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Article

Body Composition Phenotypes and Functional Limitations in Older Adults: The Impact of Sarcopenia, Obesity, and Sarcopenic Obesity

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Abstract

Background/Objectives: Sarcopenia, obesity, and sarcopenic obesity (SO) are common in older adults and may be associated with functional limitations in basic (ADL) and instrumental (IADL) activities of daily living. This study aimed to evaluate the association between body composition phenotypes and ADL/IADL limitations among older adults. **Methods:** A cross-sectional study included 440 community-dwelling adults aged ≥ 60 years (281 women, 159 men; mean age 74.7 ± 7.8 years). Sarcopenia was diagnosed according to EWGSOP2 criteria, obesity was defined as percent body fat $>42\%$ in women and $>30\%$ in men, and SO was classified based on the ESPEN/EASO recommendations. Participants without obesity or sarcopenia were categorized as 'normal' phenotype. Functional status was evaluated using the Katz and Lawton scales, with limitations defined as ADL ≤ 5 and IADL ≤ 26 points, respectively. Multivariate logistic regression analysis was performed to determine factors associated with ADL and IADL limitations. **Results:** Over half of the participants (57.1%) had abnormal body composition: 31.6% obesity, 11.4% sarcopenia, and 13.2% SO. SO was associated with a nearly threefold higher risk of ADL limitations (OR = 2.86; $p = 0.003$) and a 3.7-fold higher risk of IADL limitations (OR = 3.68; $p < 0.001$) compared to the normal phenotype. Sarcopenia was associated with IADL limitations in the unadjusted model (OR = 2.44; $p = 0.010$). Independent predictors of ADL and IADL limitations included reduced muscle strength, a higher number of chronic diseases, and a worse nutritional status. **Conclusions** SO was linked to higher risk of both ADL and IADL limitations, while sarcopenia was associated only with IADL deficits. Obesity severity may be relevant, but its impact on daily functioning in older adults requires further study.

Keywords: sarcopenia; obesity; sarcopenic obesity; older adults; ADL; IADL; functional limitations

1. Introduction

Aging is probably one of the most important demographic challenges in Europe. In 2024, one out of five citizens (21.6%) of the European Union (EU) was at least 65 years old. It is estimated that this percentage would increase to 32.5% by the year 2100 [1]. This tendency is observed all across Europe, but its rate is highest in Poland [1]. Aging of the population is associated with increased prevalence of functional limitations and disability, defined as the loss of independence in everyday functioning due to physical, cognitive, or sensory impairments [2]. The ability to perform activities of daily living is a key component of successful aging [3,4]. Basic Activities of Daily Living (ADL) refer to elementary aspects of self-care, such as taking meals, dressing, and toileting. In contrast, Instrumental Activities of Daily Living (IADL) refers to more complex activities necessary for functioning in the environment, such as shopping, preparing meals, and housekeeping [2,3,5]. In 2019, nearly half (49.7%) of EU residents aged 65 or older reported moderate to severe problems with

activities of daily living [6,7]. The most recent data from 2025 indicate that almost one-third (32.4%) of individuals aged 60 years or older have problems with performing basic activities, and as many as 56.9% have problems with instrumental activities of daily living [2]. Usually, deficits in IADL appear before problems with ADL, and may be an early sign of impairment in functional limitations [8,9]. Loss of independence not only decreases quality of life but also increases the risk of institutionalization, hospitalization, and premature death [2,8,10].

Changes in body composition may contribute to functional dependency in older adults [11–13]. Both sarcopenia and obesity, first defined as an age-related, progressive loss of muscle mass and strength, and second, as an excessive accumulation of fat tissue, independently increase the risk of mobility limitation, falls, and functional impairments in ADL and IADL [14–17]. A decrease in muscle function is an independent predictor of loss of independence, being a stronger predictive factor than muscle mass itself [11]. Sarcopenic obesity (SO), referring to sarcopenia concomitant with obesity, is an exceptionally unfavourable phenotype. It is associated with cumulative impairment in musculoskeletal function, leading to loss of functional limitations and dependency [18,19]. Pathophysiology of SO is multifactorial, including hormonal dysregulation, chronic low-grade inflammation (inflammaging), structural and metabolic changes in muscle and fat tissue [20–22]. There is some evidence to indicate that SO is a stronger determinant of functional capacity than sarcopenia or obesity alone [23]. However, the quantitative assessment of this relation and the comparison between results of various studies are questionable due to methodological discrepancies and a lack of clear diagnostic criteria for SO [24]. To address these issues, the European Society for Clinical Nutrition and Metabolism (ESPEN) and the European Association for the Study of Obesity (EASO) proposed a unified definition of SO. They issued diagnostic recommendations for clinical practice in 2022 [18]. Consequently, the results from different studies on SO are comparable, and the assessment of the clinical consequences of this phenotype, including its influence on functional impairments in ADL and IADL, is feasible.

