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ORIGINAL ARTICLE

FAT AND FAT-FREE MASS AS IMPORTANT DETERMINANTS OF BODY COMPOSITION ASSESSMENT IN RELATION TO SARCOPENIC OBESITY

Martina Gažarová[1], *Maroš Bihari*[1], *Jaroslav Šoltís*[1]

[1]Slovak University of Agriculture, Faculty of Agrobiology and Food Resources, Institute of Nutrition and Genomics, Tr. A. Hlinku 2, 949 76 Nitra, Slovak Republic

ABSTRACT

Background. Fat and fat-free/muscle mass and their ratio reflecting the possible presence of obesity or sarcopenic obesity are important in assessing body composition.

Objective. The aim of the work was to assess the use of fat and fat-free mass and their ratio in the diagnosis of sarcopenic obesity, as well as correlations with selected anthropometric, somatic and biochemical parameters and indices.

Material and Methods. The object of the study was a group of 201 women (20-68 aged) randomly selected from the population without the presence of a serious disease or without the use of medication. Body composition was assessed by the MFBIA method (InBody 720). We used the ratio of fat to fat-free mass (FM/FFM) to define sarcopenic obesity. A Biolis 24i Premium biochemical analyzer was used to determine biochemical parameters.

Results. Using FM and FFM values and their mutual ratio, we identified women with a healthy body weight (28.9%), obese women (58.2%) and women with sarcopenic obesity (12.9%). Values of anthropometric parameters (body weight, BMI, WC, WHR, WHtR, BAI, FM (kg, %), FMI, VFA, FFM (kg), FFMI, SMM (kg), SMMI, ICW, ECW, TBW, CHC, HC), with the exception of FFM (%), SMM (%) and TBW (%), increased significantly with increasing FM/FFM values, so the highest values were found in subjects with sarcopenic obesity. In the case of biochemical parameters, with increasing FM/FFM values, the values of T-CH, LDL, TAG, GLU, hs-CRP, UA, systolic and diastolic blood pressure also increased, so the highest values were again found in women with sarcopenic obesity. HDL values, on the contrary, decreased. FM/FFM had the strongest positive association with the proportion of fat mass on body weight (r=0.989), then with FMI (r=0.980), FM (r=0.965), VFA (r=0.938), WHtR (r=0.937), BMI (r=0.922), WC (r=0.901. We found the strongest negative association with the proportion of FFM on body weight (r=-0.989), the proportion of total body water (r=-0.988) and the proportion of skeletal muscle mass (r=-0.987).

Conclusions. FM/FFM correlates excellently with FM and VFA and can be implemented to diagnose obesity. In order to comprehensively evaluate the state of health and body composition, the proportionality of not only fat, but also fat-free/muscle mass should be analyzed, because it turns out that a negative impact on health and survival is associated not only with an excessive amount of adipose tissue, but also with a lower muscle mass.

Key words: *fat mass, fat-free mass, sarcopenic, obesity, body composition*

INTRODUCTION

Since the 1970s, the global prevalence of obesity in adults has almost tripled and increased even more dramatically in children and adolescents [1-3]. By 2025, approximately 2.3 billion adults are expected to be overweight and more than 700 million will be obese. Globally, the prevalence of obesity is higher in wealthier countries in Europe, North America and Oceania. Overweight and obesity in adults have currently reached epidemic proportions in the WHO European Region. WHO estimates that 59% of adults are overweight or obese, with more than half of adults in 50 of the 53 Member States in the European region being overweight or obese [2,4]. Since the prevalence of obesity is alarmingly increasing not only among adults, it increases the risk of adverse health consequences.

An increase in fat mass (FM) is associated with an increase in the incidence of pathological conditions, which include metabolic syndrome. The latter represents a cluster of risk factors such as insulin resistance, dyslipidemia and hypertension, which ultimately result in an increased risk of type 2 diabetes mellitus and cardiovascular disorders, some types of cancer, arthritis or sleep apnea [5,6].

The discovery of leptin and adiponectin more than 20 years ago clearly showed that adipose tissue is an

Corresponding author: Martina Gažarová, Slovak University of Agriculture, Faculty of Agrobiology and Food Resources, Institute of Nutrition and Genomics, Tr. A. Hlinku 2, 949-01 Nitra, Slovakia, phone: +421 37 641 4210, e-mail: martina.gazarova@uniag.sk

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endocrine organ that produces bioactive substances called adipokines, through which it regulates not only appetite, satiety and energy expenditure, but also the secretion and metabolism of glucose, insulin and lipids and the function of the immune system [7, 8].

Fat accumulation induces increased production of pro-inflammatory cytokines, creating the conditions for local as well as systemic low-grade chronic inflammation [9-11]. This inflammation has been shown to contribute to the development and progression of sarcopenia [12,13]. Sarcopenia is defined as a state of age-related loss of muscle mass and muscle strength with functional impairment in terms of physical performance and is associated with a series of adverse health outcomes such as falls and fractures, reduced mobility and quality of life, depression and increased mortality [14, 15, 16, 17].

