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Evaluation of the prevalence of metabolic obesity and normal weight among the Polish population

Częstość występowania metabolicznej otyłości z prawidłową masą ciała w populacji polskiej

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Abstract

Introduction: In the 1980s, the idea evolved that some individuals with normal weight (Metabolically Obese, Normal-Weight), who probably have increased abdominal fat, have metabolic disturbances related to obesity. This observation initiated the concept of the metabolically obese but normal-weight syndrome (MONW). Since then, there have been only a few studies in non-obese subjects. MONW men and women should be regarded as at high risk for cardiovascular disease.
Material and method: A group of 854 randomly chosen non-obese men and women, 20–40 years of age, was selected from three different areas of Poland — Szczecin, Krakow and Wroclaw. All subjects were interviewed and underwent physical examination, anthropometric measurements (waist circumference, hip circumference, BMI and WHR) as well as densitometry (total body DPX, total fat, android/gynoid deposit). Serum level of fasting glucose and insulin, indices of insulin sensibility (QUICKI) and insulin resistance (HOMA, FIRI), total cholesterol, triglycerides and HDL-C were measured using commercially available kits. LDL-C level was calculated using Friedewald's formula.
Results: The total amassed fatty tissue and its android deposit was found to be significantly greater in MONW men and women. MONW women were found to exhibit increased levels of triglycerides and LDL-C but lower levels of HDL-C. In women with excess abdominal fat (EAF), fasting glucose and insulin levels, HOMA and FIRI were considerably higher, while QUICKI was lower. Triglyceride and LDL-C levels were also higher while HDL-C levels were lower. In men with EAF, increased levels of total cholesterol and LDL-C were confirmed.
Conclusions: The occurrence of MONW is contingent upon the diagnosis criterion and increases when the criterion represents the value of HOMA — 21.76% in women and 31.42% in men. The frequency of MONW occurrence is lower when the criterion for abdominal fat content limit is used, amounting to 15.78% in women and 7.83% in men. **(Endokrynol Pol 2012; 63 (6): 447–455)**

Key words: *insulin resistance, metabolic syndrome, fat distribution*

Streszczenie

Wstęp: W latach 80. zaobserwowano, że u nieotyłych osób, które gromadzą nadmierną ilość tkanki tłuszczowej w okolicy brzucha, rozwijają się powikłania metaboliczne charakterystyczne dla otyłości. Powstała wówczas koncepcja zespołu metabolicznej otyłości z prawidłową masą ciała — MONW (Metabolically Obese Normal-Weight). W Polsce badania takie nie były dotychczas prowadzone. Identyfikacja ludzi obciążonych tym zespołem pozwoliłaby na wczesne podjęcie działań prewencyjnych.
Materiał i metody: Zbadano 854 nieotyłych kobiet i mężczyzn, wybranych losowo w 3 regionach kraju – Szczecina, Krakowa, Wrocławia w wieku 20–40 lat. Przeprowadzono wywiad lekarski, badanie fizykalne, pomiary antropometryczne (obwód talii, bioder, BMI, WHR), badanie denzytometryczne (*total body DPX; total fat; android/gynoid deposit*). Ilość i dystrybucję tkanki tłuszczowej oceniano przy użyciu podwójnej absorpcjometrii energii RTG-DXA. W surowicy krwi oznaczono stężenie glukozy i insuliny na czczo, stężenie cholesterolu całkowitego, triglicerydów oraz HDL-C i wyliczono stężenie LDL-C oraz wartości wskaźników insulinowrażliwości (QUICKI) i insulinooporności (HOMA, FIRI).
Wyniki: U kobiet i mężczyzn całkowita ilość tkanki tłuszczowej i jej androidalnego depozytu były istotnie wyższe w grupie z MONW. Stężenia glukozy i insuliny na czczo oraz wartości HOMA i FIRI były istotnie wyższe, a QIUCKI istotnie niższe u badanych z MONW. U kobiet z MONW stwierdzano istotnie wyższe stężenia trójglicerydów oraz LDL-C natomiast znacząco niższe stężenia HDL-C. Istotnych różnic nie było u mężczyzn.
Wnioski: Częstość występowania metabolicznej otyłości z prawidłową masą ciała zależy od kryterium rozpoznania i jest większa, gdy kryterium to stanowi wielkość HOMA — 21,76% kobiet i 31,42% mężczyzn i mniejsza, gdy posługiwano się kryterium granicznej ilości tłuszczu brzusznego — częstość rozpoznania MONW wynosi — 15,78% u kobiet i 7,83% u mężczyzn. **(Endokrynol Pol 2012; 63 (6): 447–455)**

