] The chronological age of 65 is widely accepted as a cut-off point for the onset of older adulthood, a life stage generally characterised by metabolic, physiological, and behavioural changes, while acknowledging individual variability in the ageing process influenced by genetic, lifestyle, and health factors.[22,23] Despite the increasing burden of MetS and obesity on society, there is still insufficient knowledge of how age affects their prevalence among women with excess body weight. Differences in body composition, anthropometric parameters, and lifestyle between younger and older women remain insufficiently understood, particularly in the relation to dietary patterns. Although existing research highlights the importance of lifestyle factors in the development of MetS, there is a lack of studies focusing on age-related differences in these variables among women with excess body weight.[10–14] To our knowledge, this is the first study conducted in Poland to investigate the relationship between dietary patterns and MetS in this specific population. Understanding how these factors vary with by age may support the development of more effective, age-appropriate prevention and treatment strategies for metabolic disorders.

In the present study, it was hypothesised that older age would be associated with a higher prevalence of MetS and with significant differences in anthropometric parameters, body composition and lifestyle compared with younger women. Therefore, the aim of this study was to assess the association between age, degree of overweight and obesity and the prevalence of MetS, and to analyse differences in the above variables between women under and over 65 years of age.

Materials and Methods

This cross-sectional study was conducted between July and October 2023 in a private health resort located in south-eastern Poland. Participants were recruited from the Podkarpackie region and other parts of the country. A total of 150 women initially agreed to participate in the study, of whom 141 met all eligibility criteria and were included in the final analysis. The sample size was determined based on the availability of eligible participants during the recruitment period (July-October 2023) and the feasibility of data collection in a single-centre setting. Although no formal power calculation was performed, the sample size was sufficient to detect statistically significant differences in key parameters between the defined age and BMI subgroups.

The inclusion criteria were as follows: female sex, age between 18 and 85 years, body mass index (BMI) indicative of overweight (25.0–29.9 kg/m²) or obesity (≥30.0 kg/m²), and the provision of written informed consent to participate in the study. Participants were also required to be free from metabolic-interfering medications (such as anti-obesity drugs or selected psychotropic medications), not currently pregnant or breastfeeding, and without diagnosed mental disorders, including schizophrenia, epilepsy, or dementia. Eligibility was determined on the basis of self-reported medical and lifestyle information obtained through a structured questionnaire. Accordingly, exclusion criteria included male sex, age below 18 or above 85 years, BMI below 25 kg/m², pregnancy or lactation, use of medications known to affect metabolic parameters, presence of mental or neurological disorders, and lack of informed consent. In addition, none of the women in the final sample were receiving pharmacological treatment for obesity or had a history of bariatric surgery.

The study sample consisted exclusively of women with either overweight or obesity (aged 18–85 years). To explore the potential impact of ageing on metabolic health, the sample was further stratified into two age groups: under and over 65 years. This age threshold was chosen according to demographic and clinical standards, with 65 years being generally accepted as the beginning of older adulthood - a stage associated with significant physiological, metabolic and behavioural changes.[22,23] The separation of these two categories was intentional and based on the hypothesis that metabolic and anthropometric parameters, as well as lifestyle characteristics, may differ significantly between women with different degrees of excess body weight. Classifying participants into these categories allowed for a more detailed examination of the relationship between adiposity level and MetS prevalence.

Measures

A questionnaire was used to obtain general information on sex, age, education level, place of residence, professional activity, sleep duration, smoking, bariatric surgery, use of pharmacotherapy and treatment.[24]

MetS Evaluation

A diagnosis of MetS was made if obesity (defined as BMI ≥30 kg/m^2) or abdominal obesity (defined as waist circumference ≥88 cm in women) was present and 2 of 3 additional criteria were met:

1. Fasting plasma glucose concentration ≥100 mg/dL
2. Serum non-high-density lipoprotein cholesterol (non-HDL) concentration ≥130 mg/dL
3. Blood pressure ≥130 and/or 85 mmHg

The described criteria for defining MetS in Poland were proposed by an expert panel in 2022.[25]

Frequency of Food Consumption

The qualitative Food Frequency Questionnaire (FFQ-6) was used to assess food frequency, which includes 62 different foods representing eight major food groups (such as sweets and snacks, dairy products and eggs, cereals, fats, fruits, vegetables and grains, meat products and fish, beverages).[26] The frequency of consumption of these food groups and food products mentioned is rated by the respondent on a scale from one *(never or almost never)* to six *(several times a day)* and covers the past 12 months. The validity of the FFQ-6 has been previously assessed, with average correlation coefficients of r=0.78 (95% CI [0.73–0.83]) for frequency of consumption and r=0.76 (95% CI [0.71–0.81]) for estimated quantity.[26] This questionnaire also collected information on the frequency of consumption of different types of alcohol. The authors of the study received formal permission from the developers of the questionnaire to use it in their research.