The results of studies in different population groups indicate that the negative impact on health and survival is associated not only with an excessive amount of adipose tissue, but primarily with lower muscle mass [18]. An increase in adipose tissue can also be accompanied by a loss of muscle mass (leading to sarcopenia), which is diagnosed as sarcopenic obesity [19]. Both sarcopenia and sarcopenic obesity are risk factors for higher mortality [20].

Demographic trends show that the proportion of the elderly and obese population is increasing at an unprecedented rate [21]. At a conservative prevalence estimate, sarcopenia affects >50 million people today and will affect >200 million in the next 40 years [22]. Aging is accompanied by a progressive loss of muscle mass and strength, which dramatically affects health status, quality of life and leads to obesity [23,24]. Obesity, in turn, worsens sarcopenia, increases fat infiltration into muscles, reduces physical functions and increases the risk of mortality [25,26]. These two states are mutually dependent. Sarcopenic obesity tends to be more common in older individuals, as both the risk and prevalence of obesity and sarcopenia increase with age or in younger obese individuals with severe disabilities [27, 28, 29, 32].

Recently, attention has focused on sarcopenic obesity, which is characterized by the coexistence of excess fat mass (FM) and reduced fat-free mass (FFM) [33, 34, 35, 36]. Therefore, when evaluating body composition, attention is focused not only on fat, but also fat-free and muscle mass and the relationships between them.

The aim of the work was to assess the adequacy and relevance of the use of anthropometric parameters fat and fat-free mass and their ratio in the diagnosis of sarcopenic obesity, as well as correlations with selected anthropometric, somatic and biochemical parameters and indices.

MATERIALS AND METHODS

Characteristics of the study group

The object of the study was a group of 201 women from 20 to 68 age, (95% CI 42 to 46) randomly selected from the population without the presence of a serious disease or without the use of medication. The measurements were carried out in the period from October 2021 to May 2022. Prior to participation in the study, written informed consent to participation in the study and its conditions was obtained from all participants. For definitive participation, we used the following exclusion criteria: age <18 years, BMI >50 $kg.m^{-2}$, pregnancy or presumption of pregnancy, athlete at professional level, presence of serious physical or psychological illnesses, use of medications that could affect study results, contraindications for bioimpedance measurement, increased physical activity just prior to measurement, intake of excessive amounts of coffee, alcohol, and fatty foods ≤8 hours prior to testing, and use of diuretics seven days prior to testing. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethical Committee of the Specialized Hospital of St. Svorad Zobor in Nitra, Slovakia (Study No. 4/071220/2020).

Anthropometric and somatic measurements

Body composition was analyzed by multi-frequency bioelectrical impedance analysis (MFBIA) using an InBody 720 (Biospace Co. Ltd., Seoul, Republic of Korea). Before the measurement, the participants were asked to exclude and refrain from drinking large amounts of water, not to consume alcohol 24 hours before testing, to avoid food with a high sugar, salt or fat content for 12 hours before testing, to refrain from intense physical activity for at least the last 12 hours in advance. In addition to informed written consent, all participants also signed consent to the processing of personal data. Lookin'Body 3.0 software was used to process data from anthropometric measurements.

Body height (H) as one of the input data was determined using a Tanita WB-300. The following parameters were determined directly by bioimpedance analysis: weight (W, kg), waist circumference (WC, cm), hip circumference (HC, cm), chest circumference (CHC, cm), fat mass (FM, % or kg), visceral fat area (VFA, cm^2), fat-free mass (FFM, % or kg), skeletal muscle mass (SMM, % or kg), extra-cellular water (ECW, l), intra-cellular water (ICW, l), total body water (TBW, l) and basal metabolic rate (BMR, kcal).

We measured the blood pressure of the participants using a fully automatic blood pressure monitor OMRON Microlife AG, 9443 (Widnau/Switzerland).

Calculation of index parameters and criteria for the diagnosis of obesity and sarcopenic obesity

Body mass index (BMI) was calculated as weight (kg) divided by the square of height (m^2). To calculate the body adiposity index (BAI), we used the formula BAI = [hip circumference / height 1.5] – 18 (%). We calculated waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) as waist circumference (cm) divided by hip circumference (cm) or height (cm) [37, 38, 39, 40].

Fat mass (kg), fat-free mass (kg) and skeletal muscle mass (kg) were used to calculate the fat mass index (FMI, $kg.m^{-2}$), fat-free mass index (FFMI, $kg.m^{-2}$) and skeletal muscle index (SMMI, $kg.m^{-2}$) as fat mass (kg) divided by height squared (m^2), or fat-free mass (kg) divided by height squared (m^2), or skeletal muscle mass (kg) divided by height squared (m^2). Body shape index (ABSI) was defined as WC / ($BMI^{11/6} \times height^{-2/3}$) and the ABSI z-score was calculated according to the methodology of *Krakauer* and *Krakauer* [41].