Słowa kluczowe: *insulinooporność, zespół metaboliczny, dystrybucja tkanki tłuszczowej*

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Introduction

Obesity is associated with a higher risk of type 2 diabetes and lipid disorders as well as cardiovascular diseases, cancer and musculoskeletal disorders. The risk of these disorders, however, has been found to be significantly lower among a small group of obese individuals, known as obese but metabolically healthy. Causes of health risks in metabolically "healthy" and "unhealthy" subjects are mainly observed in the accumulation of visceral fat which contributes to the development of hyperinsulinaemia and insulin resistance. Visceral fat accumulates primarily in the abdominal organs, mainly in the liver, pancreas and the mesentery as well as the heart, muscles and blood vessels [1, 2]. Waist circumference and waist/hip ratio (WHR) measurements constitute simpler and indirect methods in assessing visceral fat build-up. These methods also include bioelectric impedance and densitometry using dual beam radiation (DXA). Magnetic resonance imaging (MRI) and computed tomography (CT) of the abdomen provide more detailed measurements of visceral fat. Among these methods, DXA, which checks fat build-up in the abdomen but does not distinguish between subcutaneous and visceral fat, is considered the 'gold standard' as it is characterised by good specificity, reproducibility and a relatively low exposure to radiation [3]. The DXA tests conducted so far have, however, failed to determine the reference ranges for sex, age group or race.

Excess visceral fat is known to occur in obese individuals and in individuals with normal body mass index (BMI) alike. This observation originated the concept of MONW — metabolically obese but normal weight. MONW predisposes to hyperinsulinaemia/insulin resistance and is often associated with elevated levels of triglyceride, hypertension, and nonalcoholic fatty liver disease [4, 5]. It is estimated that this type of obesity may occur in 10–18% of the population aged 20–40 [6] but the actual assessment of its occurrence is impeded by the lack of uniform MONW diagnostic criteria. In 1988, Rudermann et al. introduced a diagnostic procedure based on the evaluation of 22 attributes, each of which was assigned a specific number of points. The procedure, however, never gained universal acceptance. Subsequent research sought to simplify the complex criteria in reference to the severity of insulin resistance by using the glucose clamping technique [7, 8] or by using indirect indicators calculated from the concentration of fasting insulin and glucose [3, 9], concentration of insulin [10], the visceral fat mass in computed tomography of the abdomen [11, 16], the coexistence of impaired glucose tolerance [17] or the metabolic syndrome [17–22]. Moreover, the correct body mass is defined in the cited literature as: BMI lower than 25 kg/m^2 [6, 8, 11, 14, 15, 19, 20], 26.3 kg/m^2 or 27 kg/m^2 [7, 10, 18]. Additionally, the prevalence of MONW occurrence may be influenced by age, sex and ethnic differences. This has been indicated by studies conducted on the Venezuelan population, among which 37% of individuals have been diagnosed with the MONW syndrome. In the United States, the occurrence of MONW has been more prevalent among Mexican and African Americans and Native Americans than among Caucasians [6].

The incidence of MONW in Poland is not known. That is why we have attempted to assess the scale of this phenomenon based on a study of a large, randomly chosen homogeneous population aged 20-40 in three large urban areas. An additional goal of the study was to identify the limit values of abdominal fat in men and women measured using the DXA method above which the risk of metabolic disorders increases.

Material and methods

Material

This study of a randomly selected group of people was conducted in three large urban areas of Poland (Szczecin, Krakow and Wroclaw). The selection was based on local voter lists. Letters were sent to individuals aged from 20 to 40 inviting them to participate in the study. Subjects with no previously diagnosed carbohydrate metabolism disorders, chronic diseases requiring medical treatment or cancer were invited to participate in the research. Participation was voluntary and all individuals signed an informed consent form which was authorised by local bioethical committees in all three centres.