Physical Activity and Sedentary Behaviour

Levels of physical activity (PA) and sedentary behaviours (SB) were assessed using the Global Physical Activity Questionnaire (GPAQ).[27,28] The GPAQ contains a total of 16 questions and is divided into four sections. The first three cover work-related PA, followed by mobility-related activity and leisure time activity. The fourth section deals with SB, ie the average amount of time per day spent sitting or resting, sitting, lying down, at home, at work, with friends and moving around (excluding time spent sleeping).[28] Total PA per week was calculated using metabolic equivalents (METs) according to World Health Organization (WHO) recommendations.[27–29] Reliability tests of the GPAQ in nine countries showed moderate to significant reliability (Kappa 0.67 to 0.73; Spearman's rho 0.67 to 0.81).[28] The authors of the study received formal permission from the developers of the questionnaire to use it in their research.

Anthropometric Measurements

Body composition analysis was performed by electrical bioimpedance using a body composition analyser (model Tanita BC-418 MA, Tokyo, Japan). The study was performed in the morning, after an overnight fast, according to the accepted standard of measurement and taking into account the exclusion criteria for the method.[30] However, it should be noted that BIA results can be influenced by hydration status, including the presence of edema, which may affect the accuracy of body composition estimates. Waist and hip circumference were measured twice to the nearest 0.1 cm using a 205 cm SECA tape measure. The average of the two measurements was used for analysis. The waist-to-hip ratio (WHR) was calculated from the results using the following formula: WHR= waist circumference [cm]/hip circumference [cm].[31] BMI was calculated using the formula: body mass(kg)/[height(m)]^2. World Health Organization standards were used to classify participants into BMI categories.[32]

Lipid Profile and Fasting Glucose Measurement

Fingertip capillary blood samples were taken from study participants on an empty stomach in the morning by qualified medical staff. Results for total cholesterol (TC), high-density lipoprotein (HDL), low-density lipoprotein (LDL) and triglycerides (TG) were obtained using the Cardiocheck PA analyser.[33–35] Non-HDL cholesterol was calculated using the formula: non-HDL= TC–HDL. Fasting blood glucose was measured using a Contour TM Plus One glucometer.

Blood Pressure

Blood pressure was measured using an automated electronic sphygmomanometer (Welch Allyn 4200B-E2 Inc, Aston Abbotts, UK) according to the procedures recommended by the European Society of Hypertension (ESH).[36] The blood pressure was measured three times. The final result was the average of the three measurements.

Statistical Analysis

All statistical analyses were conducted on data from 141 participants. The significance level was set at p=0.05. Variables expressed at the ordinal or nominal level were analysed using tests based on a chi-square distribution. In the case of 2×2 tables, a continuity correction was applied, while when the conditions for using the chi-square test were not met, Fisher's exact test with extension was used for tables larger than 2×2. Parametric tests (Student's T-test) or their non-parametric equivalents (Mann–Whitney U-test) were used to analyse the quantitative variables presented by group. The choice of tests was made on the basis of the distribution of the variables, verified by the Shapiro–Wilk test. Calculations were carried out in the statistical environment R ver.3.6.0, PSPP software and MS Office 2019.

Ethics Approval and Consent to Participate

The present study was conducted in accordance with the guidelines for cross-sectional studies and in accordance with the Declaration of Helsinki and was approved by the Bioethics Committee of the University of Rzeszów (Resolution No. 2023/07/0046 of 25 June 2023). Each participant was given details of the study and was assured of anonymity. In addition, each participant gave informed and voluntary written consent to participate in the study.

Results

Table 1. shows the characteristics of the study group of women with overweight and obesity (N=141), taking into account age range, education level, place of residence, professional activity, sleep duration, smoking, alcohol consumption habits, BMI classification and meeting MetS criteria. In total, 56.7% of the women with overweight and obesity in this group met the criteria for the MetS.