Despite increasing interest in changes in body composition in older adults, a comprehensive analysis of the influence of the three phenotypes: sarcopenia, obesity, and SO on functional limitations in ADL and IADL in elderly persons is still lacking. The quality of previous investigations on this topic, particularly those concerning SO, is limited due to methodological drawbacks. As most studies included institutionalized individuals, their results are hardly applicable to community-dwelling older persons, who are the most rapidly growing portion of the elderly population. A unified definition of SO, elaborated by ESPEN/EASO, offers new research options, enabling the assessment of SO prevalence and its clinical consequences. Knowledge about the influence of various body composition phenotypes on functional impairments in ADL and IADL and independence may aid in the early identification of individuals at risk of losing functional capacity. Moreover, it may contribute to the development of effective preventive strategies and rehabilitation in aging populations. The present study aimed to analyze the relationship between body composition phenotypes and ability to perform ADL and IADL, in the community-dwelling Polish elderly population. To the best of our knowledge, this is one of the first studies conducted in Central-Eastern Europe that comprehensively assesses the relationship between the three body composition phenotypes and the everyday functioning of elderly persons living in the community.

2. Materials and Methods

2.1. Study Sample

This cross-sectional study included 440 individuals aged 60 years or older, living independently in the community in Poland. Participants were recruited from senior community centers, local Universities of the Third Age, and primary care clinics. Exclusion criteria included cognitive impairment, contraindications to body composition analysis using the bioimpedance method (BIA), such as implantable devices (e.g., cardiac pacemakers, cardioverter-defibrillators), metal implants,

significant edema, or inability to maintain a standing position required for anthropometric measurements and body composition analysis.

Cognitive function was assessed with a 10-item Abbreviated Mental Test Score (AMTS). A score of ≥ 7 indicated uncompromised cognitive function, required for study enrollment [25]. All participants gave informed consent to the study. The Bioethics Committee of the Poznan University of Medical Sciences accepted the study protocol (number of approval: 459/24).

2.2. Assessment of Body Composition Phenotypes

Body Composition Analysis

Body composition was analyzed using a BIA method and an InBody 120 analyzer (Biospace, Seoul, South Korea). The BIA method is based on measurements of tissue resistance and reactance in response to a low-intensity electric current. It enables fast and non-invasive assessment of body composition parameters, such as body weight (W), body mass index (BMI), skeletal muscle mass (SMM), percent body fat (PBF), fat mass (FM), segmental lean body mass of trunk and limbs [26].

Sarcopenia phenotype. Sarcopenia phenotype. Sarcopenia was diagnosed based on criteria suggested in 2018 by the European Working Group on Sarcopenia in Older People 2 (EWGSOP2) [14]. As we performed a complete diagnostic of body composition, including both muscle mass and muscle strength, in all participants, the screening stage with the Strength, Assistance with walking, Rising from a chair, Climbing stairs, and Falls (SARC-F) questionnaire was omitted. According to the EWGSOP2 algorithm, sarcopenia was considered probable in cases of decreased muscle strength in the upper and/or lower limbs. Sarcopenia was confirmed by concomitant low muscle mass, assessed with BIA parameters [14].

- Upper limb muscle strength was assessed with a Hand Grip Strength test (HGS), using a hand dynamometer (Saehan, Changwon, Korea). The measurements were performed in a sitting position, with shoulders adducted and elbows flexed at 90° , twice for each hand. The best result out of four taken was compared with diagnostic thresholds. Cut-off point for low muscle strength was <16 kg in women and <27 kg in men [14],
- Lower limb muscle strength was assessed with a Five-Repetition Sit-to-Stand test (5STS). Participants were seated in a chair without armrests, with their arms crossed at their chest. They were instructed to stand up and sit down five times at the given sign as quickly as possible, without using their hands. Test times longer than 15 seconds indicated reduced lower limb muscle strength [14],
- Muscle mass was assessed based on Appendicular Lean Mass Index (ALM Index), defined as the sum of lean mass of lower and upper limbs divided by squared height (kg/m^2) [13]. Low muscle mass was defined using cut-off points specific to the Polish population: < 5.6 kg/m^2 for women and < 7.4 kg/m^2 for men [27].

Obesity phenotype. Obesity phenotype was diagnosed with PBF parameter and the following cut-off points: $> 42\%$ for women, $> 30\%$ for men [28]. This approach ensured methodological consistency with the ESPEN/EASO recommendations using PBF thresholds as diagnostic criteria for SO, allowing for a direct comparison between phenotypes (obesity and SO) [18].