The individuals who responded to the invitation were interviewed and underwent physical examination, on the basis of which men and women with normal BMI (less than 25 kg/m^2) were selected for the study. The use of oral contraceptives or discontinuation of their use within three months from the moment of volunteering to participate in the study was a disqualifying criterion for women. 855 people were accepted to take part in the research, comprising 615 women and 240 men.

Anthropometric measurements and body composition parameters

All subjects underwent the following anthropometric measurements: height, body mass, and waist and hip circumference. The waist/hip (WHR, waist-to-hip ratio) indicator was calculated based on the waist and hip measurements.

Body composition was estimated by the densitometry method (DXA, dual X-ray absorptiometry) using measurements of the whole body. The tests were carried out in accordance with the standard protocol provided

by the manufacturer i.e. using the appropriate rules of automated positioning and irradiation conditions. The body composition parameters were measured with the following DXA equipment: 1) Lunar Prodigy Advance, GE Lunar Radiation Corporation, Madison, WI, USA (in Szczecin), 2) Lunar DPX-plus, Lunar Corporation, Madison, WI, USA (in Wroclaw), and 3) Lunar DPX General Electric Healthcare, USA (in Krakow). In order to gauge the results, the DXA machines were cross-calibrated with the help of multiple measurements of whole-body phantoms in all three centres. The final results were presented in an adjusted form. The whole-body measurements were used to calculate total body fat (BF) in grams and as a percentage of body fat (BF%). Fat distribution was analysed in the abdominal area (android) and the hip area (gynoid) (Fig. 1). Abdominal fat deposits (in grams and as a percentage of the android mass) were measured within the area between two horizontal lines running from the top edge of the L2 vertebra and the bottom edge of the L4 vertebra. Assessment of visceral fat within the said area is more conclusive as it contains a relatively small amount of subcutaneous fat [23]. The hip deposit (presented in grams and as a percentage of the gynoid mass) was measured in the area confined by a line connecting the greater trochanters of the femur from the top, and by a horizontal line running through the flexion gap in the knee joint from the bottom.

Biochemical evaluation

Each subject underwent determination of serum glucose, insulin, total cholesterol, HDL cholesterol and triglycerides. Blood samples were collected in the morning, on an empty stomach and at least 12 hours after the last meal. The glucose concentration was tested by the enzymatic method on the Dimension Xpand analyser using tests developed by Dade Behring Marburg GmbH in Germany. The insulin concentration was measured by the immunoenzymatic method on the AxSYM analyser using systems by Abbott Diagnostics, USA. Fasting glucose and fasting insulin concentration levels were used to assess insulin sensitivity with the insulin resistance indicators:

HOMA (*homeostasis model assessment)* = insulin [μIU/mL] × glucose (mmol/L)/22.5

FIRI (*fasting insulin resistance index)* = insulin [μIU/mL] × glucose (mmol/L)/25

QUICKI (*quantitative insulin sensitivity check index*) = 1/[log (fasting insulin [μU/mL]) × log(fasting glucose [mg/dL])

Total cholesterol concentration and its HDL fraction as well as triglycerides were assessed through enzymatic methods using the systems by Dade Behring Marburg GmbH, Germany. LDL cholesterol concentration was calculated using the Friedewald formula [28].

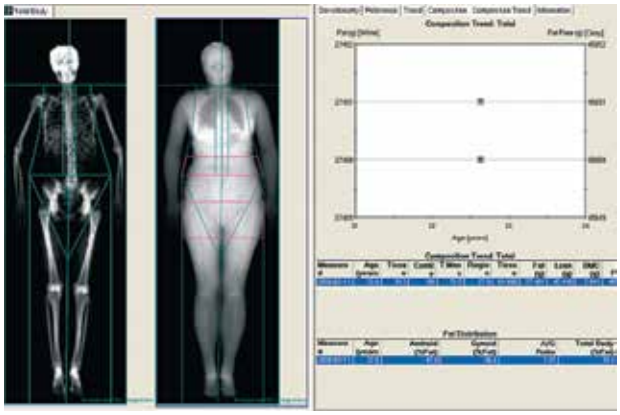

Figure 1. *Assessment of androidal and gynoidal fat (deposits)*
Rycina 1. *Miejsca pomiaru tłuszczu brzusznego i biodrowego*