The Table 2 shows the basic descriptive statistics (mean, standard deviation, minimum, maximum, median) for the anthropometric and biochemical variables in the group of female subjects (N=141). The mean age of the female subjects was 60.79 years (SD=12.08) and the mean BMI was 31.84 kg/m^2 (SD=4.65).

H1. There is a relationship between age, degree of overweight and obesity and the occurrence of MetS.

To test the main hypothesis, we first compared the prevalence of MetS between women under and over 65 years of age. Although the prevalence was higher in the older group (62.3%) than in the younger group (52.5%), this difference was not statistically significant (p = 0.321). This means that age did not have a significant effect on differences in the prevalence of MetS in the study population of women with overweight and obesity.

However, for the purposes of the study, a new grouping variable was created that allowed the relationship between the occurrence of MetS and age and BMI classification (two categories were taken into account: overweight and obesity) to

Table 1 Characteristics of the Female Study Group

Variable	***N***	**%**
Age range		
Under 65 years	80	56.7
65 years and over	61	43.3
Education		
Primary	1	0.7
Lower secondary	4	2.8
Vocational	9	6.4
Secondary	37	26.2
Higher	90	63.8
Place of residence		
Village	31	22
City	110	78
Professional activity		
Pensioner	59	41.8
Working on a casual basis	11	7.8
Working	71	50.4
Sleep time per week		
Up to 6 hours	55	39
7–8 hours	71	50.4
Over 8 hours	15	10.6
Sleep time at the weekend		
Up to 6 hours	27	19.1
7–8 hours	83	58.9
Over 8 hours	31	22
Smoking		
Yes	17	12.1
No	124	87.9
Alcohol consumption		
Several times a month or less frequently	121	85.8
Several times a week and more often	20	14.2
BMI classification		
Overweight	57	40.4
Obesity class I	53	37.6
Obesity class II	21	14.9
Obesity class III	10	7.1
Mets criteria		
No	61	43.3
Yes	80	56.7

Abbreviations: BMI, body mass index; MetS, metabolic syndrome; N, number of participants; %, percentage.

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Table 2 Values of Individual Parameters in the Study Group

Variable	N	M	SD	Min	Max	Me
Age	141	60.79	12.08	23	85	63
Body weight (kg)	141	83.1	13.16	56.9	121.6	81
BMI (kg/m^2)	141	31.84	4.65	25.1	47.6	30.9
Fat mass (%)	141	41.12	4.51	28.4	53.9	41.2
FFM (kg)	141	48.17	6.66	16.4	65	47.8
Waist circumference (cm)	141	98.11	10.99	80	133	97
Hip circumference (cm)	141	112.36	9.68	90	149	112
WHR	141	0.87	0.08	0.71	1.12	0.87
SBP (mmHg)	141	123.07	15.29	94	175	123
DBP (mmHg)	141	74.98	7.78	54	95	75
TC (mg/dL)	141	197.94	46.16	99	359	193
LDL (mg/dL)	141	110.45	38.77	24	248	109
HDL (mg/dL)	141	58.84	14.74	32	104	57
TG (mg/dL)	141	145.20	63.96	50	385	133
Fasting glucose (mg/dL)	141	105.14	14.55	81	158	103
Non-HDL (mg/dL)	141	139.11	44.84	30	313	136

Abbreviations: BMI, body mass index; DBP, diastolic blood pressure; FFM, fat free mass; HDL, high-density lipoprotein; LDL, low-density lipoprotein; M, mean; Min, minimum; Max, maximum; Me, median; N, number of participants; non-HDL, non-high-density lipoprotein cholesterol; SBP, systolic blood pressure; SD, standard deviation; WHR, waist-to-hip ratio; TC, Total cholesterol; TG, triglycerides.

be examined. It was shown that MetS was statistically significantly more common in women with obesity under and over 65 years of age than in women with overweight under 65 years of age (p=0.001). These findings indicate that the occurrence of MetS is more strongly associated with the degree of excess body weight than with age alone, but both factors contribute to increased risk. The main results of the study regarding the hypothesis on the association between age, excess body weight and MetS prevalence are presented in Table 3.

H2. There are significant differences in anthropometric data and body composition between women with overweight and obesity under and over 65 years of age.

It was found that FFM was statistically significantly higher in women aged under 65 years (p<0.001) and WHR was significantly higher in women aged 65 years and over (p=0.005). Age had no significant effect on the differences in body fat percentage (p=0.499). The results of the independent samples t-test are shown in Table 4.