According to BMI, obesity was defined as ≥30 $kg.m^{-2}$ [42]. We used the ratio of fat to fat-free mass (FM/FFM) and a value greater than 0.8 to define sarcopenic obesity. Values lower than 0.4 expressed metabolic health, values between 0.4 and 0.8 were considered obesity [43,44].

Determination of blood serum and blood plasma biochemical parameters

An automatic biochemical analyzer Biolis 24i Premium (Tokyo Boeki Machinery Ltd., Tokyo, Japan) was used to determine biochemical parameters. We focused on determining the following parameters: lipid profile – total cholesterol (T-CH, $mmol.l^{-1}$), low density lipoproteins (LDL, $mmol.l^{-1}$), high density lipoproteins (HDL, $mmol.l^{-1}$), triglycerides (TAG, $mmol.l^{-1}$); glycemia (GLU, $mmol.l^{-1}$); uric acid (UA, $\mu mol.l^{-1}$); hs-C-reactive protein (hs-CRP, $mg.l^{-1}$). Venous blood sampling was performed in a standard manner (fasting) from a peripheral vein in the elbow socket into a dry sterile tube intended for blood sampling. The blood was subsequently processed according to the need and nature of the analyses. After separating the blood serum and plasma, the samples were stored in a deep-freeze box at a temperature of -80 °C until the analyses.

Statistical analysis

We used Microsoft Office Excel 2016 (Los Angeles, CA, USA) in combination with XLSTAT (version 2019.3.1) for statistical data processing. We performed descriptive analysis using mean ± standard deviation. For monitored parameters, we present additional statistical characteristics: max (maximum), min (minimum), 95% CI (confidence interval). We used Pearson's r correlation and correlograms to evaluate the relationship between variables. We performed statistical analysis using the computer software STATISTICA 13 (TIBCO Software, Inc., Palo Alto, CA, USA) and MedCalc software (MedCalc® Statistical Software Ltd, Ostend, Belgium, version 20.113). The level of statistical significance was set as $P<0.05$. Using one-way analysis of variance (ANOVA), we tested differences between variables and compared using *Tukey's* post hoc test.

RESULTS AND DISCUSSION

The cohort of women in the study was assessed as being at high risk for premature mortality based on ABSI z-scores along with cutoff values for waist circumference, waist-to-hip ratio, waist-to-height ratio, visceral fat, total fat, body mass index, and adiposity, as well as total cholesterol and LDL. The basic characteristics of the group are shown in Table 1.

The body mass index represented a value of 26.4±5.4 $kg.m^{-2}$, the body adiposity index should reflect the proportion of fat in body weight, but in our case the average value of BAI was 28.5±4.6%, which is relatively underestimated and substantially lower than the FM value (34.1%) in our set. The mean value of WHR was 0.93±0.1, which means that it is above the reference range of optimal values (>0.85). The ratio of waist circumference to height (WHtR) represented an average value of 0.56±0.1, which categorizes women into the overweight group. The average value of the body fat index was in the range of values defining an increased amount of body fat. The average FMI value of 9.45±4.2 $kg.m^{-2}$ was found in the group. Based on the proportion of fat mass, this value was expected. With the next indicator, it is more difficult to determine in which category in terms of obesity to classify a group of women based on their average FFMI values. The average value of this indicator was at the level of 16.99±1.6 $kg.m^{-2}$, which can classify women as average, fat, but also athletic types, depending on the proportion of fat in the body. In our case and from the point of view of the proportion of fat, the fatty category comes into consideration (FM=34.1%). The average value of the ratio of fat and fat-free mass was 0.55±0.2, which falls into the category of obese. The analysis of biochemical parameter values showed increased total and LDL cholesterol. HDL, triglycerides, fasting blood glucose, uric acid as one of the indicators of cardiovascular risk and hs-C-reactive protein as an inflammatory marker had an average values in the optimal range. Systolic blood pressure in women was slightly increased (124.7±13 mmHg), diastolic blood pressure was normal (82.1±9.7 mmHg).

Using the values of fat and fat-free mass and their mutual ratio, we obtained data on the basis of which we found the differentiation of the group into

Table 1. Descriptive characteristics of study group (n = 201)