Sarcopenic obesity phenotype. SO phenotype was defined by the ESPEN/EASO diagnostic algorithm, omitting the screening phase [18]. Participants were classified as SO phenotype if they had concomitant:

- Low muscle strength defined as HGS <16 kg in women and <27 kg in men and/or 5STS >15 seconds [18,29],
- Low muscle mass assessed based on percentage of skeletal muscle mass in total body mass (SMM/W). Cut-off points were $<27.6\%$ in women and $<37.0\%$ in men [18,30],
- Excessive percentage of fat tissue, defined as PBF $>42\%$ in women and $>30\%$ in men [18,28].

All participants were classified into one of four phenotype groups based on the above criteria: sarcopenia without obesity, obesity without sarcopenia, sarcopenic obesity, or normal phenotype (without sarcopenia and obesity).

2.3. Functional Capacity

Basic Activities of Daily Living (ADL). Basic activities of daily living were assessed using the Katz scale, which includes six areas: bathing, dressing, toileting, transferring (in and out of bed or chair), continence, and taking meals [31]. Each area was scored as follows: 1 - fully independent, 0.5 - requires some help, 0 - entirely dependent. Maximum score - 6 points - indicated complete functional independence. In accordance with previous studies, ADL scores were classified as either no limitation or at least one limitation. A score of ≤ 5 points indicated limited independence in ADL [32–37]. This approach allowed exclusion of participants whose only deficit was urinary incontinence, as this condition alone was not considered indicative of functional limitation.

Instrumental Activities of Daily Living (IADL). Ability to perform IADL was assessed with the Lawton scale, comprising nine items: using a telephone, shopping, food preparation, housekeeping, home repairs, laundry, mode of transportation, responsibility for taking medications, and ability to handle finances [38]. Each item was scored 1-3 (3 - fully independent, 2 - partially dependent, 1 - dependent). The maximum score was 27. In accordance with previous studies, IADL scores were classified as either no limitation or at least one limitation. A score of ≤ 26 points indicated limited independence in IADL [32–37].

2.4. Nutritional Status

Nutritional status was assessed using the Mini Nutritional Assessment (MNA) questionnaire. In this study, all participants completed the full version of the MNA (MNA-full), regardless of their MNA-Short Form (MNA-SF) score during the screening phase. The MNA-full questionnaire consists of items, concerning anthropometric variables, qualitative and quantitative assessment of the diet, mode of feeding and living, and self-assessment of nutritional status and health condition. The total score was classified as follows: ≥ 24 - normal nutritional status, 17-23.5 - at risk of malnutrition, < 17 - malnutrition [29]. We pooled all participants with fewer than 24 points in one category - poor nutritional status (PNS).

2.5. Concomitant Variables

The health condition was characterized by the number of chronic diseases (based on medical history and documentation) and the number of prescription drugs taken regularly.

2.6. Statistical Analysis

Statistical analyses were performed with STATISTICA 10 PL (Statsoft, Poland) and PQStat Software. Categorical variables were presented as numbers (n) and percentages (%), while quantitative variables were presented as mean $\pm$ standard deviation (SD). Between-group comparisons were performed using the Student t-test or the Cochrane-Cox test, depending on the homogeneity of variance. Comparisons between three or more groups (sarcopenia, obesity, SO, and normal phenotype) were performed with analysis of variance ANOVA or Welch F test, depending on the homogeneity of variance, and Bonferroni test as a post-hoc procedure. Homogeneity of variance was assessed with the Levene test. Correlations between quantitative variables were assessed with the Spearman correlation coefficient. Univariate and multivariate logistic regression models were used to verify the association between factors and the risk of functional dependency in ADL (Katz score < 6) and IADL (Lawton score ≤ 26). Qualitative variables were assessed with Pearson's chi-square test or likelihood-ratio chi-square in case of low expected frequencies in the contingency table's cells. P value < 0.05 was considered significant.

3. Results

3.1. General Characteristics of the Study Sample

Data on 440 persons aged 60 years and older (mean age 74.7 ± 7.8 , 63.9% of women). One out of four participants had low muscle mass by the ALM index. The prevalence of low muscle mass was twofold higher in men as compared to women (34.6% vs. 19.6%; $p < 0.001$). Half of the study sample (50.0%) fulfilled the EWGSOP2 criteria for probable sarcopenia based on low muscle strength parameters. Reduced lower limb muscle strength was more common than the upper limb strength (38.2% vs. 27.5%, respectively). Poor nutritional status was found in 36.8% participants, including 3.2% malnourished persons and 33.6% at risk of malnutrition. Persons included in the study had four chronic diseases on average (4.3 ± 2.5) and were taking more than six medications daily (6.4 ± 3.9). Despite relatively high mean scores for functional capacity (ADL 5.5 ± 0.7 ; IADL 23.9 ± 4.4), more than half of the study participants (55.9%) declared problems with performing at least one instrumental activity of daily living, and one out of five persons (20.9%) had problems with ADL. These results did not differ between sexes. Detailed data (by sex) are shown in Table 1.

Table 1. Characteristics of study sample by sex.

