

Phenotypic Variability of Body Composition in Men Adjusted for Body Mass Index and Body Fat Percentage

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Obesity represents major health and social problem, and in clinical practice, its assessment is based primarily on body mass index (BMI). This index is practical and widely used, but it has certain limitations which, especially in men, can lead to incorrect classification. The aim of the study was to evaluate the body composition of a group of 201 men in terms of several anthropometric indices adjusted for body mass index and body fat percentage (PBF), and five phenotypes were defined. BMI was unable to distinguish between phenotypes with different body composition within the same weight category, such as the phenotypes normal weight obesity (NWO) and normal weight without obesity (NWWO). Both groups were defined as normal weight by BMI, but NWO had higher PBF, VFL, and WC compared to NWWO ($P < 0.05$). The phenotypes overweight obesity (OWO) and overweight without obesity (OWWO) were also evaluated similarly. OWO had significantly higher fat mass than OWWO ($P < 0.05$). An interesting contrast was observed between the NWO and OWO phenotypes, as their fat mass indices did not differ significantly. In contrast, significant differences were found in the fat-free mass indices ($P < 0.05$). These findings suggest that based on BMI alone, the NWO phenotype would be considered non-risk without further specification, although its fat mass is comparable to the morbid obesity of the OWO phenotype. Increased fat mass is associated with cardiometabolic risk, which is exacerbated when accompanied by low muscle mass, representing a particularly adverse phenotype with higher morbidity and mortality. Therefore, the assessment of obesity should also be based on body composition indices and not solely on BMI.

Keywords: obesity, body composition, BMI, body fat, visceral fat, anthropometric indices, phenotype

1 Introduction

In the current professional and social context of public health, obesity is one of the most widespread and complex phenomena of civilization, with its prevalence constantly increasing across different populations and age groups (Lim et al., 2019). Overweight and obesity today represent not only a health problem but also a major social challenge. Overweight and obesity significantly increase the likelihood of developing several chronic non-communicable diseases, such as cardiovascular disease, type 2 diabetes, and certain types of cancer. It is also accompanied by increased economic costs and a reduced quality of life for millions of people. Given its multifactorial nature, which is conditioned by changes in the environment, culture, and lifestyle, addressing overweight and obesity requires a comprehensive public

health approach that goes far beyond the boundaries of the healthcare system (Afshin et al., 2017; Bauman, 2022).

However, if we move from the societal level to the individual level, the key question becomes how we measure and define obesity. In practice, this multidimensional disease is reduced to a single indicator – body mass index (BMI). Despite the complexity of this issue, BMI remains the most commonly used tool for assessing overweight and obesity in clinical practice. It is calculated as the ratio of body weight in kilograms to the square of body height in meters ($\text{kg}\cdot\text{m}^{-2}$). The popularity and widespread use of this index is due to its simple methodology and application, which are also its limitations in terms of informative value.

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Although this simple index effectively captures increased body weight, it fundamentally overlooks actual body composition. As a result, it has only limited sensitivity to excess adipose tissue and, at normal threshold values, can only identify a portion of individuals with truly increased body fat content (Frankenfield et al., 2001; Wu et al., 2024).

In the male population, BMI often does not reflect the reality of body composition and classification into individual groups. Individuals with a higher proportion of muscle mass are falsely classified as overweight and/or obese, even though their body fat percentage remains within the recommended range. Conversely, men with a normal BMI may have an excessive proportion of body fat, which remains undiagnosed. These methodological blind spots lead to the overlooking of clinically relevant risk phenotypes that are not detected by routine screening (Jean et al., 2014; Lessons et al., 2021). However, in addition to these cases, combining BMI with body fat percentage (PBF) allows us to define other specific phenotypes: normal weight obesity (NWO), normal weight without obesity (NWWO), overweight obesity (OWO), overweight without obesity (OWWO) and obesity with obesity (OO), that can more accurately capture variability among men and reveal different health risks (Romero-Corral et al., 2009; Kapoor et al., 2020; Khonsari et al., 2022; Angriani et al., 2024).