Parameters	Mean	±SD	Minimum	Maximum	95% CI
Age (years)	44.71	13.67	20.00	68.00	42 – 46
Weight, W (kg)	72.84	14.50	42.80	114.20	70.82 – 74.86
Height, H (m)	1.66	0.06	1.49	1.80	1.65 – 1.67
Waist Circumference, WC (cm)	92.86	14.27	65.80	131.20	90.87 – 94.83
Hip Circumference, HC (cm)	99.26	7.96	83.90	118.80	98.15 – 100.36
Chest Circumference, CHC (cm)	96.05	8.76	77.30	118.10	94.83 – 97.27
Fat Mass, FM (%)	34.11	8.77	15.42	51.58	32.89 – 35.33
Fat Mass, FM (kg)	25.91	11.15	8.60	55.60	24.35 – 27.46
Visceral Fat Area, VFA (cm^2)	102.64	38.50	32.97	200.04	97.28 – 107.99
Fat-free Mass, FFM (%)	65.89	8.77	48.37	84.55	64.67 – 67.11
Fat-free Mass, FFM (kg)	46.93	5.11	34.20	60.80	46.22 – 47.64
Skeletal Muscle Mass, SMM (%)	36.12	4.80	25.95	46.64	35.44 – 36.78
Skeletal Muscle Mass, SMM (kg)	25.75	3.03	18.32	34.00	25.33 – 26.17
Extra-cellular Water, ECW (l)	13.12	1.43	9.50	17.10	12.92 – 13.31
ECW/TBW (%)	38.14	0.54	36.88	40.00	38.06 – 38.21
Intra-cellular Water, ICW (l)	21.28	2.32	15.60	27.60	20.95 – 21.60
ICW/TBW (%)	61.86	0.54	60.00	63.12	61.78 – 61.93
Total Body Water, TBW (l)	34.40	3.73	25.10	44.40	33.87 – 34.91
TBW/W (%)	48.29	6.44	36.00	62.26	47.39 – 49.18
Basal Metabolic Rate, BMR (kcal)	1383.73	110.28	1109.27	1683.27	1368 – 1399
Body Adiposity Index, BAI (%)	28.48	4.61	19.40	44.70	27.83 – 29.11
Body Mass Index, BMI ($kg.m^{-2}$)	26.44	5.43	17.37	40.04	25.68 – 27.19
Waist-to-Hip Ratio, WHR	0.93	0.08	0.76	1.13	0.92 – 0.94
Waist-to-Height Ratio, WHtR	0.56	0.09	0.40	0.78	0.54 – 0.57
Fat Mass Index, FMI ($kg.m^{-2}$)	9.45	4.20	3.03	20.68	8.86 – 10.03
Fat-free Mass Index, FFMI ($kg.m^{-2}$)	16.99	1.58	14.03	21.27	16.76 – 17.20
Skeletal Muscle Mass Index, SMMI ($kg.m^{-2}$)	9.32	0.94	7.48	11.84	9.18 – 9.45
A Body Shape Index, ABSI ($m^{11/6}.kg^{-2/3}$)	0.08	0.00	0.07	0.09	0.0808 – 0.0817
ABSI z-score	0.40	0.65	-1.44	2.71	0.313 – 0.493
Total Cholesterol, T-CH ($mmol.l^{-1}$)	5.83	1.04	3.48	8.66	5.68 – 5.97
LDL ($mmol.l^{-1}$)	3.49	0.90	1.70	7.34	3.36 – 3.61
HDL ($mmol.l^{-1}$)	1.78	0.40	1.02	3.51	1.72 – 1.83
Triglycerides ($mmol.l^{-1}$)	1.23	0.66	0.39	5.00	1.14 – 1.32
Glycaemia ($mmol.l^{-1}$)	4.89	0.61	3.60	7.40	4.80 – 4.97
hs-C-Reactive Protein, hs-CRP ($mg.l^{-1}$)	3.72	4.21	0.02	28.65	3.13 – 4.30
Uric Acid, UA ($\mu mol.l^{-1}$)	277.49	81.86	136.90	529.36	266 – 288
Blood Pressure Systolic, BPS (mmHg)	124.66	13.46	99.00	164.00	122 – 126
Blood Pressure Diastolic, BPD (mmHg)	82.07	9.66	55.00	117.00	80 – 83

Note. ± SD = standard deviation

women with a healthy body weight (28.9%), obese women (58.2%) and women with sarcopenic obesity (12.9%). The evaluation of anthropometric and biochemical parameters and indices, as well as the risk of premature mortality based on the distribution of women according to the defined limit values of the FM/FFM ratio, is clearly presented in Table 2.

When assessing anthropometric parameters and indices, we found that the values of all of them (body weight, BMI, WC, WHR, WHtR, BAI, FM (kg, %), FMI, VFA, FFM (kg), FFMI, SMM (kg), SMMI, ICW, ECW, TBW, CHC, HC), with the exception of the proportion of fat and muscle mass and total water in body weight, increased with increasing FM/FFM values. This means that in the case of the mentioned

Table 2. Evaluation of anthropometric, somatic and biochemical parameters and indices based on the distribution of women according to the defined limit values of the FM/FFM ratio