MONW identification

Among the studied subjects, only 0.67% of women and 0.9% of men with normal body weight met the metabolic syndrome criteria as defined by the NCEP-ATP III and IDF standards; hence the definitions to diagnose MONW based on the coexistence of the syndrome with normal body weight [19] were not used. In subsequent analyses to diagnose MONW, the criteria specified by Conus et al. were employed; thanks to these criteria, MONW can be identified in individuals with HOMA > 1.69 [6].

Statistics

Elements of descriptive statistics were used in describing the variables such as: minimum and maximum values, the lower and upper quartile, the mean, the median, and the standard deviation; tables, histograms, as well as scatter diagrams, medians and confidence intervals for means.

The Shapiro-Wilk test was used to verify the compatibility of the distribution of the studied characteristics with normal distribution. The distribution of most of the variables analyzed in this paper was significantly different from the normal distribution, thus nonparametric methods were used to conduct the analysis.

The equality of distribution hypotheses were verified using the Kolmogorov-Smirnov test and the Mann-Whitney test. Differences were considered statistically significant at $p < 0.05$, while at $0.05 < p < 0.1$ differences were found to be on the border of statistical significance.

The significance of the Spearman correlation between characteristics was analyzed using the Student's t-test. The statistical significance was established at $p < 0.05$. The results found on the border of statistical significance ($0.05 < p < 0.1$) were also taken into consideration. The cut-off point — the border value of the android deposit expressed in grams and percentage, was defined with the error rate of 20%.

Table I. *Anthropometric features, fat distribution and biochemical parameters in MONW and C groups of women*
Tabela I. *Parametry antropometryczne, skład ciała i parametry biochemiczne w grupach kobiet MONW i C*

	C (n = 483)		p	MONW (n = 131)	
	Mean	SD		Mean	SD
Age (years)	29.11	6.10	0.064	28.02	6.23
Weight [kg]	57.42	6.56	0.118	58.62	7.11
Height [cm]	164.97	5.74	0.427	165.39	5.85
BMI [kg/m^2]	21.08	1.99	0.125	21.38	1.90
Waist circumference [cm]	71.06	6.12	0.123	71.78	6.23
Hip circumference [cm]	95.05	5.48	0.955	95.08	5.47
WHR	0.75	0.05	0.118	0.76	0.05
Systolic BP [mm Hg]	109.70	12.18	0.053	111.86	12.28
Diastolic BP [mm Hg]	70.98	8.95	0.604	71.14	8.64
Total fat [g]	16,252.4	4,240.7	0.026	17,300.9	4,662.6
Total fat (%)	29.38	5.68	0.006	30.91	5.98
Androidal deposit [g]	1,051.5	457.5	0.047	1,124.3	441.1
Androidal deposit (%)	22.83	6.85	0.031	24.23	6.88
Gynoidal deposit [g]	5,186.9	1,561.6	0.056	5,421.2	1,385.0
Gynoidal deposit (%)	35.28	5.50	0.029	36.34	5.53
Androidal deposit/gynoidal deposit	0.22	0.16	0.354	0.21	0.07
Glucose [mg/dL]	82.04	8.64	< 0.001	87.46	9.05
Insulin [μIU/mL]	5.02	1.76	< 0.001	10.86	3.09
HOMA	1.02	0.35	< 0.001	2.35	0.70
FIRI	0.91	0.32	< 0.001	10.86	3.09
QUICKI	0.39	0.03	< 0.001	0.34	0.01
Total cholesterol [mg/dL]	185.86	33.40	0.397	188.92	32.80
HDL-C [mg/dL]	66.57	15.41	< 0.001	60.95	14.60
LDL-C [mg/dL]	106.17	28.76	0.015	112.62	30.05
LDL-C/HDL-C	1.69	0.64	< 0.001	1.97	0.76
Triglycerides [mg/dL]	69.83	28.22	< 0.001	76.88	26.71

BMI — body mass index; WHR — waist-to-hip ratio

The statistical calculations were done using Statistica 9.0 software.