From a clinical practice perspective, it is therefore essential to distinguish between weight determined by muscle mass and weight caused by excess adipose tissue. In this regard, body composition indices such as skeletal muscle mass (SMM), skeletal muscle mass index (SMMI), fat mass (FM), fat mass index (FMI), fat-free mass (FFM), fat-free mass index (FFMI), FM/FFM ratio, percentage of body fat (PBF), and visceral fat (VFL) have proven to be beneficial. These indices can more effectively distinguish not only who is actually obese, but also how they are obese, whether it is due to excessive accumulation of adipose tissue or increased weight determined primarily by muscle mass (Messina et al., 2020; Holmes and Racette, 2021; Merchant et al., 2021; Gažarová et al., 2022; Gažarová et al., 2023). New data show that higher FMI, PBF, and VFL values are strongly associated with cardiometabolic morbidity and mortality, while higher FFMI and SMMI values have a protective effect, especially in older age (Chang et al., 2022; Liu et al., 2024). More recent evidence also suggests that parameters related to fat-free mass, muscle mass, and visceral fat distribution can more accurately reflect variability in cardiovascular parameters than isolated indicators of body fat accumulation.

This opens up space for our work, which aims to systematically compare male phenotypes defined by

a combination of BMI and PBF across a wide range of different anthropometric indicators.

2 Material and Methods

2.1 Study Design and Characteristics of Participants

A total of 201 male Caucasian volunteers aged 20–65 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) and the volunteer's consent to inclusion in the study. 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.

2.2 Body Size and Composition Measurement

Body composition was analysed 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 (BH) was measured using professional electronical scales Tanita WB-300 in a standing position, while shoulders were in normal alignment and the head was in the horizontal Frankfurt plane. The participant stood upright on a horizontal surface, barefoot, with palms turned inwards and fingers pointing downwards. The height was measured from the sole of the feet to the top of the head. Body weight (BW) was measured in light clothing using an electronic scale with an accuracy of 0.1 kg. Waist circumference at the umbilical level (WC) and hip circumference at the maximum level were determined using a measuring device with a stretched tape with an accuracy of 0.1 cm without any pressure on the body surface (Clinical Practice Guidelines).

According to BMI, obesity was defined as $\text{BMI} \geq 30 \text{ kg}\cdot\text{m}^{-2}$, underweight as $\text{BMI} < 18.5 \text{ kg}\cdot\text{m}^{-2}$, normal weight in the value range of 18.5 and $25 \text{ kg}\cdot\text{m}^{-2}$ and overweight in the range of 25 and $30 \text{ kg}\cdot\text{m}^{-2}$ (Clinical Practice Guidelines; WHO, 2026). For the purposes of further analysis,

we divided the sample into three BMI categories. Body fat percentage was determined to be less than 20%. Based on BMI and PBF values, the following phenotypes were determined: normal weight obesity (NWO; BMI 18.5–24.99 kg·m⁻² and PBF ≥ 20%), normal weight without obesity (NWWO; BMI 18.5–24.99 kg·m⁻² and PBF < 20%), overweight obesity (OWO; BMI 25–29.99 kg·m⁻² and PBF ≥ 20%), overweight without obesity (OWWO; BMI 25–29.99 kg·m⁻² and PBF < 20%) and obesity with obesity (OO; BMI ≥ 30 kg·m⁻² and PBF ≥ 20%).

2.3 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). 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. The level of statistical significance was set as *P* < 0.05.

3 Results and Discussion

A total of 201 men aged 20–65 years, with an average age of 40.04 ± 10.76 years, were included in the study. The mean height value was 1.81 ± 0.07 m and weight 88.20 ± 12.7 kg. Based on these values, the mean BMI value was calculated at 27.0 ± 3.72 kg·m⁻², which classifies the group as a whole as overweight, with individuals ranging from normal weight to class II obesity. The mean waist circumference was 80.82 ± 6.61 cm, and the waist-to-hip ratio was 0.90 ± 0.07, indicating the presence of central adiposity. The mean visceral fat level (VFL) reached 7.64 ± 3.91, with values ranging widely from low to clinically significantly elevated, reflecting high interindividual variability.

The mean fat mass in the group was 18.82 ± 8.39 kg, which represented 20.81 ± 7.01% of their body weight. This value is on the borderline between the physiological range and obesity, which allows the study group to be characterized as a group with a slight excess of body fat. However, it should be emphasized that total body weight is not determined solely by the amount of adipose tissue. Muscle mass, which is traditionally very high in the male population, also plays a significant and undeniable role.