Parameters	Metabolic health (n=58)	Obese (n=117)	Sarcopenic obesity (n=26)
Age (years)	35[a]	47[b]	56[c]
Weight, W (kg)	58.72[a]	74.90[b]	95.11[c]
Height, H (m)	1.68[a]	1.66	1.64[b]
Waist Circumference, WC (cm)	77.37[a]	95.73[b]	114.47[c]
Hip Circumference, HC (cm)	91.25[a]	100.42[b]	111.92[c]
Chest Circumference, CHC (cm)	87.29[a]	97.50[b]	109.09[c]
Fat Mass, FM (%)	23.30[a]	36.46[b]	47.69[c]
Fat Mass, FM (kg)	13.80[a]	27.58[b]	45.40[c]
Visceral Fat Area, VFA (cm^2)	58.13[a]	111.77[b]	160.85[c]
Fat-free Mass, FFM (%)	76.70[a]	63.55[b]	52.31[c]
Fat-free Mass, FFM (kg)	44.92[a]	47.31[b]	49.71[b]
Skeletal Muscle Mass, SMM (%)	42.00[a]	34.86[b]	28.67[c]
Skeletal Muscle Mass, SMM (kg)	24.62[a]	25.98[b]	27.27[b]
Extra-cellular Water, ECW (l)	12.53[a]	13.21[b]	14.03[c]
ECW/TBW (%)	38.03[a]	38.11[a]	38.48[b]
Intra-cellular Water, ICW (l)	20.41[a]	21.45[b]	22.44[b]
ICW/TBW (%)	61.97[a]	61.89[a]	61.52[b]
Total Body Water, TBW (l)	32.95[a]	34.66[b]	36.47[b]
TBW/W (%)	56.25[a]	46.55[b]	38.37[c]
Basal Metabolic Rate, BMR (kcal)	1340[a]	1392[b]	1444[b]
Body Adiposity Index, BAI (%)	24.04[a]	29.10[b]	35.55[c]
Body Mass Index, BMI ($kg.m^{-2}$)	20.85[a]	27.20[b]	35.49[c]
Waist-to-Hip Ratio, WHR	0.85[a]	0.95[b]	1.02[c]
Waist-to-Height Ratio, WHtR	0.46[a]	0.58[b]	0.70[c]
Fat Mass Index, FMI ($kg.m^{-2}$)	4.90[a]	10.03[b]	16.95[c]
Fat-free Mass Index, FFMI ($kg.m^{-2}$)	15.95[a]	17.16[b]	18.53[c]
Skeletal Muscle Mass Index, SMMI ($kg.m^{-2}$)	8.74[a]	9.42[b]	10.16[c]
A Body Shape Index, ABSI ($m^{11/6}.kg^{-2/3}$)	0.0789[a]	0.0821[b]	0.0826[b]
ABSI z-score	0.1558[a]	0.5374[b]	0.3479
Total Cholesterol, T-CH ($mmol.l^{-1}$)	5.60[a]	5.85	6.27[b]
LDL ($mmol.l^{-1}$)	3.37	3.50	3.71
HDL ($mmol.l^{-1}$)	1.96[a]	1.70[b]	1.68[b]
Triglycerides ($mmol.l^{-1}$)	1.00[a]	1.28[b]	1.53[b]
Glycaemia ($mmol.l^{-1}$)	4.74[a]	4.87[a]	5.28[b]
hs-C-Reactive Protein, hs-CRP ($mg.l^{-1}$)	2.12[a]	4.03[b]	5.88[b]
Uric Acid, UA ($\mu mol.l^{-1}$)	220[a]	290[b]	349[c]
Blood Pressure Systolic, BPS (mmHg)	120[a]	125[b]	132[b]
Blood Pressure Diastolic, BPD (mmHg)	78[a]	83[b]	87[b]

Note. Data are expressed as mean.
[abc] = different symbols in a line mean significant differences between groups.

parameters, the highest values were found in women with sarcopenic obesity, the lowest in metabolically healthy ones. Mostly, there were significant differences between groups. In the case of the proportion of fat-free mass, muscle mass and total body water in body weight, their values decreased with increasing FM/FFM values. We found the highest ABSI z-score, i.e. the risk of premature death, in obese women (high risk), the lowest in metabolically healthy women (average risk; significant differences). In the case of

Table 3. Correlation analysis of interrelationships between FM/FFM and other variables

