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ORIGINAL ARTICLE

NORMAL WEIGHT OBESITY – HIDDEN OBESITY BEHIND A NORMAL BMI: APPLICATION OF COMPOSITE BODY COMPOSITION INDICES IN NUTRITIONAL STATUS EVALUATION IN SLOVAK FEMALES

Laura Hačková, Martina Gažarová, Mária Kijovská

Institute of Nutrition and Genomics, Faculty of Agrobiology and Food Resources,
Slovak University of Agriculture, Slovak Republic

ABSTRACT

Background. Normal weight obesity (NWO) is defined as a phenotype in which individuals present with a body mass index within the normal range, yet exhibit an excessive proportion of body fat (> 28%). This condition is linked to elevated risks of metabolic and cardiovascular disorders. Although BMI remains a widely applied screening parameter, it does not capture the distribution of fat and lean tissue, which may result in misclassification and underestimation of health hazards.
Objective. This study sought to compare the body composition profiles of women classified as normal weight according to BMI but differing in adiposity levels, and to determine the diagnostic value of composite indices – fat mass index (FMI), fat-free mass index (FFMI), skeletal muscle mass index (SMMI), and the fat mass (FM)/fat-free mass (FFM) ratio – in identifying NWO phenotype and assessing nutritional status.
Material and Methods. A total of 402 female Caucasian volunteers aged 18.6-65 years were included in the study. Body composition was analyzed using the InBody 270 (MF-BIA).
Results. Among 402 participants, 235 fell within the normal-weight BMI range, and 62 of them fulfilled the criteria for the NWO phenotype. Relative to their normal weight (NW) counterparts, the NWO group displayed higher adiposity (%FM: 32.85 vs. 24.08%; FMI: 7.53 vs. 5.08 kg/m²; FM/FFM: 0.49 vs. 0.32, respectively), greater visceral fat accumulation (VFL: 8.68 vs. 5.43), and lower values of lean body mass (FFM: 41.93 vs. 45.22 kg; SMM: 22.76 vs. 24.79 kg). In NWO, BMI correlated only weakly with body fat percentage, whereas FMI and FM/FFM showed substantially stronger associations with an unfavorable body composition pattern.
Conclusions. BMI in isolation does not provide sufficient sensitivity to detect the NWO phenotype. Composite indices offer a more precise depiction of body composition and should be considered as complementary tools in both diagnostic procedures and metabolic risk prevention strategies. Their integration into clinical assessment protocols may facilitate earlier detection and targeted intervention.

Keywords: *normal weight obesity, body composition, fat accumulation, lean mass, composite indices*

INTRODUCTION

Excess body fat is recognized as a major risk factor contributing to an estimated 2.8 million deaths worldwide each year. Elevated body weight, encompassing both overweight and obesity, substantially increases the likelihood of developing several chronic non-communicable diseases, including cardiovascular disease, type 2 diabetes, and certain cancers [1]. The World Health Organization (WHO) defines obesity as an abnormal or excessive accumulation of body fat that may impair health. As direct measurement of body fat percentage can be technically demanding, the WHO recommends the use of the body mass index (BMI) as a practical tool for estimating the prevalence of overweight and obesity within populations [2]. BMI has therefore long been established as a standard measure for evaluating nutritional status in individuals and plays a key role in obesity screening [3]. BMI, calculated as body weight in kilograms divided by the square of height in meters (kg/m²), provides a framework for classifying individuals into categories such as underweight, normal weight, pre-obesity, and obesity. These classifications serve as a basis for identifying individuals at elevated risk of chronic diseases, including cardiovascular disease, type 2 diabetes, asthma, chronic obstructive pulmonary disease, gastrointestinal disorders, musculoskeletal conditions, and multiple sclerosis [4-6]. Although BMI remains a valuable tool for assessing health risks at the population level, it cannot differentiate

Corresponding author: Martina Gažarová, Institute of Nutrition and Genomics, Faculty of Agrobiology and Food Resources, Slovak University of Agriculture, Tr. A. Hlinku 2, 94976, Nitra, Slovak Republic; email: martina.gazarova@uniag.sk

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between fat mass and lean mass, nor does it account for fat distribution [7]. Its accuracy may be influenced by several factors – such as age, sex, and ethnicity – that affect patterns of body fat distribution [8-10].

As a result, an individual with a BMI in the "normal" range (18.5-24.9 kg/m²) may have either an appropriate amount of body fat or an excess of fat that remains undetected due to their seemingly normal weight. This limitation can lead to misclassification of individuals [2]. One clinically significant manifestation of this limitation is normal weight obesity (NWO), a phenotype defined by normal BMI values coupled with an excessive body fat percentage. In the scientific literature, this condition has also been described using related terms such as metabolically obese normal weight (MONW) and thin-outside-fat-inside (TOFI), which emphasize the presence of excessive or ectopic fat accumulation and metabolic disturbances despite a normal BMI [11, 12]. These overlapping concepts collectively describe individuals who may appear lean based on BMI but display adverse metabolic profiles, increased visceral adiposity, and elevated cardiometabolic risk.