Results

Among 855 subjects, 202 (23.7%) were diagnosed with MONW, including 131 women (21.3%) and 71 men (29.6%). Individuals with HOMA < 1.69 belonged to a control group (C). Mean values of the anthropometric and body composition measurements as well as biochemical tests in the MONW subjects were compared to healthy individuals and are summarised in Table I (women) and Table II (men). With respect to the control group, both men and women with MONW had comparable body weight, waist and hip circumference as well as lean mass, while they showed significantly greater total fat content and its abdominal deposit. Additionally, greater concentration levels of fasting glucose and fasting insulin were observed in MONW, along with worse insulin sensitivity and abnormal (atherogenic) profile of the blood lipids. The abdominal fat mass in all studied subjects positively correlated with the concentration levels of glucose, insulin, triglycerides, total cholesterol and its LDL-C as well as insulin sensitivity indicators. It negatively correlated with HDL-C and the QUICKI indicator. Also, a weak yet significant correlation between abdominal fat and blood pressure was observed (Table III). In terms of the hip fat deposit, no such correspondence was discovered.

Table II. *Anthropometric features, fat distribution and biochemical parameters in MONW and C groups of men*
Tabela II. *Parametry antropometryczne, skład ciała i parametry biochemiczne w grupach mężczyzn MONW i C*

	C (n = 169)		p	MONW (n = 71)	
	Mean	SD		Mean	SD
Age (years)	27.99	5.32	0.854	28.25	5.66
Weight [kg]	72.19	8.10	0.460	72.84	7.44
Height [cm]	180.29	6.77	0.193	178.85	6.31
BMI[kg/m^2]	22.18	1.87	0.043	22.74	1.62
Waist circumference [cm]	82.09	6.78	0.132	83.48	6.01
Hip circumference [cm]	97.36	4.89	0.350	97.84	5.17
WHR	0.84	0.05	0.101	0.85	0.05
Systolic BP [mm Hg]	117.30	12.29	0.536	115.89	11.32
Diastolic BP [mm Hg]	75.63	9.96	0.710	76.10	10.30
Total fat [g]	11,941.8	4,696.0	0.014	SD	4,631.0
Total fat (%)	17.09	5.89	0.006	19.22	5.67
Androidal deposit [g]	1,041.7	528.01	0.084	1,159.0	536.5
Androidal deposit (%)	17.51	6.80	0.047	19.37	6.62
Gynoidal deposit [g]	3,157.5	1,225.8	0.065	3,499.4	1,334.6
Gynoidal deposit (%)	18.43	5.91	0.020	20.43	6.27
Androidal deposit/gynoidal deposit	0.33	0.10	0.835	0.34	0.13
Glucose [mg/dL]	86.17	8.96	0.011	90.0	9.85
Insulin [μIU/mL]	4.90	1.84	< 0.001	10.46	2.92
HOMA	1.04	0.39	< 0.001	2.32	0.72
FIRI	0.999	0.315	< 0.001	2.207	0.534
QUICKI	0.383	0.031	< 0.001	0.335	0.01
Total cholesterol [mg/dL]	183.71	34.80	0.119	192.18	37.12
HDL-C [mg/dL]	57.28	13.20	0.255	55.18	13.62
LDL-C [mg/dL]	109.82	33.23	0.102	117.86	33.85
LDL-C/HDL-C	2.04	0.86	0.058	2.28	0.90
Triglycerides [mg/dL]	82.13	34.41	0.224	95.80	52.23

Table III. *Correlations between abdominal fat and anthropometric features with biochemical parameters*
Tabela III. *Korelacje pomiędzy masą tłuszczu brzusznego a parametrami antropometrycznymi i biochemicznymi*