Variable	Women n= 281	Men n= 159	P value
	Mean $\pm$ SD	Mean $\pm$ SD	
Age [years]	74.84 $\pm$ 7.66	74.49 $\pm$ 8.14	0.658
Body weight [kg]	70.40 $\pm$ 15.38	79.65 $\pm$ 14.87	<0.001
BMI [kg/m ²]	28.81 $\pm$ 6.20	27.44 $\pm$ 4.47	0.008
PBF [%]	38.92 $\pm$ 8.92	29.60 $\pm$ 7.64	<0.001
SMM [kg]	22.46 $\pm$ 3.34	30.67 $\pm$ 4.71	<0.001
FFM [kg]	41.78 $\pm$ 5.79	55.35 $\pm$ 7.64	<0.001
ALM index [kg/m ²]	6.55 $\pm$ 1.03	7.85 $\pm$ 0.96	<0.001
SMM/W [%]	0.33 $\pm$ 0.05	0.39 $\pm$ 0.05	<0.001
HGS [kg]	20.39 $\pm$ 5.43	32.77 $\pm$ 9.47	<0.001
5STS [s]	14.22 $\pm$ 6.95	14.30 $\pm$ 7.90	0.915
MNA score	24.39 $\pm$ 3.58	24.57 $\pm$ 3.36	0.598
Number of chronic diseases	4.49 $\pm$ 2.54	3.91 $\pm$ 2.24	0.013
Number of medications	6.18 $\pm$ 3.96	6.77 $\pm$ 3.75	0.121
ADL score	5.50 $\pm$ 0.67	5.59 $\pm$ 0.73	0.202
IADL score	24.12 $\pm$ 4.11	24.60 $\pm$ 3.35	0.185
	n (%)	n (%)	
Low muscle mass (ALM Index)	55 (19.6)	55 (34.6)	<0.001
Low muscle mass (SMM/W)	40 (14.2)	55 (34.6)	<0.001
Reduced upper limb muscle strength	73 (26.0)	47 (29.6)	0.485
Reduced lower limb muscle strength	113 (40.2)	55 (34.6)	0.287
Probable sarcopenia	145 (51.6)	75 (47.2)	0.427
Limitations in ADL $\leq$ 5	61 (21.7)	31 (19.5)	0.584
Limitations in IADL $\leq$ 26	156 (55.5)	89 (56.0)	0.926
Poor nutritional status	102 (36.3)	60 (37.8)	0.844
MNA			
Malnutrition	10 (3.6)	4 (2.5)	0.752
At risk of malnutrition	92 (32.7)	56 (35.2)	0.672
Normal nutritional status	179 (63.7)	99 (62.3)	0.844

Notes: Quantitative variables shown as mean $\pm$ standard deviation (SD), categorical variables as number (n) and percentage (%). **Abbreviations:** BMI, Body Mass Index; PBF, Percent Body Fat; SMM, Skeletal Muscle Mass; FFM, Fat-Free Mass; ALM Index, Appendicular Lean Mass Index; SMM/W, Skeletal Muscle Mass to Weight Ratio; HGS, Hand Grip Strength; 5STS, Five Times Sit-to-Stand Test;

MNA, Mini Nutritional Assessment - Long Form; ADL, Basic Activities of Daily Living; IADL, Instrumental Activities of Daily Living.

3.2. Prevalence of Body Composition Phenotypes

More than half of the study sample (57.1%) had abnormal body composition: 31.6% participants were obese, 11.4% had sarcopenia, and 13.2% had sarcopenic obesity. The prevalence of abnormal body composition was higher in men than in women (62.9% vs. 52.3%, respectively; $p=0.017$). The difference was particularly evident for sarcopenic obesity (19.5% in men vs. 9.6% in women; $p=0.003$). Detailed data (by sex) are shown in Table 2.

Table 2. Body composition phenotypes by sex.

Variable	Women n= 281	Men n= 159	P value
	n (%)	n (%)	
Body composition phenotypes			0.017
Sarcopenia	32 (11.4)	18 (11.3)	0.983
Obesity	88 (31.3)	51 (31.1)	0.869
Sarcopenic obesity	27 (9.6)	31 (19.5)	0.003
Normal phenotype	134 (47.7)	59 (37.1)	0.032

Notes: Categorical variables as number (n) and percentage (%).