Table 1 Descriptive characteristics of the group in terms of anthropometric parameters (*n* = 201)

Parameters	Mean	SD	Min	Max
Age (years)	40.04	10.76	20.00	65.00
BW (kg)	88.20	12.72	57.90	152.40
BMI (kg·m ⁻²)	27.00	3.72	19.30	47.00
Height (m)	1.81	0.07	1.62	1.94
WC (cm)	80.82	6.61	66.60	103.50
WHR	0.90	0.07	0.74	1.15
FFM (kg)	69.39	8.34	45.40	93.20
FFMI (kg·m ⁻²)	21.18	1.81	16.14	26.47
SMM (kg)	39.58	5.01	25.10	53.70
SMMI (kg·m ⁻²)	12.08	1.11	8.89	15.50
BFM (kg)	18.82	8.39	4.00	68.40
PBF (%)	20.81	7.01	5.30	44.90
FMI (kg·m ⁻²)	5.82	2.72	1.09	21.11
FM/FFM	0.27	0.12	0.06	0.81
VFL	7.64	3.91	1.00	27.00
TBW (L)	50.92	6.08	33.50	68.30
TBW/BW (%)	58.12	5.17	40.49	69.84
BMR (kcal)	1869	180	1352	2383

BW – Body Weight; BMI – Body Mass Index; WC – Waist Circumference; WHR – Waist-to-Hip Ratio; FFM – Fat-Free Mass; FFMI – Fat-Free Mass Index; SMM – Skeletal Muscle Mass; SMMI – Skeletal Muscle Mass Index; BFM – Body Fat Mass; PBF – Percentage of Body Fat; FMI – Fat Mass Index; VFL – Visceral Fat Level; TBW – Total Body Water; BMR – Basal Metabolic Rate

This phenomenon is the result of biological and hormonal factors, as higher testosterone levels and evolutionary predispositions promote the building and maintenance of greater muscle tissue volume (Handelsman et al., 2018). In our sample, the mean fat-free mass was 69.39 ± 8.34 kg, with skeletal muscle accounting for approximately 39.58 ± 5.01 kg.

These parameters indicate considerable variability in body composition and fat tissue distribution among individuals, which provides a solid basis for subsequent phenotypic classification and comparison of anthropometric indices. The complete results of the basic descriptive analysis are shown in Table 1.

The average BMI value was 23.11 ± 1.41 kg·m⁻² in the normal weight group, 27.14 ± 1.38 kg·m⁻² in the overweight group, and 32.67 ± 3.35 kg·m⁻² in the obese group. The increase in BMI in our group was not exclusively related to an increase in the amount of adipose tissue and its percentage, but was also accompanied by a simultaneous increase in muscle mass. In the normal weight group, FM reached 11.48 kg (PBF 15.12%) and SMM 36.90 kg; in the overweight group, FM reached 18.84 kg (PBF 21.21%) and SMM 39.94 kg; and in the obese group, FM reached 30.25 kg (PBF 28.58%) and SMM 42.94 kg. The overall trend therefore shows

that with the transition from normal weight through overweight to obesity, there is a gradual increase in both components of body composition. However, in the overweight range, the difference between the increase in muscle mass and fat (in kg) compared to normal weight was relatively moderate, while in obesity, the increase in fat mass significantly outweighed the increase in muscle tissue. Detailed anthropometric characteristics of each category are shown in Table 2.

We identified the following phenotypes in the studied group of men: NWWO phenotype (normal weight according to BMI at physiological PBF), NWO (normal weight according to BMI with increased PBF), OWWO (overweight according to BMI at physiological PBF), OWO (overweight according to BMI with increased PBF), and OO (obesity according to BMI with increased PBF). A detailed overview of these five phenotypes, together with the values of the relevant anthropometric indices for each subgroup, is provided in Supplementary Table 1.