Androidal deposit [g]	Abdominal fat		Anthropometric features	
	R	p	R	p
Glucose [mg/dL]	0.130	0.001	0.132	0.049
Insulin [μIU/mL]	0.168	< 0.0001	0.162	0.015
HOMA	0.189	< 0.0001	0.167	0.013
QUICKI	–0.189	< 0.0001	–0.167	0.013
FIRI	0.189	< 0.0001	0.167	0.013
Total cholesterol [mg/dL]	0.085	0.038	0.318	< 0.0001
LDL-C [mg/dL]	0.153	0.0001	0.346	< 0.0001
HDL-C [mg/dL]	–0.195	< 0.0001	–0.179	0.007
LDL-C/HDL-C	0.227	< 0.0001	0.363	< 0.0001
Triglycerides [mg/dL]	0.162	< 0.0001	0.182	< 0.0001
Systolic BP [mm Hg]	0.114	0.004	0.201	0.002
Diastolic BP [mm Hg]	0.154	< 0.001	0.202	0.002

Table IV. *Anthropometric features, fat distribution and biochemical parameters in NAF and EAF groups of women*
Tabela IV. *Parametry antropometryczne, skład ciała i parametry biochemiczne w grupach kobiet NAF i EAF*

	NAF (n = 520)		p	EAF (n = 94)	
	Mean	SD		Mean	SD
Age (years)	28.56	6.12	0.01	30.35	6.10
Weight [kg]	56.69	6.34	< 0.0001	62.89	5.29
Height [cm]	165.19	5.73	0.103	164.24	5.69
BMI [kg/m^2]	20.74	1.81	< 0.0001	23.29	1.21
Waist circumference [cm]	69.88	5.28	< 0.0001	78.26	5.50
Hip circumference [cm]	94.41	5.26	< 0.0001	98.74	4.35
WHR	0.74	0.04	< 0.0001	0.79	0.05
Systolic BP [mm Hg]	109.11	11.79	0.001	113.63	13.26
Diastolic BP [mm Hg]	70.16	8.49	< 0.0001	74.94	9.87
Glucose [mg/dL]	82.76	9.15	0.014	85.35	8.05
Insulin [μIU/mL]	6.16	3.16	0.012	6.99	3.32
HOMA	1.26	0.69	0.002	1.48	0.75
QUICKI	0.37	0.03	0.002	0.36	0.03
FIRI	1.14	0.62	0.002	1.33	0.67
Total cholesterol [mg/dL]	186.09	32.84	0.232	189.66	35.18
HDL-C[mg/dL]	66.31	15.69	0.0002	60.24	12.63
LDL-C [mg/dL]	106.41	28.81	0.015	114.80	29.37
LDL-C/HDL-C	1.70	0.64	0.0001	2.0	0.74
Triglycerides [mg/dL]	69.55	26.53	0.001	80.54	32.31

The limit value for abdominal fat was calculated in the subsequent phase. Beyond the threshold of the limit value, the prevalence of at least two out of five risk factors of type 2 diabetes increases along with cardiovascular diseases [15]: 1) HOMA > 1.69, 2) glucose > 100 mg/dL, 3) triglycerides 150 mg/dL, 4) HDL-C < 50 mg/dL for women and < 40 mg/dL for men, and blood pressure 130/85 mm Hg. The frequency of manifestation of the factors increases significantly when the mass of abdominal fat in women is greater than 1,496.8 grams which amounts to 30.2 % (OR = 2.0726, –95% CI — 1.0495, +95% CI — 4.0933), and 2,013.2 grams and 28.3% in men respectively (OR = 0.4625, –95% CI — 0.0579, + 95% CI — 3.6912). Women with the android mass above the cut-off point (excess abdominal fat or EAF) had significantly greater BMI, body mass and waist and hip circumference, as well as increased WHR blood pressure than women with abdominal fat values below the cut-off point (normal abdominal fat or NAF) (Table IV).

Furthermore, in comparison with NAF, the EAF group was found to manifest higher fasting insulin and glucose levels, significantly worse insulin sensitivity and an adverse lipid profile (an increased TG and LDL-C concentration and decreased HDL-C). Similar differences in BMI and waist and hip circumference were observed between NAF and EAF men (Table V). However, in contrast with women, no significant differences were found between the two groups of men in terms of blood pressure, glucose and insulin concentration or insulin sensitivity indicators. Men with EAF had a higher concentration of LDL-C and lower HDL-C than men with NAF.