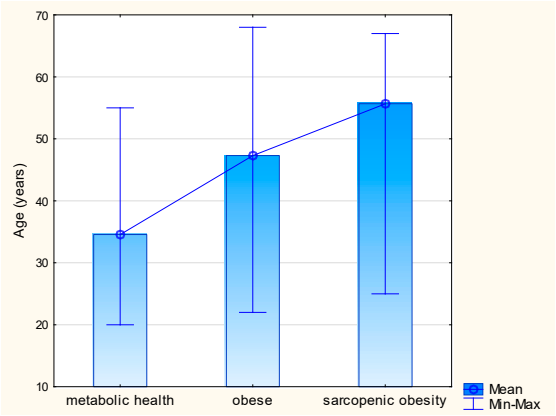
Parameters	r	*P*	Parameters	r	P
Age (years)	0.586	<0.0001	Basal Metabolic Rate (kcal)	0.303	<0.0001
Weight (kg)	0.848	<0.0001	Body Adiposity Index	0.868	<0.0001
Height (m)	-0.282	0.0001	Body Mass Index ($kg.m^{-2}$)	0.922	<0.0001
Waist Circumference (cm)	0.901	<0.0001	Waist-to-Hip Ratio	0.826	<0.0001
Hip Circumference (cm)	0.887	<0.0001	Waist-to-Height Ratio	0.937	<0.0001
Chest Circumference (cm)	0.853	<0.0001	Fat Mass Index ($kg.m^{-2}$)	0.98	<0.0001
Fat Mass (%)	0.989	<0.0001	Fat-free Mass Index ($kg.m^{-2}$)	0.564	<0.0001
Fat Mass (kg)	0.965	<0.0001	Skeletal Muscle Mass Index ($kg.m^{-2}$)	0.521	<0.0001
Visceral Fat Area (cm^2)	0.938	<0.0001	A Body Shape Index ($m^{11/6}.kg^{-2/3}$)	0.423	<0.0001
Fat-free Mass (%)	-0.989	<0.0001	ABSI z-score	0.132	0.0621
Fat-free Mass (kg)	0.303	<0.0001	Total Cholesterol ($mmol.l^{-1}$)	0.211	0.0027
Skeletal Muscle Mass (%)	-0.987	<0.0001	LDL ($mmol.l^{-1}$)	0.108	0.1259
Skeletal Muscle Mass (kg)	0.282	0.0001	HDL ($mmol.l^{-1}$)	-0.315	<0.0001
Extra-cellular Water (l)	0.337	<0.0001	Triglycerides ($mmol.l^{-1}$)	0.343	<0.0001
ECW/TBW (%)	0.258	0.0002	Glycemia ($mmol.l^{-1}$)	0.325	<0.0001
Intra-cellular Water (l)	0.282	0.0001	hs-C-Reactive Protein ($mg.l^{-1}$)	0.311	<0.0001
ICW/TBW (%)	-0.258	0.0002	Uric Acid ($\mu mol.l^{-1}$)	0.562	<0.0001
Total Body Water (l)	0.304	<0.0001	Blood Pressure Systolic (mmHg)	0.342	<0.0001
TBW/W (%)	-0.988	<0.0001	Blood Pressure Diastolic (mmHg)	0.35	<0.0001

biochemical and somatic parameters, with increasing FM/FFM values, the values of T-CH, LDL, TAG, GLU, hs-CRP, UA, systolic and diastolic blood pressure also increased, i.e. the highest values were again found in women with sarcopenic obesity. HDL values, on the contrary, decreased.

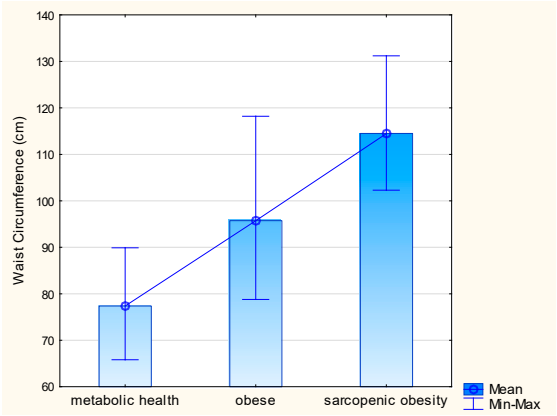
Within the correlation analysis (Table 3), we found that the FM/FFM ratio had the strongest positive association with the proportion of fat mass on body weight (r=0.989), followed by correlations in order with FMI (r=0.980), FM (r=0.965), VFA (r=0.938), WHtR (r=0.937), BMI (r=0.922), WC (r=0.901), HC (r=0.887), BAI (r=0.868), CHC (r=0.853), body weight (r=0.848) and WHR (r=0.826). We found the strongest negative association with the proportion of FFM on body weight (r=-0.989), the proportion of total body water (r=-0.988) and the proportion of skeletal muscle mass (r=-0.987). We also found indirect dependencies in the case of HDL (r=-0.315) and body height (r=-0.282), although these were significant relationships, but weak. We also found direct significant dependencies with FM/FFM in the case of age (r=0.586), FFMI (r=0.564), UA (r=0.562), SMMI (r=0.521) and ABSI (r=0.423). Our results show that the FM/FFM ratio is excellently correlated with fat mass and visceral fat and can be implemented to diagnose obesity and replace the questioned BMI.