NWO is associated with increased mortality, morbidity, and risk of chronic metabolic diseases, despite BMI-based classification suggesting a "healthy" weight status [13-15]. This phenotype is particularly common among women, with multiple studies highlighting its association with higher prevalence of metabolic syndrome, insulin resistance, dyslipidemia, hypertension, and type 2 diabetes – even in the absence of overweight according to BMI [6, 8, 15].

In light of these findings, the literature increasingly advocates for complementing BMI assessment with composite body composition indices that enable more accurate identification of at-risk individuals. Such indices include the fat mass index (FMI), fat-free mass index (FFMI), skeletal muscle mass index (SMMI), and the FM/FFM ratio, which express fat mass relative to height, lean (muscle) mass relative to height, skeletal muscle proportion, and the ratio of fat to lean mass, respectively [16-18]. These parameters make it possible to distinguish between healthy and unhealthy body composition, even among individuals with identical BMI values [19].

The aim of this study was to compare two groups of women with similar BMI but differing body fat values, and to evaluate the applicability of selected composite indices in diagnosing the NWO phenotype and assessing nutritional risk.

MATERIAL AND METHODS

Study design

A total of 402 female Caucasian volunteers aged 18.6-65 years were included in the study. The selection of volunteers was random and voluntary. Before inclusion in the study, the participants were informed about the research protocol, which contained details about the research carried out with the objectives, methodological procedure, possible risks in the case of withholding important information regarding health status (risks in the case of an electrical device implanted in the body on the heart or in the case of pregnancy) and the volunteer's consent to inclusion in the study. Inclusion criteria included age between 18 and 70 years, BMI below 50 kg/m^2, absence of serious physical or psychological illnesses, no medication affecting body weight, physiological obstacles such as pregnancy or suspected pregnancy, no professional sports, no contraindication for bioimpedance measurement, no increased physical activity immediately before measurement, no recent weight loss, no increased intake of coffee, alcohol or fat ≤ 8 hours before testing and diuretics one week before testing. The study was conducted with the approval of the Ethics Committee of the Specialized Hospital of St. Zoerardus Zobor in Nitra, Slovakia (protocol no. 20230512/2) according to the guidelines of the Declaration of Helsinki.

Body composition

Body composition was analyzed using the InBody 270 (MF-BIA; InBody Corporation, Seoul, South Korea). Before the measurement, 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 12 hours beforehand. In addition to informed written consent, all participants also signed consent to the processing of personal data.

Body height was measured using a professional electronic altimeter BSM370 (Biospace Co. Ltd., Seoul, Republic of Korea), the advantage of which lies in the automation of the measurement performance with the elimination of human errors during measurement. To assess the body composition, the following parameters were measured directly by bioimpedance analysis: basal metabolic rate (BMR, kcal); body weight (BW, kg); waist circumference (WC, cm); hip circumference (HC, cm); fat-free mass (FFM, kg); skeletal muscle mass (SMM, kg); body fat mass (FM, kg, %); visceral fat level (VFL); total body water (TBW, L).

Waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) were calculated as waist circumference (cm) divided by hip circumference (cm) or height (cm), respectively. Fat mass (kg), fat-free mass (kg) and skeletal muscle mass (kg) were taken to calculate fat mass index (FMI, kg/m^2), fat-free mass index (FFMI, kg/m^2) and skeletal muscle mass index (SMMI, kg/m^2)

as fat mass (kg) divided by square of the height (m^2) or fat-free mass (kg) divided by square of the height (m^2) or skeletal muscle mass (kg) divided by square of the height (m^2). We also expressed fat-free mass, skeletal muscle mass and total body water in relative proportions.

From the group of women with normal BMI values, we created two key groups – a normal weight group (NW; BMI 18.5-24.99 kg/m^2 and %FM < 28%) and normal weight obesity group (NWO; BMI 18.5-24.99 kg/m^2 and %FM > 28%).

Statistical analysis

We used Microsoft Office Excel 2016 (Los Angeles, CA, USA) in combination with XLSTAT (version 2019.3.1) for data processing. 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 23.0.2). The normality of the variable distribution was checked by the Shapiro-Wilk test. We used the paired t-test if the data were normally distributed, if the distribution was not normal, the Wilcoxon signed rank test was used. We performed descriptive analysis using mean ± standard deviation. To evaluate the relationship between variables, we used Spearman›s correlation analysis and expressed it graphically with color scales through correlograms. The level of statistical significance was set as $p < 0.05$.