Sorting by BMI in conjunction with PBF revealed unexpected compositional diversity where BMI alone would suggest homogeneity. Phenotypes with similar weight classification differ markedly in our sample in terms of adipose and muscle composition. This

Table 2 Comparison of anthropometric parameters between groups adjusted for body mass index

Parameters	Normal weight				Overweight				Obesity			
	mean	SD	min	max	mean	SD	min	max	mean	SD	min	max
Age (years)	36.67 ^a	9.39	22.00	62.00	40.59 ^b	10.29	20.00	65.00	43.70 ^b	12.71	23.00	65.00
BW (kg)	76.17 ^a	7.00	57.90	89.40	88.86 ^b	7.51	73.50	109.90	105.17 ^c	11.24	93.20	152.40
BMI (kg·m ⁻²)	23.11 ^a	1.41	19.30	24.90	27.14 ^b	1.38	25.00	29.90	32.67 ^c	3.25	30.00	47.00
Height (m)	1.82	0.06	1.62	1.93	1.81	0.07	1.63	1.94	1.79	0.06	1.69	1.94
WC (cm)	75.68 ^a	4.80	66.60	86.40	80.89 ^b	4.94	69.30	94.50	88.69 ^c	5.38	79.20	103.50
WHR	0.84 ^a	0.05	0.74	0.96	0.90 ^b	0.05	0.77	1.05	0.99 ^c	0.06	0.88	1.15
FFM (kg)	64.69 ^a	7.64	45.40	81.70	70.02 ^b	7.28	53.30	86.10	74.92 ^c	8.41	61.00	93.20
FFMI (kg·m ⁻²)	19.58 ^a	1.39	16.14	22.57	21.35 ^b	1.18	18.23	25.23	23.21 ^c	1.60	19.73	26.47
SMM (kg)	36.78 ^a	4.65	25.10	47.10	39.94 ^b	4.34	29.50	49.40	42.94 ^c	5.07	34.70	53.70
SMMI (kg·m ⁻²)	11.13 ^a	0.89	8.89	12.94	12.18 ^b	0.74	10.23	14.56	13.30 ^c	1.01	11.14	15.50
BFM (kg)	11.48 ^a	4.31	4.00	21.70	18.84 ^b	4.56	9.40	31.60	30.25 ^c	8.93	21.40	68.40
PBF (%)	15.12 ^a	5.69	5.30	28.60	21.21 ^b	4.89	10.80	36.80	28.58 ^c	6.09	19.20	44.90
FMI (kg·m ⁻²)	3.53 ^a	1.44	1.09	7.09	5.79 ^b	1.52	2.75	10.93	9.47 ^c	2.96	5.96	21.11
FM/FFM	0.18 ^a	0.08	0.06	0.40	0.27 ^b	0.08	0.12	0.58	0.41 ^c	0.13	0.24	0.81
VFL	4.16 ^a	2.13	1.00	9.00	7.71 ^b	2.19	3.00	14.00	12.89 ^c	3.97	9.00	27.00
TBW (L)	47.52 ^a	5.59	33.50	60.00	51.38 ^b	5.31	39.20	63.00	54.95 ^c	6.15	44.80	68.30
TBW/BW (%)	62.35 ^a	4.20	52.43	69.84	57.81 ^b	3.58	46.50	65.55	52.38 ^c	4.45	40.49	59.19
BMR (kcal)	1767 ^a	165	1,352	2,134	1,882 ^b	157	1,521	2,230	1,988 ^c	182	1,688	2,383

BW – Body Weight; BMI – Body Mass Index; WC – Waist Circumference; WHR – Waist-to-Hip Ratio; FFM – Fat-Free Mass; FFMI – Fat-Free Mass Index; SMM – Skeletal Muscle Mass; SMMI – Skeletal Muscle Mass Index; BFM – Body Fat Mass; PBF – Percentage of Body Fat; FMI – Fat Mass Index; VFL – Visceral Fat Level; TBW – Total Body Water; BMR – Basal Metabolic Rate

heterogeneity is clearly demonstrated by a comparison of the NWO and NWWO phenotypes, where, in terms of adipose mass, NWO has significantly higher average values across FM indices, reaching 19.23 kg compared to 10.24 kg for the NWWO phenotype, PBF was 25.89% vs. 13.40%, FMI 6.30 kg·m⁻² vs. 3.08 kg·m⁻², and the FM/FFM ratio was 0.35 vs. 0.16. The difference is also reflected in abdominal obesity indices, where WC in the NWO phenotype was 84.15 cm vs. 74.32 cm in the NWWO phenotype, and VFL was 8.00 vs. 3.54, indicating a higher accumulation of fat (including visceral fat) in the NWO group. Conversely, fat-free and muscle mass dominate in the NWWO phenotype, where FFM reached an average value of 66.19 kg vs. 55.31 kg in NWO, FFMI 19.83 kg·m⁻² vs. 18.02 kg·m⁻², SMM 37.71 kg vs. 31.00 kg, and SMMI 11.29 kg·m⁻² vs. 10.09 kg·m⁻². The differences between the NWO and NWWO phenotypes were statistically significant across all of the above indices ($P < 0.05$).