Table 3 Prevalence of MetS by Age Group and Degree of Overweight or Obesity in Women

Variable			Age Range		Test Result
			Under 65 Years	65 Years and Over	
MetS	No	N	38	23	$\chi^2(1) = 0.983$, $p = 0.321$
		%	47.5	37.7	
	Yes	N	42	38	
		%	52.5	62.3	
Total		N	80	61	
		%	100	100	

(*Continued*)

Table 3 (Continued).

			Group of women				
			Under 65 years with overweight	Under 65 years with obesity	65 years and over with overweight	65 years and over with obesity	
MetS	No	N	23	15	14	9	$\chi^2(3) = 20.855$, $p = 0.001$
		%	74.2	30.6	53.8	25.7	
	Yes	N	8	34	12	26	
		%	25.8	69.4	46.2	74.3	
Total		N	31	49	26	35	
		%	100	100	100	100	

Abbreviations: N, number of participants; p, p-value (statistical significance); χ^2, chi-square test statistic.

Table 4 Age-Related Differences in Anthropometric Data and Body Composition in Women with Overweight and Obesity

Variable	*t(df)*	*p*	*M*	*SD*
Fat mass (%)	0.00(135)	0.499		
Under 65 years			40.95	4.47
65 years and over			40.95	3.55
FFM (kg)	−4.02(130)	<0.001		
Under 65 years			49.42	4.67
65 years and over			46.19	4.45
WHR	2.61(133)	0.005		
Under 65 years			0.85	0.06
65 years and over			0.88	0.06

Abbreviations: FFM, fat-free mass; M, mean; p, p-value (statistical significance); SD, standard deviation; WHR, waist-to-hip ratio; t, test statistics; df, degrees of freedom.

H3. There are significant lifestyle differences between women with overweight and obesity under and over 65 years of age.

Frequency of Food Consumption

Table 5 presents statistically significant differences in the frequency of food consumption between women with overweight and obesity under and over 65 years of age. Women with overweight and obesity aged 65 years and over were found to be significantly more likely to consume honey, and they were less likely to consume fresh legumes and canned vegetables, nuts, seeds, sugar-sweetened beverages (SSBs) and - despite identical medians - wholemeal bread or with seeds, mayonnaise and dressings, dry legumes and energy drinks.

Physical Activity and Sedentary Behaviours

Table 6 presents the differences in total PA and SB between women with overweight and obesity under and over 65 years of age. Total PA was statistically significantly higher in women under 65 years of age (*p*=0.006). No statistically significant differences were found for SB (*p*=0.118). In the total study group, the mean total PA was 1909.93 MET-min/week (*SD* = 3340.59), and the mean daily SB time was 360.46 minutes (*SD* = 160.25).

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Table 5 Age-Related Differences in Frequency of Consumption of Selected Foods Among Women with Overweight and Obesity Under and Over 65 years of Age

Variable	*U*	*p*	*Me*	*Min-Max*
Honey	1746	0.003		
Under 65 years			3	1–6
65 years and over			4	1–5
Wholemeal bread or with seeds	1930	0.028		
Under 65 years			4	1–6
65 years and over			4	1–5
Mayonnaise and dressings	1984.5	0.049		
Under 65 years			3	1–5
65 years and over			3	1–5
Fresh legumes and canned vegetables, such as sweet corn, green peas, and green beans	1936.5	0.026		
Under 65 years			3	1–5
65 years and over			2	1–4
Dry legumes, eg, broad beans, lentils, chickpeas, soybeans, peas, and in dishes such as pea soup, hummus, and bean-based spreads	1896	0.015		
Under 65 years			2	1–4
65 years and over			2	1–4
Nuts	1876	0.015		
Under 65 years			3	1–5
65 years and over			2	1–6
Seeds, eg, pumpkin, sesame, sunflower	1781	0.005		
Under 65 years			3	1–5
65 years and over			2	1–6
Energy drinks	1959	0.005		
Under 65 years			1	1–5
65 years and over			1	1–4
SSBs	1956	0.025		
Under 65 years			1.5	1–5
65 years and over			1	1–4

Abbreviations: Me, median; Min, minimum; Max, maximum; p, p-value (statistical significance); U, Mann–Whitney U-test statistic.