RESULTS

A total of 402 adult women aged 18.6-65.0 years (mean 42.51 ± 10.67 years) were included in the study. The sample encompassed a wide range of body height from 1.53 m to 1.83 m (mean 1.67 ± 0.06 m), body weight from 46.0 kg to 118.5 kg (mean 67.75 ± 13.02 kg), and BMI ranging from 18.50 to 40.70 kg/m² (mean 24.45 ± 4.60 kg/m²). The mean waist circumference was 78.39 ± 5.85 cm, the waist-to-hip ratio 0.87 ± 0.07, and the waist-to-height ratio 0.47 ± 0.04. The mean fat-free mass was 46.85 ± 6.09 kg, skeletal muscle mass 25.73 ± 3.64 kg, and fat mass 19.82 ± 9.27 kg. The average visceral fat level was 8.11 ± 4.66, total body water 34.35 ± 4.46 liters, and the mean basal metabolic rate 1384 ± 131.57 kcal. These values indicate considerable inter-individual differences in body composition and fat tissue distribution, which are detailed in Table 1.

Based on body mass index values, the women were divided into three primary weight categories. The

Table 1. Descriptive characteristics of the study group

Parameters N = 402	Mean	SD	Minimum	Maximum
Age (years)	42.51	10.67	18.60	65.00
Body weight (BW, kg)	67.75	13.02	46.00	118.50
Body mass index (BMI, kg/m²)	24.45	4.60	18.50	40.70
Height (m)	1.67	0.06	1.53	1.83
Waist circumference (WC, cm)	78.39	5.85	66.60	95.40
Waist-to-hip ratio (WHR)	0.87	0.07	0.74	1.06
Waist-to-height ratio (WHtR)	0.47	0.04	0.37	0.59
Fat-free mass (FFM, kg)	46.85	6.09	27.40	77.00
Fat-free mass (FFM, %)	69.62	7.99	42.06	90.03
Fat-free mass index (FFMI, kg/m²)	16.91	1.73	10.98	23.25
Skeletal muscle mass (SMM, kg)	25.73	3.64	14.50	44.20
Skeletal muscle mass (SMM, %)	38.23	4.39	23.16	50.00
Skeletal muscle mass index (SMMI, kg/m²)	9.28	1.05	5.81	13.34
Fat mass (FM, kg)	19.82	9.27	6.10	58.10
Fat mass (FM, %)	30.38	8.00	10.00	58.00
Fat mass index (FMI, kg/m²)	7.15	3.42	1.88	22.38
Fat mass to fat-free mass ratio (FM/FFM)	0.42	0.17	0.11	1.38
Visceral fat level (VFL)	8.11	4.66	2.00	25.00
Total body water (TBW, L)	34.35	4.46	20.10	56.40
TBW/BW (%)	51.06	5.89	30.74	66.34
Basal metabolic rate (BMR, kcal)	1384	131.57	961	2032

SD – standard deviation

normal weight category, with a BMI ranging from 18.5 to 24.99 kg/m², included 235 women. Another 106 women fell into the pre-obesity category, with a BMI between 25.0 and 29.99 kg/m², while the remaining 61 women were classified as obese, with a BMI equal to or greater than 30.0 kg/m². A detailed distribution of the entire sample according to BMI categories, along with the corresponding basic anthropometric characteristics, is presented in Table 2.

Women with normal weight adjusted for BMI and with healthy body fat

For NW group, positive correlations were observed between body weight, skeletal muscle mass, fat-free mass, and total body water content. Body weight showed strong positive correlations with FFM, SMM, TBW, and BMR. Body mass index was strongly and positively correlated with FFMI, SMMI, FM, and FMI. Moderate positive correlations were found with SMM, FFM, TBW, BMR, and VFL. Negative correlations were observed with %SMM, %FFM, and TBW/BW.

Fat mass index had a strong positive correlation with FM and %FM, while also being strongly and negatively correlated with %FFM, TBW/BW, and %SMM. Fat-free mass index showed positive correlations with SMM, FFM, TBW, and BMR. A moderate positive correlation was observed with %SMM. The only negative correlation was with %FM. Skeletal muscle mass index, similar to FFMI, showed very strong positive correlations with SMM, FFM, TBW, and BMR. A moderate positive correlation was found with %SMM, and negative correlations were found with %FM. The FM/FFM ratio exhibited a very strong positive correlation with %FM. Strong negative correlations were noted with %FFM, TBW/BW, and %SMM. Between %FM and composite indices, very strong negative correlations were found – the highest with %FFM, followed by TBW/BW and %SMM. All three components – FFM, TBW, and SMM –