Discussion

The concept of MONW evolved in the 1980s. It was then that Ruderman et al. indicated the existence of non-obese individuals who, despite normal body weight, developed complications of obesity as well as type 2 diabetes, hypertension, dyslipidaemia and coronary heart disease. They also discovered that hyperinsulinaemia was the key to these disorders [4, 5]. In the etiology of MONW, special attention was paid to the excess accumulation of abdominal fat and low physical activity. It is crucial to identify such individuals, as early treatment of metabolic disorders through lifestyle modifications and possible pharmacotherapy can prove helpful in avoiding serious complications

Table V. *Anthropometric features, fat distribution and biochemical parameters in NAF and EAF groups of men NAF*
Tabela V. *Parametry antropometryczne, skład ciała i parametry biochemiczne w grupach mężczyzn NAF i EAF*

	NAF (n = 222)		p	EAF (n = 18)	
	Mean	SD		Mean	SD
Age (years)	27.74	5.33	$p > 0.10$	30.61	6.00
Weight [kg]	72.06	7.84	$p < 0.025$	77.88	5.32
Height [cm]	179.81	6.71	$p > 0.10$	179.50	5.62
BMI [kg/m^2]	22.25	1.71	$p < 0.001$	24.15	0.74
Waist circumference [cm]	82.18	6.30	$p < 0.001$	89.69	4.20
Hip circumference [cm]	97.14	4.85	$p < 0.025$	101.88	4.35
WHR	0.84	0.04	$p < 0.005$	0.88	0.04
Systolic BP [mm Hg]	116.83	12.10	$p < 0.10$	122.72	8.60
Diastolic BP [mm Hg]	75.65	9.92	$p < 0.10$	80.50	6.35
Glucose [mg/dL]	87.72	9.34	$p > 0.10$	87.74	8.23
Insulin [μIU/mL]	6.48	3.35	$p < 0.10$	7.66	3.62
HOMA	1.42	0.78	$p > 0.10$	1.65	0.76
FIRI	1.44	0.71	$p > 0.10$	1.13	0.73
QUICKI	0.40	0.47	$p > 0.10$	0.52	0.17
[mg/dL]	184.17	35.52	$p < 0.01$	210.72	30.81
HDL-C [mg/dL]	56.61	13.53	$p > 0.10$	52.66	11.87
LDL-C [mg/dL]	109.98	32.80	$p < 0.005$	141.27	31.38
LDL-C/HDL-C	2.07	0.85	$p < 0.005$	2.81	0.87
Triglycerides [mg/dL]	83.66	42.46	$p > 0.10$	87.15	29.31

connected with lowered death risk such as type 2 diabetes or ischaemic heart disease. The frequency of MONW occurrence is difficult to establish due to the lack of uniform diagnostic criteria; studies carried out thus far have been conducted among various age and ethnic groups. No optimal parameters for diagnosing MONW have been created which renders it challenging to study the incidence of the syndrome in different populations or countries.

There are no case studies of MONW in women and men between 20 and 40 years of age in the Polish literature. A study of postmenopausal women conducted in Wroclaw revealed that the phenotype of metabolic obesity with normal body weight constitutes about 10.1% [24].

The epidemiological data collected thus far has proved divergent, equivocal and challenging to compare due to the lack of uniform standards for identifying MONW individuals. The commonest criterion in Polish literature is the limit values of insulin resistance parameters. The consequences of insulin resistance are metabolic disorders which occur in obese and non-obese individuals alike. In the study of the Polish population, a criterion similar to that of Conus et al. was used. According to the criterion, the value of HOMA ≥ 1.69 classifies a normal-weight individual in the MONW group. Using the above criterion, 202 individuals (23.65%) were placed in the MONW group and 652 subjects in the control group (C group); after taking gender into account, 131 patients (21.34%) classified in the MONW among women. Among men, 71 individuals (29.58%) were placed in the MONW group. Conus et al. demonstrated the presence of MONW in approx. 10% of women. The larger percentage of women with insulin resistance among residents of Szczecin, Krakow and Wroclaw may stem from the age difference among the studied groups – Polish men and women were older [6]. The study conducted by Jennings et al. showed that the prevalence of MONW in women is similar to that in the Polish population and amounts to 22%. The researchers employed a similar identification criterion, i.e. HOMA ≥ 1.95 [9]. Italian researchers obtained similar results and concluded that 20% of non-obese women and men manifested impaired insulin secretion and action. In a group of Venezuelan patients, MONW was diagnosed more often, up to 56% of boys and 43% of girls between the ages of 14 and 17 [10]. This high prevalence of MONW diagnosis stems from rigorous

diagnostic criteria used by the researchers. Ferrannini et al. discovered insulin resistance in 10% of studied European men and women with BMI below 25 kg/m^2 [25]. Dvorak et al. found the presence of MONW in 18% of Caucasian, Asian and Hispanic subjects [7]. Similarly, Goodpaster et al. identified metabolic obesity with normal weight in 14% of American men and 22% of American women [17].