Table 6 Differences in SB and Total PA Levels by Age Between Women with Overweight and Obesity Under and Over 65 years of Age

Variable	*U*	*p*	*Me*	*Min-Max*
Total PA (MET-min/week)	1441.5	0.006		
Under 65 years			640	0–5040
65 years and over			380	0–3960
SB (min/day)	2157	0.118		
Under 65 years			405	60–720
65 years and over			300	60–720

Abbreviations: PA, physical activity; SB, sedentary behaviours; U, Mann–Whitney U-test statistic; p, p-value (statistical significance); Me, median; Min, minimum; Max, maximum.

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Table 7 Age-Related Differences in Sleep, Smoking, and Alcohol Consumption in Women with Overweight and Obesity

Variable			Age Range		Test Result
			Under 65 Years	65 Years and Over	
Amount of sleep per week	Up to 6 hours	N	36	19	$\chi^2(2) = 2.826$, $p = 0.243$
		%	45	31.1	
	7–8 hours	N	36	35	
		%	45	57.4	
	Over 8 hours	N	8	7	
		%	10	11.5	
Amount of sleep per weekend	Up to 6 hours	N	16	11	$\chi^2(2) = 2.421$, $p = 0.298$
		%	20	18	
	7–8 hours	N	43	40	
		%	53.8	65.6	
	Over 8 hours	N	21	10	
		%	26.3	16.4	
Smoking	Yes	N	11	6	$\chi^2(1) = 0.199$, $p = 0.656$
		%	13.8	9.8	
	No	N	69	55	
		%	86.3	90.2	
Alcohol consumption	Several times a month or less frequently	N	68	53	$\chi^2(1) = 0.006$, $p = 0.941$
		%	85	86.9	
	Several times a week and more often	N	12	8	
		%	15	13.1	

Abbreviations: χ^2, test statistics; N, number of participants; p, p-value (statistical significance).

Amount of Sleep, Smoking and Alcohol Consumption

For the other lifestyle components, the results were not statistically significant. This shows that there were small differences in the distribution of sleep duration, smoking and alcohol consumption by age. Table 7 presents the lack of statistically significant relationships between the study variables.

Discussion

This study examined the relationship between age, degree of overweight and obesity and the prevalence of MetS as well as differences in anthropometric parameters, body composition and lifestyle between women with overweight and obesity under and over 65 years of age. Significant differences were found in the prevalence of MetS, FFM, WHR, frequency of food consumption and total PA. However, there were no significant differences in percentage of fat tissues, smoking, alcohol consumption and SB. Previous research by our group focused on the associations between overweight, obesity, and factors such as food addiction, sedentary behavior, and mental health.[37] The present study expands on these findings by analyzing age-related differences in metabolic risk factors and lifestyle patterns in women with overweight and obesity. This study provides a novel contribution by examining age-stratified differences in both metabolic risk and lifestyle factors in women with overweight and obesity, a population often underrepresented in research combining MetS and behavioural analysis. It is important to note that this is the first study in Poland to investigate the relationship between dietary patterns and MetS in women with overweight and obesity.

1. MetS has been shown to be statistically significantly more common among women with obesity under and over the age of 65 than among women with overweight under 65 years.

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Some studies have shown that the incidence of MetS increases with age and is higher in women than in men.[38,39] The risk increases after menopause, with prevalence ranging from 31% to 55%.[40,41] In addition, certain components of the MetS have stronger associations with mortality in older women, including low HDL cholesterol, high fasting glucose, and elevated blood pressure.[42] Liu et al reported that both men and women aged 50–70 years were more likely to have MetS than those aged 30–49 years, although the increase in risk was greater in women.[43] Similarly, Moreira et al found that women aged 55–64 had significantly higher odds of having MetS compared to those aged 45−54.[44] These findings confirm that age is an important risk factor for metabolic dysregulation, particularly in women, and that targeted public health interventions are needed.[42–44] The lack of significant differences in the prevalence of MetS between age groups (under and over 65 years) in our study may indicate that other factors, such as lifestyle, genetics or diet, may be more important in this population. Our results also show significant differences in the prevalence of MetS according to the degree of overweight and obesity, suggesting a dominant influence of obesity over chronological age alone.