Table 2. Anthropometric characteristics of subgroups adjusted for BMI

Parameters	Normal weight (N = 235)				Pre-obesity (N = 106)				Obesity (N = 61)			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Age (years)	39.19[a]	10.29	18.60	63.00	46.37[b]	9.30	26.00	63.00	48.56[c]	9.47	19.00	65.00
BW (kg)	60.35[a]	6.01	46.00	77.00	75.41[b]	6.45	58.70	91.40	90.47[c]	9.18	74.70	118.50
BMI (kg/m²)	21.58[a]	1.74	18.50	24.90	27.09[b]	1.42	25.00	29.70	33.09[c]	2.53	30.00	40.70
Height (m)	1.67[a]	0.06	1.54	1.82	1.67[b]	0.06	1.53	1.83	1.65[a]	0.06	1.53	1.82
WC (cm)	75.34[a]	4.16	66.60	88.20	81.58[b]	4.40	72.00	93.60	85.38[b]	4.98	71.10	95.40
WHR	0.84[a]	0.05	0.74	0.98	0.91[b]	0.05	0.80	1.04	0.95[c]	0.06	0.79	1.06
WHtR	0.45[a]	0.03	0.37	0.54	0.49[b]	0.03	0.44	0.56	0.52[c]	0.03	0.42	0.59
FFM (kg)	44.53[a]	5.09	27.40	62.90	49.04[b]	5.17	37.90	73.10	52.65[b]	6.01	41.60	77.00
FFM (%)	74.38[a]	5.85	52.09	90.03	65.40[b]	4.30	55.82	80.60	58.66[c]	4.35	42.06	72.30
FFMI (kg/m²)	16.05[a]	1.20	10.98	19.63	17.68[b]	1.12	14.95	22.07	19.40[c]	1.38	16.25	23.25
SMM (kg)	24.33[a]	3.03	14.50	35.80	27.04[b]	3.08	20.60	41.60	29.23[b]	3.57	22.80	44.20
SMM (%)	40.66[a]	3.44	27.57	50.00	36.08[b]	2.62	30.03	45.87	32.58[b]	2.60	23.16	41.50
SMMI (kg/m²)	8.78[a]	0.74	5.81	11.17	9.75[b]	0.69	8.08	12.56	10.78[c]	0.84	8.95	13.34
FM (kg)	15.54[a]	4.17	6.10	27.30	26.12[b]	4.16	17.60	35.80	37.02[c]	6.30	29.00	58.10
FM (%)	25.62[a]	5.86	10.00	48.00	34.60[b]	4.30	19.40	44.10	41.13[c]	4.35	27.70	58.00
FMI (kg/m²)	5.60[a]	1.57	1.88	10.15	9.42[b]	1.46	5.31	12.42	13.61[c]	2.27	8.91	22.38
FM/FFM	0.34[a]	0.11	0.11	0.92	0.54[b]	0.10	0.24	0.79	0.70[c]	0.14	0.38	1.38
VFL	5.79[a]	2.18	2.00	15.00	11.55[b]	2.60	7.00	18.00	16.72[c]	2.76	13.00	25.00
TBW (L)	32.66[a]	3.73	20.10	46.20	35.94[b]	3.79	27.80	53.90	38.60[b]	4.38	30.40	56.40
TBW/BW (%)	54.55[a]	4.33	38.21	66.34	47.94[b]	3.19	40.87	59.43	43.00[c]	3.19	30.74	52.96
BMR (kcal)	1334[a]	109.95	961	1729	1431[b]	111.77	1188	1949	1509[b]	129.72	1268	2032

BW – body weight; BMI – body mass index; WC – waist circumference – WHR – waist-to-hip ratio; WHtR – waist-to-height ratio; FFM – fat-free mass; FFMI – fat-free mass index; SMM – skeletal muscle mass; SMMI – skeletal muscle mass index; FM – fat mass; FMI – fat mass index; VFL – Visceral Fat Level; TBW – total body water; BMR – basal metabolic rate; SD – standard deviation; Min – minimum; Max – maximum; [a, b, c] – different letters indicate a significant difference; normal weight was defined as: BMI between 18.5-24.99 kg/m², pre-obesity: BMI between 25.0-29.99 kg/m², obesity: BMI equal to or greater than 30 kg/m².

showed strong positive correlations with each other, confirming their mutual interconnection and inverse relationship to body fat levels. An overview of the correlation relationships between individual variables is shown in the correlation matrix in Table 3.

Women with normal weight obesity phenotype

In this group of women with a normal BMI but elevated body fat percentage, BMI showed very strong correlations with body weight, SMMI, and FFMI. Correlations with SMM, FFM, TBW, FM, and VFL were strong, whereas relationships with key relative composition indicators – %FM and FM/FFM ratio – were weak. Fat mass index exhibited very strong positive correlations with %FM, FM, and VFL. Strong correlations were also confirmed with WC, WHR, and WHtR. Negative correlations were found with %SMM, %FFM, and TBW/BW. Fat-free mass index was very strongly correlated with SMMI, SMM, FFM, and TBW. Moderate negative correlations were recorded with %FM. Skeletal muscle mass index had very strong correlations with SMM, FFM, and TBW. Moderate negative relationships were noted with %FM. The FM/FFM ratio showed very strong positive correlations with %FM and VFL. Very strong negative correlations were confirmed with %SMM, %FFM, and TBW/BW, while the relationship with SMM was moderate. In the NWO group, BMI showed only weak correlations with %FM and FM/FFM ratio, whereas FMI and FM/FFM had very strong relationships with these indicators (FMI vs. %FM: r = 0.828; FM/FFM vs. %FM: r = 0.995). BMI was also less sensitive in reflecting the relationship between fat burden and muscle mass indicators (%SMM: r = 0.076; %FFM: r = -0.078) compared with FM/FFM (%SMM: r = -0.974; %FFM: r = -0.995). For absolute muscle and fat-free mass values, BMI was strongly correlated (SMM: r = 0.636; FFM: r = 0.622), but the associations were weaker than those for FFMI and SMMI (SMMI vs. SMM: r = 0.810; FFMI vs. FFM: r = 0.771). All correlation coefficient values for the NWO group are provided in Table 3.