These differences with virtually the same BMI clearly show that weight indices alone do not capture actual body composition and can lead to false classification in the “healthy” range. At the same time, a growing number of studies point to this limited ability of BMI to capture high body fat percentage. Lin et al. (2021) pointed out that BMI cannot accurately predict body fat percentage and tends to underestimate obesity in individuals with low muscle mass, a finding that is consistent with our results. Romero-Corral et al. (2010) followed up on this issue, emphasizing that BMI is unsuitable as a sole criterion for detecting hidden obesity. Okorodudu et al. (2010) also showed that BMI is characterized by low sensitivity and a high proportion of false negative results in the diagnosis of overweight and obesity, thereby systematically overlooking individuals with a high percentage of body fat but normal weight.

Individuals with NWO tend to have a higher fat mass index (FMI) compared to individuals of normal weight (NW), indicating an excess of adipose tissue that is not captured by BMI. The fat-free mass index (FFMI) is usually lower or similar in NWO, indicating an absence of increased muscle mass. The FM/FFM ratio is higher in NWO, reflecting a higher proportion of fat to muscle mass and is associated with increased metabolic risk. Similarly, the skeletal muscle mass index (SMMI) tends to be lower, indicating reduced muscle mass. These indices (FMI, FFMI, FM/FFM, SMMI) thus allow for a more accurate distinction between NW and NWO than BMI alone (Jensen et al., 2019; Merchant et al., 2021; Zhang et al., 2021; Messner et al., 2024). The same trends were observed in our results in a sample of Slovak men. In addition, it is necessary to take into account the growing evidence of higher health risks associated with the NWO phenotype, which indicates that excessive adiposity with a normal

BMI represents a hidden but clinically significant form of obesity. Romero-Corral et al. (2009) demonstrated in the US population that individuals with NWO had a higher prevalence of metabolic syndrome and elevated blood pressure, triglyceride, and CRP levels, confirming their metabolically risky profile. Similarly, Correa-Rodríguez et al. (2020) described an unfavorable combination of higher visceral fat, insulin resistance, and dyslipidemia in young adult men and women aged 18–30 years in Colombia with NWO. In the Chinese population, Xu et al. (2021) demonstrated that the NWO phenotype is associated with an increased risk of developing type 2 diabetes, up to twice as high. Together, these findings show that within the same weight category, the NWO phenotype has a clearly worse metabolic and cardiovascular profile than NWWO.

Following the comparison of phenotypes with normal BMI (NWO vs. NWWO), we used an analogous procedure to examine the overweight range (BMI 25.0–29.9 kg·m⁻²), where the combination of BMI and PBF defined the OWO and OWWO phenotypes. In this category, it was confirmed that uniform weight classification alone does not guarantee a homogeneous body composition: phenotypes differ in the distribution of adipose and fat-free components. The average BMI was higher for OWO (27.63 vs. 26.46 kg·m⁻²). In terms of adipose component, OWO has systematically higher values of FM 21.79 kg vs. 14.68 kg compared to OWWO, PBF 24.50% vs. 16.57%, FMI 6.79 kg·m⁻² vs. 4.39 kg·m⁻², and FM/FFM ratio 0.33 vs. 0.20. The difference is also evident in the indices of abdominal obesity, where the WC value was 83.61 cm vs. 77.05 cm and VFL 9.10 vs. 5.75, all values were higher for the OWO phenotype. Conversely, fat-free and muscle mass dominate in OWWO, where FFM reached an average value of 73.79 kg vs. 67.35 kg in OWO, FFMI 22.07 kg·m⁻² vs. 20.84 kg·m⁻², SMM 42.26 kg vs. 38.30 kg, and SMMI 12.64 kg·m⁻² vs. 11.85 kg·m⁻². All of the above differences between OWO and OWWO were statistically significant ($P < 0.05$).