3.3. Body Composition Phenotypes – Characteristics of Phenotype Groups

Sarcopenia and SO were associated with less favorable clinical profiles and worse nutritional status in comparison with obesity and normal phenotypes. Participants with sarcopenia compared with all other phenotype groups were the oldest (77.5 ± 8.4 years; $p < 0.001$ vs. obesity), had the lowest body weight (55.2 ± 9.4 kg; $p < 0.001$), BMI (21.7 ± 2.8 kg/m²; $p < 0.001$), SMM (21.0 ± 4.2 kg; $p < 0.001$ vs. obesity), and FFM (39.2 ± 7.2 kg; $p < 0.001$ vs. obesity). Health burden was higher in the sarcopenia group (4.4 ± 2.2 diseases; 6.5 ± 2.6 medications) than in persons with normal phenotype but lower than in the SO group, which showed the highest level of multimorbidity (5.9 ± 2.5 ; $p < 0.001$) and polypharmacy (9.1 ± 4.4 ; $p < 0.001$). Of all phenotype groups, participants with SO also had the highest body weight (87.5 ± 14.1 kg), BMI (33.8 ± 5.7 kg/m²) and PBF ($43.4 \pm 7.2\%$) each significantly higher than in the normal and sarcopenia groups (all $p < 0.001$). Individuals with obesity were the youngest (72.9 ± 7.6 years) and had the best muscle profile. They also had a lower number of chronic diseases (4.3 ± 2.6) and took fewer medications (6.6 ± 3.8) ($p < 0.001$ for both), but similar to the sarcopenia group. Comprehensive characteristics of body composition phenotype groups are shown in Table 3.

Table 3. Characteristics of phenotype groups.

Variable	Body composition phenotypes				P value
	Sarcopenia n=50	Obesity n=139	SO n=58	Normal n=193	
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	
Age [years]	77.52 $\pm$ 8.43	72.91 $\pm$ 7.64	77.09 $\pm$ 7.39	74.58 $\pm$ 7.60	<0.001
Body weight [kg]	55.19 $\pm$ 9.39	84.14 $\pm$ 11.1	87.51 $\pm$ 14.10	66.93 $\pm$ 11.36	<0.001
BMI [kg/m ²]	21.74 $\pm$ 2.76	32.30 $\pm$ 3.46	33.78 $\pm$ 5.72	25.52 $\pm$ 3.68	<0.001
PBF [%]	27.74 $\pm$ 7.87	41.68 $\pm$ 6.18	43.40 $\pm$ 7.15	30.81 $\pm$ 8.20	<0.001
SMM [kg]	20.95 $\pm$ 4.19	27.15 $\pm$ 5.72	26.60 $\pm$ 5.10	25.00 $\pm$ 5.14	<0.001
FFM [kg]	39.19 $\pm$ 7.21	49.13 $\pm$ 8.92	49.41 $\pm$ 8.63	46.04 $\pm$ 8.94	<0.001
ALM index [kg/m ²]	5.76 $\pm$ 0.87	7.51 $\pm$ 1.02	7.50 $\pm$ 1.02	6.85 $\pm$ 1.11	<0.001
SMM/W [%]	0.38 $\pm$ 0.04	0.32 $\pm$ 0.05	0.31 $\pm$ 0.04	0.37 $\pm$ 0.05	<0.001
HGS [kg]	18.57 $\pm$ 4.89	27.76 $\pm$ 9.97	21.88 $\pm$ 8.48	25.31 $\pm$ 8.93	<0.001
5STS [s]	15.79 $\pm$ 6.96	13.09 $\pm$ 6.09	18.43 $\pm$ 9.45	13.42 $\pm$ 6.99	<0.001
MNA score	21.71 $\pm$ 4.19	25.58 $\pm$ 2.90	24.01 $\pm$ 2.22	24.52 $\pm$ 3.62	<0.001

Number of chronic diseases	4.44 ± 2.21	4.25 ± 2.55	5.90 ± 2.50	3.77 ± 2.20	<0.001
Number of medications	6.50 ± 2.57	6.62 ± 3.76	9.05 ± 4.38	5.41 ± 3.68	<0.001
ADL score	5.59 ± 0.40	5.63 ± 0.69	5.14 ± 0.86	5.57 ± 0.67	0.002
IADL score	23.00 ± 3.85	24.99 ± 3.55	20.88 ± 5.42	24.20 ± 4.26	<0.001
	n (%)	n (%)	n (%)	n (%)	
Sex					
Women	32 (64.0)	88 (63.3)	27 (46.6)	134 (69.4)	0.017
Men	18 (36.0)	51 (36.7)	31 (53.4)	59 (30.6)	
Low muscle mass (ALM Index)	50 (100.0)	8 (5.8)	18 (31.0)	34 (17.6)	<0.001
Low muscle mass (SMM/W)	0 (0.0)	36 (25.9)	58 (100.0)	1 (0.5)	<0.001
Reduced upper limb muscle strength	40 (80.0)	17 (12.2)	31 (53.4)	32 (16.6)	<0.001
Reduced lower limb muscle strength	29 (58.0)	36 (25.9)	46 (79.3)	57 (29.5)	<0.001
Probable sarcopenia	50 (100.0)	45 (32.4)	58 (100.0)	67 (34.7)	<0.001
Limitations in ADL ≤5	10 (20.0)	21 (15.1)	24 (41.4)	37 (19.2)	<0.001
Limitations in IADL ≤26	36 (72.0)	63 (45.3)	47 (81.0)	99 (51.3)	<0.001
Poor nutritional status	31 (62.0)	32 (23.0)	29 (50.0)	70 (36.3)	<0.001
MNA					
Malnutrition	6 (12.0)	1 (0.7)	1 (1.7)	6 (3.1)	<0.001
At risk of malnutrition	25 (50.0)	31 (22.3)	28 (48.3)	64 (33.2)	
Normal nutritional status	19 (38.0)	107 (77.0)	29 (50.0)	123 (63.7)	