Anthropometric differences between NWO and NW women

From the group of 235 women with a normal body mass index, 150 were classified – based on body fat percentage – into the group with a healthy body fat proportion, representing the "normal weight without obesity" (NW) phenotype. Another 62 women with a normal body mass index but with an elevated body fat percentage (above 28%) belonged to the phenotype referred to as "normal weight obesity" (NWO). The remaining 23 women had a body fat

Table 3. Correlation matrix of selected anthropometric variables in the NW and NWO phenotype groups

Parameters	BMI		FMI		FFMI		SMMI		FM/FFM	
	NW	NWO	NW	NWO	NW	NWO	NW	NWO	NW	NWO
Age (years)	0.20*	0.29*	0.15	0.43***	0.16*	0.04	0.15	0.04	0.08	0.34**
BW (kg)	0.73***	0.72***	0.40***	0.40**	0.70***	0.61***	0.72***	0.65***	0.13	-0.04
Height (m)	-0.01	0.07	-0.18*	-0.03	0.13	0.11	0.18*	0.15	-0.23**	-0.12
WC (cm)	0.23**	0.40**	0.37***	0.55***	0.02	0.10	0.04	0.13	0.36***	0.40**
WHR	0.23**	0.40**	0.37***	0.55***	0.02	0.10	0.04	0.13	0.36***	0.40**
WHtR	0.20*	0.35**	0.42***	0.56***	-0.07	0.03	-0.08	0.03	0.45***	0.47***
FFM (kg)	0.54***	0.62***	0.01	0.03	0.76***	0.77***	0.79***	0.80***	-0.29***	-0.44***
FFM (%)	-0.39***	-0.08	-0.92***	-0.83***	0.21*	0.52***	0.22**	0.51***	-1.00***	-1.00***
SMM (kg)	0.55***	0.64***	0.01*	0.04	0.77***	0.78***	0.80***	0.81***	-0.29***	-0.43***
SMM (%)	-0.23**	0.08	-0.83***	-0.72***	0.36***	0.64***	0.39***	0.64***	-0.97***	-0.97***
FM (kg)	0.71***	0.59***	0.93***	0.86***	0.24**	0.11	0.24**	0.15	0.83***	0.63***
FM (%)	0.39***	0.08	0.92***	0.83***	-0.21*	-0.52***	-0.22**	-0.50***	1.00***	1.00***
VFL	0.59***	0.40**	0.83***	0.88***	0.15	-0.16	0.15	-0.13	0.77***	0.81***
TBW (L)	0.54***	0.63***	0.00	0.03	0.76***	0.77***	0.79***	0.80***	-0.29***	-0.43***
TBW/BW (%)	-0.41***	-0.07	-0.92***	-0.82***	0.20*	0.53***	0.21**	0.51***	-1.00***	-0.99***
BMR (kcal)	0.54***	0.62***	0.01	0.03	0.76***	0.77***	0.79***	0.80***	-0.29***	-0.44***

BW – body weight; BMI – body mass index; WC – waist circumference – WHR – waist-to-hip ratio; WHtR – waist-to-height ratio; FFM – fat-free mass; FFMI – fat-free mass index; SMM – skeletal muscle mass; SMMI – skeletal muscle mass index; FM – fat mass; FMI – fat mass index; VFL – Visceral Fat Level; TBW – total body water; BMR – basal metabolic rate; NW – normal weight; NWO – normal weight obesity.

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; 1.0 … −1.0

Table 4. Comparison of selected anthropometric parameters in the NW and NWO phenotype groups

Parameters	NW (N = 150)		NWO (N = 62)		p-value
	Mean	SD	Mean	SD	
Age (years)	37.73	9.82	42.07	10.99	< 0.01
BW (kg)	59.60	6.00	62.52	5.59	< 0.01
BMI (kg/m²)	21.27	1.59	22.97	1.37	< 0.001
Height (m)	1.67	0.06	1.65	0.05	< 0.05
WC (cm)	74.83	3.46	78.53	3.99	< 0.001
WHR	0.83	0.04	0.87	0.04	< 0.001
WHtR	0.45	0.02	0.48	0.02	< 0.001
FFM (kg)	45.22	4.74	41.93	4.09	< 0.001
FFM (%)	75.85	3.28	67.07	2.84	< 0.001
FFMI (kg/m²)	16.17	1.13	15.40	1.08	< 0.001
SMM (kg)	24.79	2.83	22.76	2.40	< 0.001
SMM (%)	41.58	1.96	36.37	1.67	< 0.001
SMMI (kg/m²)	8.86	0.69	8.36	0.65	< 0.001
FM (kg)	14.38	2.58	20.59	2.50	< 0.001
FM (%)	24.08	3.27	32.85	2.84	< 0.001
FMI (kg/m²)	5.08	0.93	7.53	0.81	< 0.001
FM/FFM	0.32	0.06	0.49	0.07	< 0.001
VFL	5.43	1.15	8.68	1.86	< 0.001
TBW (L)	33.17	3.46	30.73	2.99	< 0.001
TBW/BW (%)	55.64	2.43	49.14	2.07	< 0.001
BMR (kcal)	1347	102.24	1276	88.28	< 0.001