As it turns out, the prevalence of obesity, as well as sarcopenic obesity, is increasing, which was also contributed to by unfavorable circumstances related to the pandemic and the restriction of movement and sports activities of the population. Worse, the prevalence of obesity and sarcopenia (even sarcopenic obesity) is starting to appear in younger age groups, which is an alarming situation. This is also confirmed by our results, when the average age in the group of women with sarcopenic obesity was 56 years. It is generally known that the proportion of fat-free mass represents approximately 75-80% of body weight in women [45]. Fat-free mass values gradually decrease with age. This decrease is also confirmed by a study by *Forbes* [46], in which he states that the reduction of FFM in older people is due to a change in body weight. This decrease tends to be more pronounced in women during menopause and after the age of 60. Also *Schutz* et al. [47] in their study point to a decline in FFM with age. According to him, women aged 34-54 reach FFM values of 43 kg on average, while women aged 55-74 have values below 42 kg. As a result of increased or decreased physical activity, changes in body weight may not occur, because only the ratio of fat-free mass to body fat can change. In our group, although the value of fat-free mass did not decrease with increasing age, its share in body weight did, to the disadvantage of sarcopenically obese women.

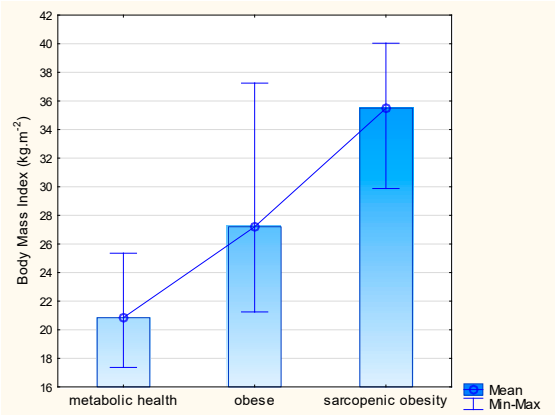
Another important change in body composition associated with aging is an increase in fat mass and visceral fat, which increases susceptibility to metabolic syndrome. The coexistence of sarcopenia and obesity, termed sarcopenic obesity, represents abnormal muscle