Notes: Quantitative variables shown as mean ± standard deviation (SD), categorical variables as number (n) and percentage (%). **Abbreviations:** BMI, Body Mass Index; PBF, Percent Body Fat; SMM, Skeletal Muscle Mass; FFM, Fat-Free Mass; ALM Index, Appendicular Lean Mass Index; SMM/W, Skeletal Muscle Mass to Weight Ratio; HGS, Hand Grip Strength; 5STS, Five Times Sit-to-Stand Test; MNA, Mini Nutritional Assessment - Long Form; ADL, Basic Activities of Daily Living; IADL, Instrumental Activities of Daily Living, SO, Sarcopenic Obesity.

3.4. Body Composition Phenotypes - Functional Capacity ADL/IADL

One-way analysis of variance (ANOVA) showed significant differences in the ability to perform both basic and instrumental activities of daily living ($p < 0.001$) between phenotype groups. Individuals with sarcopenic obesity had the worst functional profile: the percentage of people with limitations in performing ADL was twofold higher than in other groups (41.4%; $p < 0.001$), and the vast majority of them had problems with IADLs (81.0%; $p < 0.001$). The mean scores for ADL and IADL were the lowest in participants with SO in comparison with other groups (respectively 5.1 ± 0.9 ; $p < 0.001$, and 20.9 ± 5.4). The SO group had the lowest ADL (5.1 ± 0.9 ; $p < 0.001$ vs. all other groups) and IADL score (20.9 ± 5.4), lower than in the normal and obesity groups (both $p < 0.001$), but not different from the sarcopenia group ($p = 0.053$). People with sarcopenia had better functional capacity than those with SO and worse than obese individuals. While the prevalence of limitations in ADL was similar in sarcopenia, obesity, and normal phenotype groups (about 20.0%), deficits in IADL were significantly more frequent in sarcopenic individuals than in the obese ones (72.0% vs. 45.3%; $p < 0.001$). The mean IADL score was also higher in the sarcopenia group in comparison with the obesity group (23.0 ± 3.9 vs. 25.0 ± 3.6 ; $p < 0.024$).

Participants with obesity had the most favorable functional profile of all four body composition phenotype groups. Only 15.1% obese individuals had problems with performing basic activities of daily living; this percentage was the lowest among these groups, and significantly lower than in the SO group ($p < 0.001$). The percentage of obese people with deficits in IADL was 45.3% and was significantly lower than in the sarcopenia group (72.0%; $p < 0.001$) and SO group (81.0%; $p < 0.001$). Mean scores for ADL (5.6 ± 0.7) and IADL (25.0 ± 3.6) in the obesity group were the highest among the four groups. Individuals with normal phenotype had a moderate level of functional ability: 19.2% of them had limitations in performing ADL, and 51.3% in IADL; both percentages were significantly

lower than in the SO group ($p < 0.001$) and similar to those found in sarcopenia and obesity groups. Mean scores for ADL (5.6 ± 0.7) and IADL (24.2 ± 4.3) in the normal phenotype group were comparable with the obesity phenotype and significantly higher than in the SO group ($p < 0.001$). Detailed data are shown in Table 3 and Figure 1.

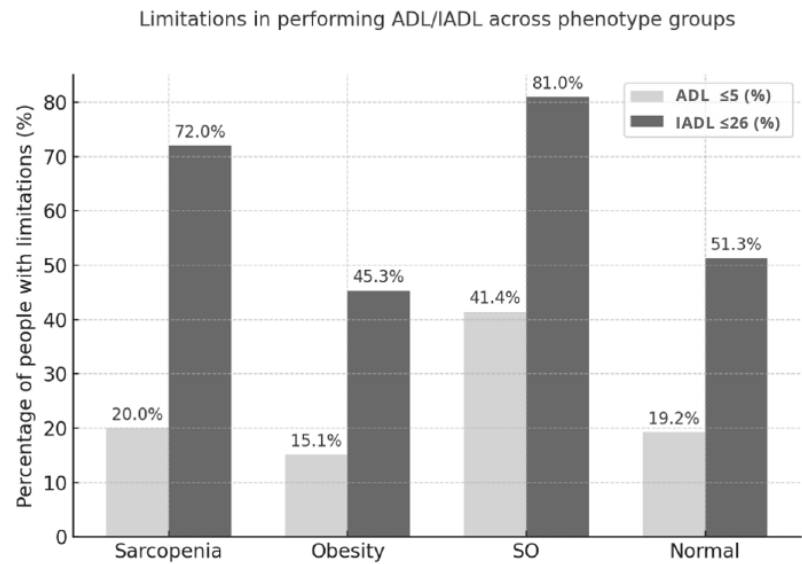


Figure 1. Limitations in performing ADL/IADL across phenotype groups.