BW – body weight; BMI – body mass index; WC – waist circumference – WHR – waist-to-hip ratio; WHtR – waist-to-height ratio; FFM – fat-free mass; FFMI – fat-free mass index; SMM – skeletal muscle mass; SMMI – skeletal muscle mass index; FM – fat mass; FMI – fat mass index; VFL – Visceral Fat Level; TBW – total body water; BMR – basal metabolic rate; SD – standard deviation; NW – normal weight; NOW – normal weight obesity.

percentage outside the defined reference range or incomplete data on its proportion, and therefore did not meet the criteria for inclusion in either of these two phenotypes.

When comparing the "normal weight without obesity" (NW) and "normal weight obesity" (NWO) phenotypic groups, statistically significant differences were confirmed in several key body composition indicators. Women with the NWO phenotype had higher mean age compared to the NW group (42.07 vs. 37.73 years; $p < 0.01$), body weight (62.52 vs. 59.60 kg; $p < 0.01$), body mass index (22.97 vs. 21.27 kg/m²; $p < 0.001$), and markedly higher fat mass indicators – FM/FFM (0.49 vs. 0.32; $p < 0.001$), FM (20.59 vs. 14.38 kg; $p < 0.001$), %FM (32.85 vs. 24.08%; $p < 0.001$), and FMI (7.53 vs. 5.08 kg/m²; $p < 0.001$). The NWO group also had higher values of visceral fat level (8.68 vs. 5.43; $p < 0.001$), waist circumference (78.53 vs. 74.83 cm; $p < 0.001$), waist-to-hip ratio (0.87 vs. 0.83; $p < 0.001$), and waist-to-height ratio (0.48 vs. 0.45; $p < 0.001$).

In contrast, the NW phenotype, despite the identical BMI classification, had higher values of fat-free mass and muscle mass indicators. BMR (1347 vs. 1276 kcal; $p < 0.001$), FFM (45.22 vs. 41.93 kg; $p < 0.001$), %FFM (75.85 vs. 67.07%; $p < 0.001$), and the FFMI (16.17 vs. 15.40 kg/m²; $p < 0.001$) were higher. A similar trend was observed for SMM 24.79 vs. 22.76 kg; $p < 0.001$), %SMM (41.58 vs. 36.37%; $p < 0.001$), and the SMMI (8.86 vs. 8.36 kg/m²; $p < 0.001$). The NW group also had a higher TBW (33.17 vs. 30.73 L; $p < 0.001$) and TBW/BW (55.64 vs. 49.14%; $p < 0.001$).

Correlation analyses indicated different sensitivity of the evaluated indices between phenotypes. In the NW group, BMI showed very strong correlations with SMM ($r = 0.549$), FM ($r = 0.712$) and relatively stronger with %FM ($r = 0.393$) compared to NWO (SMM: $r = 0.636$; FM: $r = 0.593$; %FM: $r = 0.079$). In the NWO phenotype, the strongest associations with fat indicators were observed for FMI (%FM: $r = 0.828$) and FM/FFM (%FM: $r = 0.995$), whereas BMI did not capture these relationships. Similarly, in

NWO, BMI weakly reflected the negative association between fat load and muscle mass (%SMM: r = 0.076; %FFM: r = -0.078) compared to FM/FFM (%SMM: r = -0.974; %FFM: r = -0.995). Differences in the sensitivity of BMI and FMI were most evident for parameters of relative and absolute body composition. In the NWO group, BMI had only weak correlations with %FM (r = 0.079), %SMM (r = 0.076), and %FFM (r = -0.078), whereas FMI showed very strong correlations with these indicators (%FM: r = 0.828) and strong negative associations with %SMM (r = -0.724; %FFM: r = -0.827). A similar difference was observed for absolute fat mass and visceral fat, where BMI correlated with FM (r = 0.593) and VFL (r = 0.400) less strongly than FMI (FM: r = 0.856; VFL: r = 0.884), indicating markedly higher sensitivity of FMI in assessing fat load in this phenotype.

These differences confirm that in the NWO phenotype, BMI is a less reliable indicator of body composition, whereas indices such as FMI, FM/FFM, FFMI, and SMMI provide a more sensitive picture of actual body composition and potential health risks. A comparison of the mean values of individual parameters for both groups is presented in Table 4.