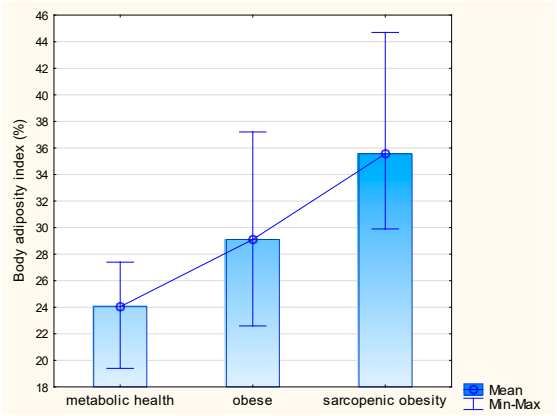
Age



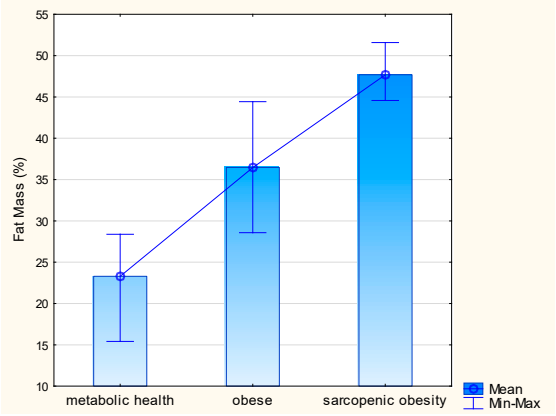
Waist Circumference



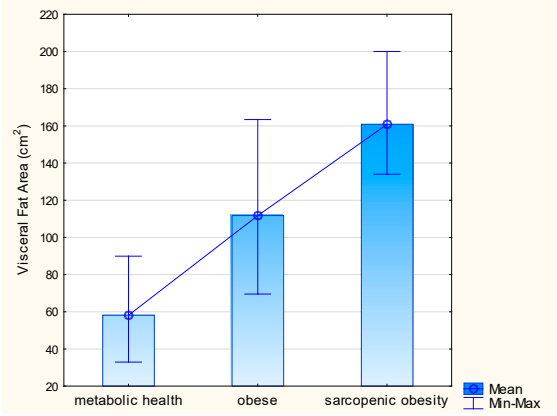
Body Mass Index



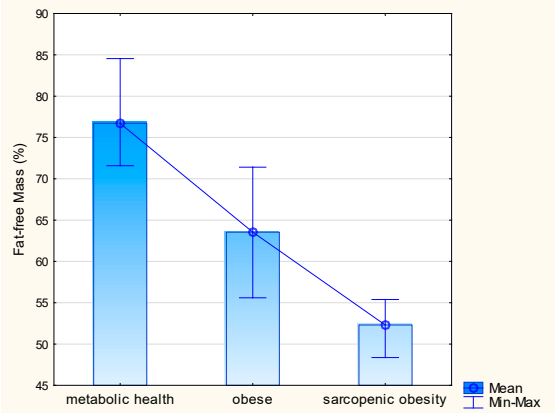
Body Adiposity Index



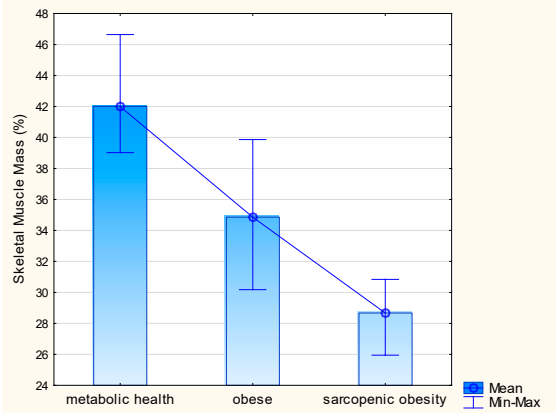
Fat Mass



Visceral Fat Area



Fat-free Mass



Skeletal Muscle Mass

Figure 1. Box Plots of parameters based on the distribution of subjects according to the FM/FFM ratio

loss and fat accumulation, both acting synergistically to maximize their health-threatening effects [48,49]. Preserving muscle mass can help maintain functional status and reduce the negative effects of falls, fractures and a sedentary lifestyle [50]. Previous studies have shown that with increasing obesity, the loss of skeletal muscle leads to an increase in inflammatory adipocytes such as leptin, tumor necrosis factor alpha and interleukin-6 and a decrease in the concentration of adiponectin or interleukin-15 [51]. Higher secretion of pro-inflammatory markers further increases insulin resistance [52]. The relationship between inflammation, adipose tissue and muscle mass is very close, the main inflammatory markers are associated with obesity [53]. As shown by *Kim* et al. [54], serum hs-CRP levels were significantly increased in association with sarcopenic obesity. *Schrager* et al. [52] found that sarcopenic obesity, defined by high BMI and low muscle strength, was associated with increased levels of IL-6 and CRP. *Cesari* et al. [53] found a positive association of CRP and IL-6 with total fat mass. According to the FM/FFM ratio in the study by *Biolo* et al. [55] 30% of cases had sarcopenic obesity, with a significant preponderance of women. In the group of women with sarcopenic obesity, plasma concentrations of CRP were 4-5 times higher than in non-sarcopenic obese women, in our cohort we found an almost three-fold increase in CRP values in sarcopenic women compared to non-sarcopenic lean women, but only a 1.4-fold increase in comparison with non-sarcopenic obese women. The FM/FFM ratio was positively correlated in the study by *Biolo* et al. [55] with plasma CRP concentrations in women (r=0.31) but not in men (r=0.01). These findings of a correlation between FM/FFM ratio and plasma CRP concentrations in women, but not in men, are consistent with previous data [56] that the amount and distribution of body fat affects CRP to a greater extent in women in compared to men. We can also confirm these findings with our results (FM/FFM vs CRP in women r=0.311). According to the authors of *Biolo* et al. [57], in women the FM/FFM ratio was not associated with ABSI, but was positively correlated with BMI and WC (BMI: r=0.610; WC: r=0.640). These findings support the hypothesis that abdominal fat deposition may lead to loss of skeletal muscle mass [57]. However, in our cohort, we found that FM/FFM was positively associated with ABSI, even significantly (r=0.423; P <0.0001). Regarding the relation of FM/FFM to BMI and WC, we found similar but stronger correlations (BMI: r=0.922; WC: r=0.911).

According to some authors, sarcopenic obesity increases the risk of metabolic damage and physical disability more than sarcopenia or obesity alone [58,59]. It is a fact that visceral adiposity plays a key role in the development of sarcopenic obesity. It is characterized by a systemic inflammatory response, oxidative stress and insulin resistance, which can stimulate muscle proteolysis and inhibit protein synthesis [29]. A sedentary lifestyle can lead to inactivity-related sarcopenia and, in parallel, promote the deposition of abdominal fat [29,60]. Moreover, muscle loss and physical inactivity directly promote visceral fat accumulation, which causes systemic inflammation, oxidative stress, and muscle atrophy [60,61]. Activation of both mechanisms can represent a vicious circle leading to progressive sarcopenia and abdominal obesity.

The prevalence of sarcopenic obesity is increasing significantly worldwide, therefore it is very important to screen its occurrence in the population and implement the necessary nutrition and exercise training programs for preventive strategies that could reduce the adverse health outcomes associated with sarcopenic obesity.

CONCLUSIONS

In order to comprehensively evaluate the state of health and body composition, the proportionality of not only fat but also muscle mass should be analyzed in routine practice, which is often overlooked, even though it turns out that the negative impact on health and survival is associated not only with an excessive amount of fat tissue, but also with lower muscle mass. Therefore, measuring the amount and proportion of muscle tissue should become a generally accepted indicator of effective diagnosis and screening of obesity, as well as severe sarcopenic obesity.

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Conflicts of interest

The authors declare there were no conflicts of interest.

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