Our results are partly consistent with previous studies that have analysed the association between these factors. Slagter et al conducted a study of 74531 participants aged 18–79 years and showed that the prevalence of MetS increased with BMI and age. Regardless of BMI, abdominal obesity was more common in women, while elevated blood pressure was more common in young men.[45] Rigamonti et al in a cross-sectional study of an Italian cohort of women with obesity aged 18–83 years, also showed that the prevalence of MetS increased with age.[46] Similar trends were observed in a study conducted in Warsaw by Szostak-Węgierek and Waśkiewicz among women of reproductive age (20–49 years). Overweight and obesity, especially abdominal obesity, were found to be common in this group and their prevalence increased with age. The prevalence of MetS was 7.3% and also showed an increasing trend with age.[47] A study by Raczkiewicz et al in intellectually active women aged 44–66 years showed that the prevalence of MetS and its criteria depended on BMI, body fat accumulation and physical inactivity, but not on age.[48] These findings highlight the need for early, targeted weight management interventions and promotion of healthy behaviours, particularly among younger women, to effectively reduce metabolic risk.

2. FFM was statistically significantly higher in women aged under 65 years and WHR was significantly higher in women aged 65 years and over. Age had no significant effect on differences in body fat.

The differences in body composition observed in our study - higher FFM in younger women and higher WHR in older women - reflect age-related physiological changes. As shown in similar studies, FFM tends to decrease with age due to loss of muscle mass, while WHR increases due to central fat accumulation.[49] These changes are strongly associated with metabolic risk, particularly in older populations where abdominal obesity is more common.[50] In addition, abdominal obesity has been associated with increased risk of all-cause mortality and increased CVD mortality in older adults.[51] This is supported by the pooled analysis of seven prospective cohorts, which showed inverse associations between fat mass and FFM and risk of death. While excess fat mass increased the risk of death, higher FFM was protective.[52] Moreover, low FFM and muscle mass in older women with type 2 diabetes are associated with poorer glycemic control and higher oxidative stress.[53] Importantly, menopause is associated with a natural decline in estrogen, which increases visceral fat mass and decreases bone density, muscle mass and strength.[54,55]

It is interesting to note that in our study there were no significant differences in the percentage of total body fat between the female age groups. Bakhtiari et al showed that waist circumference and body fat percentage were strongly correlated with MetS components.[56] This suggests that fat redistribution and loss of lean body mass may play a more important role in determining metabolic health in older women. Postmenopausal women are more prone to sarcopenic obesity, a combination of low muscle mass and excess body fat.[57] This is important because a study of older people in Colombia by Barranco-Ruiz et al found that smoking, female gender and sarcopenia ‘proxy’ status were associated with MetS.[58] In addition, Park et al found that sarcopenia, a state of reduced FFM, is associated with insulin resistance and type 2 diabetes.[59] These findings support recommendations to focus not only on BMI, but also on specific measures, such as WHR and FFM, when assessing metabolic risk in clinical practice. Our observations are consistent with previous studies showing that ageing is associated with loss of muscle mass and increased visceral fat accumulation, which may have important health implications, including an increased risk of CVD. Decreasing FFM with age may increase the risk of sarcopenia, so more research is needed into ways to prevent sarcopenia, especially loss of muscle mass.

3. There are significant differences in the frequency of food consumption and total PA between women with overweight and obesity under and over 65 years of age. For the other lifestyle components, the results were not statistically significant.

Frequency of Food Consumption

A recent study by Białek-Dratwa et al in Poland between 2011 and 2022 observed changes in the dietary habits of women aged 20–50 years. Women were more likely to choose cereal products considered healthy and rich in fibre (eg wholemeal bread, wholemeal pasta, oatmeal, bran), eat more vegetables, legumes and vegetarian meals, and eat less meat, sausages, fish and dairy products. However, the consumption of fast food, salty snacks and sweets increased.[60] The results of our study partly overlap with the observations described above, as women with overweight and obesity under 65 years were more likely to consume wholemeal bread and legumes, which is in line with the trend of increasing popularity of health-promoting products in younger age groups. Among older women (60+), socio-economic status, dietary restrictions and health-related factors significantly influence food consumption patterns. Lower socioeconomic status and multiple limitations are associated with lower intakes of fruit, vegetables and dairy products.[61] A recent Swedish cohort study found that notable lifestyle factors strongly associated with MetS included fast food and soda consumption, portion sizes of meat and other protein-rich foods, consumption of red and processed meat, and consumption of cakes, sweets, chocolate, ice cream and chips.[62]

In our study, women with overweight and obesity under the age of 65 were more likely to consume SSBs and energy drinks. A survey of adults in Poland by Piekara and Krzywonos found that SSBs consumption tended to decrease with age, with men consuming more than women. Energy drinks were most commonly consumed by respondents aged 30–44, with lower levels of education and higher reported incomes.[63] A recent study by Sajdakowska et al of Polish adults aged 18–45 found that they were most likely to consume sweetened beverages for their taste and in a social context. At the same time, greater knowledge of the sugar tax and health awareness were shown to reduce the frequency of their consumption, highlighting the importance of education and legislation in reducing SSBs consumption.[64]