DISCUSSION

In recent years, it has become increasingly evident that individuals with similar body mass index may exhibit markedly different values for the components of body composition, particularly in the proportion of fat mass and muscle mass, which clearly highlights the limitations of using BMI alone in nutritional status assessment. This issue is especially apparent when evaluating the phenotype of normal weight obesity (NWO), in which individuals classified as "normal" according to BMI simultaneously present with excessive body fat [20]. Our results confirm that, even among women with comparable BMI values, significant differences were observed in body composition parameters, particularly in fat mass percentage, fat mass index, and skeletal muscle indices. These findings illustrate the well-recognized limitation of BMI, which does not account for differences in fat and lean mass distribution. This observation is consistent with previous studies reporting that a notable proportion of women with a normal BMI present excessive body fat and can thus be classified as having the NWO phenotype [2, 7, 21]. The similarity between our results and those reported in other populations suggests that this phenotype – and its associated health risks – may also be relevant within the Slovak female population. Significant differences between the NW and NWO groups in our sample were observed primarily in parameters related to adipose tissue. Participants classified in the NWO group exhibited markedly higher mean values of body fat percentage compared to the NW group, fat mass index, FM/FFM, and visceral fat level. These findings indicate that even with identical BMI classification, body composition between the groups can differ substantially – an aspect that plays a key role in evaluating health risks for specific phenotypic groups. Our findings are consistent with previous observations showing that individuals with the NWO phenotype tend to have a higher proportion of total and visceral fat despite comparable BMI values [14, 22, 23].

Similar results were reported by Romero Corral et al. [14] in a U.S. adult population and by De Lorenzo et al. [22] in Caucasian Italian women with normal BMI. This agreement suggests that comparable adiposity patterns may also be present among Slovak women, indicating that excessive abdominal fat could be a key factor contributing to the less favorable metabolic profile observed in the NWO phenotype. Our results showed that women with the NWO phenotype had higher visceral fat levels and greater waist circumference compared to women with normal body composition, despite identical BMI classification. This pattern of central fat accumulation was also described in other populations, including U.S. adults [14] and middle-aged Europeans [24], as well as in broader reviews of NWO characteristics across ethnic groups [2]. The similarity of these findings suggests that excessive abdominal adiposity is a consistent feature of the NWO phenotype across diverse populations and is also evident in Slovak women, potentially contributing to an increased cardiometabolic risk profile. As central obesity may be present even with a normal BMI, Lee et al. [25] recommend specific waist circumference cut-off values for more accurate identification of at-risk individuals, which may also be beneficial in detecting the NWO phenotype.

Gómez-Ambrosi et al. [26] reported that individuals with a normal BMI but a high body fat percentage ("NOOB") had higher waist circumference, blood pressure, CRP levels, uric acid, ALT, and insulin resistance compared to individuals with a normal BMI and normal body fat percentage. The prevalence of abdominal obesity among individuals with NWO ranges from 15.6-28.8%, compared with only 3.7-4.4% in those with NW [27-29]. Reported values include Italian women aged 20-45 years [27], Chinese adults [28], and Ethiopian adults of both sexes [29], indicating population-related variability but consistently higher prevalence in NWO. Correa-Rodríguez et al. [30] also highlighted the high prevalence of NWO among young adults and its association with multiple cardiometabolic risk factors, further supporting the need for early identification of this phenotype. Interestingly, correlation analysis showed a stronger association between BMI and visceral fat in the NW group than in the NWO group. This paradox suggests that BMI cannot reliably capture risky body composition in the NWO group – emphasizing the need for more targeted diagnostics beyond BMI alone.

Apart from adipose tissue, differences between the groups were also observed in indicators of fat-free mass. Despite having the same BMI, women in the NW phenotype group had higher values of FFM, SMM, as well as FFMI and SMMI compared to the NWO group. These differences indicate a more favorable representation of fat-free body tissue in the NW group and also suggest that the NWO phenotype is characterized not only by excess fat but also by a lower proportion of fat-free body mass, which in the long term may lead to the development of a condition known as sarcopenic obesity. This condition, described in detail by Barazzoni et al. [31], represents a combination of increased fat mass and reduced muscle mass, which significantly worsens an individual's metabolic profile.

In the NW group, BMI strongly correlated with muscle mass indicators – most notably with FFMI and SMMI – indicating that a higher BMI in this group is associated with muscle mass. In NWO, these correlations were similarly high, but due to lower absolute muscle mass values, BMI in this group cannot be interpreted as reflecting a favorable composition. The higher correlation simply means that even small changes in BMI are accompanied by changes in muscle mass – often alongside an increase in fat mass.

The differing nature of BMI in both groups is further illustrated by fat-related correlations. For NW, BMI showed a stronger relationship with FM and FMI than in NWO. This suggests that BMI in the NWO group fails to adequately reflect body fat content. A significant marker of the disproportion between fat and lean components proved to be the FM/FFM ratio, which showed markedly different values between the groups – 0.32 for the NW group compared to 0.49 for the NWO group. This difference confirms that the NWO phenotype is characterized not only by an absolute increase in fat mass but, more importantly, by a disturbed balance between fat and the functional components of the body.