3.5. Relationship Between Age, Sex, Body Composition Phenotypes, and Functional Disability

In women, the four phenotype groups had comparable prevalence of limitations in ADL ($p = 0.237$) but differed in IADL ($p = 0.012$). Full ability to perform instrumental activities of daily living was the most common in women with normal phenotype (50.7%), and the least common in SO (18.5%). Among men, ADL limitations were most common in the SO group (45.2%; $p < 0.001$), while IADL limitations occurred most frequently in the individuals with sarcopenia (83.3%; $p < 0.001$). The lowest prevalence of limited functional capacity was found in the obesity group (ADL 5.9%; IADL 31.4%). Detailed data are presented in Table 4.

Table 4. Prevalence of functional limitations in ADL/IADL by phenotype.

Variable	Body composition phenotypes				P value
	Sarcopenia	Obesity	SO	Normal	
	n (%)	n (%)	n (%)	n (%)	
Women	n=32	n=88	n=27	n=134	
ADL ≤5	7 (21.9)	18 (20.5)	10 (37.0)	26 (19.4)	0.237
IADL ≤26	21 (65.6)	47 (53.4)	22 (81.5)	66 (49.3)	0.012
Men	n=18	n=51	n=31	n=59	
ADL ≤5	3 (16.7)	3 (5.9)	14 (45.2)	11 (18.6)	<0.001
IADL ≤26	15 (83.3)	16 (31.4)	25 (80.6)	33 (55.9)	<0.001

Notes: Categorical variables as number (n) and percentage (%). **Abbreviations:** ADL, Basic Activities of Daily Living; IADL, Instrumental Activities of Daily Living, SO, Sarcopenic Obesity.

3.6. Predictors of Functional Limitations in ADL and IADL

Multivariate analysis of variance showed significant associations between some clinical variables and functional limitations in basic and instrumental activities of daily living. The number of chronic diseases was a predictor of disability in ADL - each disease increased the risk by 22.5% (OR = 1.225; $p = 0.003$). Nutritional status had protective effects: an increase in the MNA score by 1

reduced the risk of deficits in ADL by 15.8% (OR = 0.842; $p < 0.001$). Reduced lower limb muscle strength was the strongest predictor of functional limitations. Persons with reduced lower limb muscle strength had a threefold higher risk of problems with performing ADL (OR = 3.225; $p < 0.001$). Other variables, such as number of medications, reduced upper limb muscle mass, low ALM Index, BMI, PBF, had no association with limitations in ADL.

Reduced lower limb muscle strength also had the strongest association with limitations in IADL - the risk was fourfold higher in individuals with reduced strength (OR = 4.297; $p < 0.001$). Unlike for ADL, low upper limb muscle strength increased twofold the risk of deficits in IADL (OR = 2.261; $p = 0.011$). Another important predictor of IADL disability was nutritional status, each additional point in the MNA score reduced the risk by 13.4% (OR = 0.866; $p = 0.001$). Each chronic disease increased the risk of limitations in IADL by 20.8% (OR = 1.208; $p = 0.009$), and each medication increased the risk by 9.9% (OR = 1.099; $p = 0.024$). The risk of problems with performing IADL also increased with BMI (OR = 1.107; $p = 0.024$). Detailed data are shown in Table 5.

Table 5. Multivariate logistic regression analysis of factors associated with functional limitations in ADL and IADL.

Variables	OR (ADL ≤5)	95% CI	P value	OR (IADL ≤26)	95% CI	P value
Number of chronic diseases	1.225	1.072-1.399	0.003	1.208	1.048-1.393	0.009
Number of medications	1.062	0.978-1.153	0.155	1.099	1.012-1.192	0.024
MNA score	0.842	0.769-0.922	<0.001	0.866	0.794-0.945	0.001
Reduced lower limb muscle strength	1.591	0.877-2.888	0.127	2.261	1.202-4.253	0.011
Reduced upper limb muscle strength	3.225	1.815-5.729	<0.001	4.297	2.497-7.394	<0.001
Low muscle mass (ALM Index)	0.817	0.359-1.860	0.630	1.063	0.525-2.153	0.866
BMI [kg/m²]	1.020	0.926-1.125	0.685	1.107	1.014-1.210	0.024
PBF [%]	1.017	0.969-1.067	0.488	0.968	0.928-1.010	0.137

Abbreviations: MNA, Mini Nutritional Assessment - Long Form; ALM Index, Appendicular Lean Mass Index; BMI, Body Mass Index; PBF, Percent Body Fat; ADL, Basic Activities of Daily Living; IADL, Instrumental Activities of Daily Living.