This is important in the context of MetS, as a meta-analysis showed that consumption of SSBs, including energy drinks, was positively associated with an increased risk of MetS in adults.[65] A case-control study revealed a significant correlation between SSBs intake and pre-metabolic syndrome in adult women (40–55 ages).[66] Furthermore, evidence supports a strong positive association between SSBs and weight gain, type 2 diabetes, and coronary heart disease risk, independent of adiposity.[67] In a randomized controlled trial, a single high-volume intake of energy drinks consumption in young adults led to increased systolic blood pressure, prolonged QTc interval, and decreased insulin sensitivity.[68] These findings underscore the importance of limiting SSBs and energy drinks consumption to improve cardiometabolic health and metabolic profile, especially in young women with and without obesity.[68,69]

Our study also found that women with overweight and obesity aged 65 and over were significantly more likely to consume honey. Šedík et al showed that older generations, especially the silver generation, are more likely to consume honey for its perceived nutritional value.[70] Age, sex, education, and income influence honey consumption behaviours, with nutritional knowledge having a moderate effect.[71] Interestingly, according to a review by Palma-Morales et al, honey consumption may have more positive than negative effects on cardiovascular and metabolic risk factors, especially when replacing other sweeteners.[72] However, considering the relatively high prevalence of MetS and elevated fasting glucose levels observed in our study population, the role of honey in the diet of older women with excess body weight remains uncertain. Further research is needed to determine whether regular honey consumption is associated with metabolic benefits or risks in this particular group.

Our study also found that women with overweight and obesity aged 65 and over were significantly less likely to also consume fresh legumes and canned vegetables, nuts, seeds, mayonnaise and dressings, dried legumes. Hartley et al reported that consuming 55–70g of legumes daily was associated with reduced hypertension risk, particularly in women.[73] A systematic review of randomized controlled trials found that daily intake of 150 g of cooked pulses (range: 54–360 g) led to improvements in blood lipid profile, blood pressure, inflammation biomarkers, and body composition.[74] Gholami Karim Abad et al have shown that legume intake is positively correlated with age, education level, and PA.[75] Recent studies suggest that nut and seed consumption is inversely associated with MetS, particularly in females. In females, habitual nut and seed intake is associated with lower odds of MetS and its components.[76] In recent meta-analysis of observational studies showed, that nut consumption was negatively associated with MetS. However, such an inverse relationship only existed in tree nuts, not in peanuts.[77] In particular, regular consumption of nuts, seeds and legumes may be beneficial in reducing the risk of MetS and its components, highlighting the need to promote such dietary habits, especially in older age groups. It is also worth paying attention to the consumption of mayonnaise, dressings, sweetened drinks and energy drinks, which are more commonly chosen by younger women. Excessive consumption of these products, which are rich in saturated fats, simple sugars and salt, may contribute to an increased risk of MetS and related conditions.[78,79] This points to the need to adapt dietary recommendations to age groups, taking into account their preferences and abilities.

Physical Activity and Sedentary Behaviours

In our study, younger women reported higher levels of total PA, which is consistent with evidence of age-related declines in activity level.[80] Similarly, a 21-year longitudinal study identified five PA trajectories in middle-aged to older women, with some groups showing stable low activity or declining activity over time.[81] A sedentary lifestyle is significantly associated with an increased risk of MetS in both men and women.[82] Research has shown that higher levels of moderate-to-vigorous PA are consistently associated with lower odds of MetS, regardless of sedentary time.[83–85] PA, particularly moderate-to-vigorous activity for more than 2 hours per day, is associated with a reduced risk of MetS in both men and women.[86] These findings highlight the importance of targeted interventions to promote PA maintenance in older women. This may prevent not only obesity and MetS, but also loss of muscle mass and deterioration in general health. Reduced PA in women may contribute to a higher risk of metabolic dysfunction, especially when combined with obesity.