In the NWO group, FM/FFM was strongly positively correlated with indicators of body fat content, particularly FMI and %FM, while at the same time showing pronounced negative associations with indicators of active tissue, such as FFM, SMMI, or TBW/BW. High FM/FFM values in this group thus result from an increase in fat mass combined with a loss of muscle mass, creating a metabolically risky profile that BMI fails to capture. In both groups, a very strong positive relationship was confirmed between fat mass (FM) and the FM/FFM ratio, meaning that as fat mass increases, this ratio rises. In the NW group, this relationship is stronger, possibly because changes in the ratio are mainly due to an increase in fat mass with relatively stable fat-free mass. In the NWO group, the correlation is weaker, since FM/FFM is influenced not only by higher fat mass but also by lower fat-free mass.

This difference indicates that in NWO, the worsening of the ratio is driven by a combination of increased fat load alongside a loss of muscle mass, which represents a less favorable health profile.

This imbalance between muscle and fat mass creates a metabolically risky profile that is not fully apparent when using BMI as a single indicator**.** This imbalance between fat and muscle mass, observed in Slovak women with the NWO phenotype, suggests a metabolically disadvantageous composition that may predispose to higher cardiometabolic risk. Similar patterns have been reported in other populations – young adults from Spain [30], medical professionals in India [32], and Ethiopian adults [29] – indicating that the coexistence of excess fat and reduced muscle mass is a globally observed feature of NWO. According to Mohammadian Khonsari et al. [33], such alterations in body composition are linked to higher mortality and metabolic disturbances, supporting the importance of maintaining adequate muscle mass as a protective factor. In our study, women with a higher proportion of muscle tissue showed a more favorable fat-to-lean ratio, consistent with evidence from U.S. adults [34] and Caucasian subjects studied by Poggiogalle et al. [35], where greater muscle mass was associated with lower cardiometabolic risk. These results reinforce that evaluating both fat and muscle compartments is essential for accurately identifying health risks in normal-weight individuals, as also emphasized by Ashtary Larky et al. [36].

However, it is also necessary to consider the quality of muscle tissue. Trouwborst et al. [37] point out the paradox that, although a higher fat volume may mask muscle loss in older adults, the function of these muscles is often impaired, highlighting the risk of so-called sarcopenic obesity and the importance of assessing the body's functional capacity.

It is also important to emphasize the methodological significance of distinguishing between absolute values (kg) and relative values (%) when comparing them, as each of these parameters reflects a different aspect of body composition. This fact is also noted by Gažarová et al. [38], who state that functional indicators should be assessed in mutually compatible units – such as ratio with ratio and weight with weight. Our findings support this recommendation, as comparisons between variables expressed in different units may produce misleading interpretations. In the NWO group, correlations between percentage-based indicators (%FM vs. %FFM and %SMM) were strongly negative, reflecting their inherent proportional relationship, whereas correlations between %FM and SMM in kilograms were only weakly negative. A similar pattern was observed in the NW group. This demonstrates that percentage indicators can vary independently of their absolute counterparts, which should be taken into account when assessing body composition and functional status. Despite our efforts, our study has some weaknesses. The relatively small sample size, as well as the fact that the participants came from a homogeneous population, limit the possibility of transferring the conclusions to other ethnic groups. The study included only women, which does not provide a complete picture and limits the applicability of the findings to a wider population. The need for studies including the male population is desirable, therefore our further research activities will be focused in this direction. Likewise, the absence of functional indicators such as muscle strength or physical performance, which would complement the interpretation of muscle mass indices.

Among the strengths of the study can be included a detailed analysis of body composition using several composite indices (FMI, FFMI, SMMI, FM/FFM), which provided a comprehensive view of the differences between phenotypic groups. The inclusion of correlation analysis allowed us to reveal the links between absolute and relative indicators, as well as the accurate classification of the phenotype of the participants according to the combination of BMI and body fat percentage.

CONCLUSIONS

Our study confirms that women with similar body mass index values can differ substantially in composite indicators of body composition. By employing the composite indices fat mass index, fat-free mass index, skeletal muscle mass index, and fat mass to fat-free mass ratio, we identified that the normal weight obesity group exhibited higher fat mass index values and a less favorable FM/FFM ratio, accompanied by lower fat-free mass index and skeletal muscle mass index scores – indicating a combination of excessive fat mass and reduced muscle mass. In contrast, the normal weight group showed a higher proportion of muscle mass and more favorable values across all evaluated indices. These findings confirm that nutritional status assessment based solely on body mass index should be complemented with comprehensive body composition measures to enable accurate identification of individuals with the NWO phenotype and to support targeted preventive interventions. In line with current research trends, our work supports the integration of advanced body composition diagnostics alongside traditional BMI classification, providing a more nuanced evaluation that reflects individual characteristics of the assessed population.

Conflict of interest

There were no conflicts of interest.

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