For the OO phenotype, we recorded the highest BMI of 32.72 kg·m⁻² across all phenotypes. In terms of fat component indicators, OO achieved the highest or one of the highest values across phenotypes: FM 30.47 kg, FMI 9.57 kg·m⁻², FM/FFM 0.42, WC 88.95 cm, and VFL 13.00, and all of these parameters were statistically significant compared to the NWO, NWWO, OWO, and OWWO phenotypes. It is important to emphasize the proportion of fat in the total body weight of individuals with the OO phenotype, where PBF with a value of 28.84% was significantly higher than in NWWO (13.40%; $P < 0.05$), OWWO (16.57%; $P < 0.05$), and OWO (24.50%; $P < 0.05$), but did not differ statistically from NWO (25.89%; $P > 0.05$).

Although it is widely known that individuals with a BMI in the overweight range (25.0–29.9 kg·m⁻²) have an increased risk of developing chronic diseases such as type 2 diabetes, hypertension, ischemic heart disease, dyslipidemia, and gallstones (Field et al., 2001), and that these risks persist in older adults, where they are associated with increased morbidity and mortality (Janssen, 2007). Our results in the Slovak male population also point to the need for critical interpretation of BMI, especially when assessing body composition. Unlike phenotypes with normal BMI, where we observe so-called false negatives (failure to detect hidden fat), OWO and OWWO phenotypes are false positives, a situation where BMI classifies an individual as overweight despite a low percentage of body fat. This phenomenon is typical for people with a higher proportion of muscle mass, such as athletes or physically fit men.

This trend is also confirmed by observations from other populations, where BMI similarly overestimated the prevalence of overweight in groups with higher muscle mass, for example, British firefighters and Chinese soldiers (Poston et al., 2011; Lessons et al., 2021). A similar discrepancy between BMI and actual fat profile was also observed in university athletes who, despite having a BMI ≥ 25 kg·m⁻², did not show elevated PBF values (Etchison et al., 2011). Our data on Slovak men show a similar pattern, where the OWWO phenotype represented a group with a higher BMI but a more favorable body composition (lower PBF, higher FFM) than the OWO phenotype. This limited informative value of BMI is also reflected in the growing emphasis on more complex anthropometric indices that integrate multiple body dimensions and fat distribution and show greater accuracy in identifying obesity risk phenotypes. Compared to these, BMI is a simple and practical indice, but often insufficient in clinical practice, especially when the goal is to accurately identify individuals with increased metabolic risk or specific forms of obesity (Sommer et al., 2020; Kuang et al., 2022; Salmón-Gómez et al., 2023; Chen et al., 2024; Salihefendic et al., 2025). Indices such as FMI, FFMI, SMMI, and FM/FFM ratio provide a more comprehensive view of body composition and allow us to distinguish between risky “fat” forms of overweight and “muscle” forms, which has also been confirmed in our data on Slovak men (Gažarová et al., 2022; Górnicka et al., 2022; Merchant et al., 2021).

4 Conclusions

The results obtained suggest that although BMI remains a commonly used index of nutritional status, its ability to accurately reflect the actual body composition of men is limited. Analysis of individual phenotypes revealed significant intra-group variability, which was particularly

evident in the different proportions of fat and muscle mass at the same weight values. The NWO phenotype, representing individuals with normal BMI but increased body and visceral fat percentage, points to the existence of hidden forms of obesity with a potentially unfavourable metabolic profile. In contrast, the OWWO phenotype was characterized by a more favourable composition, a higher proportion of muscle mass, and a lower percentage of fat despite being classified as overweight, highlighting the possibility of false positive assessments based on BMI. These observations underscore the importance of a more comprehensive approach to assessing body composition, which should go beyond traditional weight indices. The combination of anthropometric indices provides a more refined and accurate picture of the ratio between fat and fat-free mass and allows differentiation between metabolically risky and more favourable phenotypes even within the same BMI categories. For these reasons, multidimensional assessment of body composition can be considered a more promising tool in the diagnosis and prevention of obesity in the male population.

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Conflict of interest

The authors declare no conflict of interest.

Authors' contributions

Hačková – conceptualization, methodology, data curation, writing-original draft; Gažarová: conceptualization, data curation, formal analysis, funding acquisition, methodology, software, validation, writing-review and editing, visualization, project administration, investigation, supervision; Lenártová – methodology, data curation, validation, visualization. All authors have read and agreed to the published version of the manuscript.

AI and AI-Assisted Technologies use Declaration

No generative AI tools/AI-assisted technologies were used during the preparation of the manuscript.

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