Amount of Sleep, Smoking and Alcohol Consumption

In our study, we found no statistically significant differences in the amount of sleep, smoking and alcohol consumption by age in women with overweight and obesity. In the study by Hong et al, the variables were compared in the groups of patients aged between 40 and 64 years vs between 65 and 79 years and by sex, and it was shown that age-related changes in sleep are more pronounced in women, with older women reporting shorter total sleep time and underestimating their sleep duration compared to younger women.[87] According to Baker et al hormonal fluctuations throughout a woman's life, including during perimenopause, may contribute to these differences.[88] Insomnia has also been linked to the risk of MetS, especially in postmenopausal women.[89] A systematic review and meta-analysis showed that both short and long sleep duration increased the risk of MetS by 15% and 19% respectively, showing a U-shaped association, and were associated with an increased risk of obesity and hypertension.[90] The meta-analysis by Jing et al showed that short sleep duration significantly increased the risk of incident MetS by 28%.[91] According to studies, sleep disturbances, especially short sleep duration, increase the risk of MetS in older women, highlighting the importance of considering this factor in lifestyle analysis.

According to Janik-Koncewicz et al, smoking rates have been declining in Poland since the 1970s, with education being the dominant influence on smoking behaviour, while the 45–64 age group had the highest smoking rates.[92] In a survey conducted in Poland in March 2022, 27.1% of women reported daily smoking and 4.0% were daily e-cigarette users.[93] A study by Wang et al found that lifetime smoking increased the likelihood of MetS, especially in people under the age of 70.[94] In women, both conventional and electronic cigarette use were associated with a higher risk of MetS compared to non-smokers.[95] In young adults, smokers had a 2.4-fold higher risk of MetS than non-smokers, with particularly high risks of hypertriglyceridemia and low HDL cholesterol.[96] The studies consistently show the detrimental effects of smoking on metabolic health, especially in women.

Studies in Poland have shown that excessive alcohol consumption, together with other unhealthy habits such as sweetened drinks and high salt intake, is common among people with MetS, especially in the 51–65 age group.[97] The study by Park et al suggests that the risk of MetS and obesity in Korean men, women and the elderly who drink more than 14 g/d may be higher than in non-drinkers. In people with obesity or abdominal obesity, or those who need to control their blood pressure, glucose or triglycerides, drinking more than 7 g/d may increase the risk of MetS.[98] According to Skultecka et al, moderate alcohol consumption may be associated with a lower likelihood of MetS in some populations.[99] These findings highlight the complex interplay between alcohol consumption and metabolic health, and emphasize the need for further research to elucidate the mechanisms underlying these associations and to inform public health strategies.

The lack of significant differences in smoking, alcohol consumption or sleep duration may suggest that these elements are less related to age in this group of female respondents with overweight and obesity. Our findings emphasize the importance of promoting a healthy lifestyle, including regular PA and a balanced diet, to prevent and manage MetS and its associated complications.[100] Early screening and lifestyle modification are essential to prevent MetS and related comorbidities in women. This research not only fills a gap in the literature by focusing on women with excess body weight but also supports the need for personalized, age-specific prevention strategies for MetS.

Strengths and Limitations

The strength of this study lies in its comprehensive analysis of the relationship between age, adiposity and lifestyle behaviours in relation to metabolic health in women. The distinction between overweight and different classes of obesity, together with the age-stratified analysis, enhances the clinical relevance of the findings. Importantly, we analysed for the first time the association between dietary preferences and MetS in women by age in Poland.

However, there are several limitations. First, the cross-sectional design precludes causal inferences regarding the observed associations. Second, self-reported data on diet and PA may be subject to recall bias. Finally, the study population, which was restricted to women with overweight and obesity, limits generalizability to broader populations. Another limitation of the study is also the relatively small sample size, which was limited by recruitment logistics and time. However, the results still showed statistically significant differences in several key outcomes, supporting the relevance of the observed associations. Given the number of variables analysed and the lack of adjustment for multiple comparisons, the potential for type I error cannot be excluded. Therefore, the results should be interpreted with appropriate caution.

Conclusions

This study suggests that excess body weight has a greater impact on the risk of MetS than age alone. Although older women had age-related changes in body composition, including lower fat-free mass (FFM) and higher waist-to-hip ratio (WHR), the prevalence of MetS was significantly higher in women with obesity regardless of age group. Lifestyle factors such as physical activity and dietary patterns varied by age, suggesting that age-specific interventions may be beneficial. These findings highlight the importance of addressing both body composition and lifestyle behaviours in the prevention and management of MetS. Early intervention focusing on weight control and physical activity in younger women, as well as age-appropriate nutrition education strategies, may be key to reducing metabolic risk at different stages of adulthood.

Disclosure

The authors report there are no conflicts of interest in this work.

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