In light of the lack of strictly defined diagnostic criteria for MONW, researchers in Japan, Korea and the United States employed the metabolic syndrome criteria according to the NCEP ATP III guidelines. When the metabolic syndrome criterion was taken into account, MONW was diagnosed in 12.7% of women and men in the Lee et al. study and in 15.2% of subjects in the Tsai et al. study [21, 22]. In another cross-sectional analysis of 3,747 non-obese women (BMI 18.5–27.0 kg.m^2) the metabolic syndrome was found in 11% of African and Hispanic Americans as well as in 6% of Caucasian women [18]. Meigs et al. identified the metabolic syndrome in 7.1% of individuals with normal body weight, while insulin resistance was diagnosed in 7.7% of subjects [19]. Among the population of Polish young men and women with normal body weight, prevalence of the metabolic syndrome, in compliance with criteria established by five international science organisations in 2009 (IDF, AHA, IAS, WHF, and NHLBI), was found in only 0.67% of women and 0.9% of men.

It is known that excessive abdominal fat causes insulin resistance. Some researchers classify non-obese individuals as MONW or NOW based on the high content of abdominal fat evaluated on TC scans [11]. Hyun et al. as well as Katsuki et al. concluded that 18.5% of women and men with a surface area of fat greater than 100 cm^2 face a greater probability of developing cardiovascular diseases [12, 13, 15]. Criteria for the diagnosis of excess accumulation of fat in the visceral area are not unequivocal. A number of researchers believe that the adipose tissue content on CT scans at the L4–L5 level greater than 110 cm^2 is associated with the occurrence of ischaemic heart disease [26]. Despress and Lamarche assumed a value of 100 cm^2 as the limit amount of visceral tissue [27]. Others have demonstrated that an area of visceral fat above 130 cm^2 contributes to dyslipidaemia and insulin resistance [28]. Due to the lack of uniform criteria in assessing the accumulation of excess abdominal fat, a limit value of the android deposit at which metabolic disorders occur has been introduced in this paper. Women with abdominal fat above 30.21% and men with abdominal fat above 28.31% were classified as MONW. Considering the above criterion of the android deposit limit value, 15.31% of women and 7.50% of men with normal BMI < 25 kg/m^2 had excess abdominal fat. The study results of the Polish population are congruent with the studies carried out by Hyun et al. and Katsuki et al. [11, 12, 15].

In the absence of consistent diagnostic criteria, it is not possible to make an accurate assessment of the discussed pathology, nor is it feasible to draw comparisons between given populations. The divergence in MONW prevalence is connected with the variety of methods used to identify MONW individuals.

It can be concluded that approximately 21.34% of women and 29.58% of men with normal body weight among the residents of Szczecin, Krakow and Wroclaw manifest impaired insulin sensitivity; 15.31% of non-obese women and 7.5% of non-obese men show the accumulation of excess abdominal fat.

Conclusions

As no uniform criteria for diagnosing MONW are available, it is not possible to make an accurate assessment of the disorder or draw comparisons between given populations. The divergence in MONW prevalence is connected with the variety of methods used to identify MONW individuals. It can be concluded that approximately 21.34% of women and 29.58% of men with normal body weight among the residents of Szczecin, Krakow and Wroclaw manifest impaired insulin sensitivity; 15.31% of non-obese women and 7.5% of non-obese men show the accumulation of excess abdominal fat. The increased amount of abdominal fat in people with normal body weight is connected with the presence of insulin resistance and adverse atherogenic lipid profile. Existing metabolic disorders in seemingly non-obese individuals may lead to future cardiovascular diseases.

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