After adjustment for sex and age individuals with SO phenotype had nearly threefold higher risk of deficits in ADL (OR = 2.859; $p = 0.003$) and 3.5-higher risk for limitations in IADL (OR = 3.675; $p < 0.001$) compared to participants with normal phenotype. Sarcopenia increased the risk of deficits in IADL in the unadjusted model (OR = 2.442; $p = 0.010$), but this association was weaker after adjustment for sex and age ($p = 0.064$). Obesity phenotype was not associated with a significant risk of functional limitations. Detailed data are shown in Table 6.

Table 6. Multivariate logistic regression analysis of factors associated with functional limitations in ADL and IADL.

Variable	OR ADL ≤5	95% CI	P value	OR ADL ≤5 (adjusted)	95% CI	P value
Sarcopenia	1.054	0.48-2.300	0.895	0.716	0.308-1.667	0.439
Obesity	0.750	0.417-1.349	0.337	0.872	0.465-1.634	0.669
SO	2.976	1.579-5.608	<0.001	2.859	1.423-5.744	0.003
Sex				1.373	0.795-2.370	0.256
Age				1.129	1.089-1.170	<0.001
	OR IADL ≤26	95% CI	P value	OR IADL ≤ 26 (adjusted)	95% CI	P value
Sarcopenia	2.442	1.238-4.814	0.010	2.037	0.959-4.328	0.064
Obesity	0.787	0.508-1.219	0.283	0.936	0.576-1.520	0.788
SO	4.057	1.985-8.290	<0.001	3.675	1.707-7.910	<0.001

Sex	1.026	0.652-1.616	0.911
Age	1.141	1.104-1.78	<0.001

Abbreviations: Basic Activities of Daily Living; IADL, Instrumental Activities of Daily Living, SO, Sarcopenic Obesity.

4. Discussion

To the best of our knowledge, this is the first study conducted in Central-Eastern Europe assessing the relation between functional disability and sarcopenia, obesity, and sarcopenic obesity in the community-dwelling older adults, in which ESPEN/EASO guidelines were used to diagnose SO. As many as 57.1% of our study population had abnormal body composition phenotype. Obesity was the most prevalent one (31.6%), followed by sarcopenic obesity (13.2%) and sarcopenia (11.4%). Sarcopenic obesity was the strongest, independent predictor of disability. In participants with SO phenotype, the risk of deficits in performing basic and instrumental activities of daily living was 3 and 3.5 times higher, respectively, than in persons with normal phenotype. Sarcopenia was associated with limitations in the ability to perform IADL in the unadjusted model only (OR = 2.5). Obesity did not influence functional capacity in our study sample.

So far, the relationship between four body composition phenotypes and the risk of disability in performing ADL and IADL was almost never assessed. We have found only one relevant study conducted by Bahat et al. [40], including 1468 elderly persons living in the Turkish community (68.8% of women; median age 75 years). The prevalence of pathological phenotypes in the cited paper was different from that in our sample (45.4% participants with obesity, 3.7% with sarcopenia, and 3.7% with SO phenotype). Of note, Bahat et al. [40] used a different methodology to assess body phenotypes (e.g., the SO phenotype was diagnosed based on LMM to BMI ratio, and not SMM to body weight proportion, recommended by the EASO/ESPEN experts and used in our study). Despite the various prevalence of particular body phenotypes, sarcopenic obesity was a predictor of disability in activities of daily living in both our and their studies, and the strength of this association was very similar in both investigations (OR = 2.7 for ADL, p=0.001; and IADL, p=0.002 in the study of Bahat et al. [40] vs. OR = 3.0 for ADL and OR = 3.5 for IADL in our study). Contrary to our findings, Bahat et al. [40] observed an even stronger relationship for sarcopenia (OR = 3.4 for ADL, p <0.001; OR = 6.4 for IADL, p <0.001); in our sample, sarcopenia was only associated with limitations in the ability to perform IADL, and this association was only found in the unadjusted model (OR =2.4, p= 0,010). Unlike in our study, the cited authors found that obesity was linked to a functional decline in both IADL and ADL, although the magnitude of the effect was only modest (OR = 1.3 and OR = 1.5, respectively).

Sarcopenic obesity phenotype was associated not only with functional limitation, but also with unfavorable clinical profile (the most severe multimorbidity, polypharmacy, and impaired nutritional status). This finding suggests that obesity concomitant with loss of muscle mass and strength is not only a risk factor for disability, but it is also a marker of cumulated health burden. The German study KORA-Age, including 998 elderly persons (mean age 75.6 years) yielded similar results: SO phenotype was associated with increased risk of multimorbidity (OR = 2.59), polypharmacy (OR = 1.96) and cognitive dysfunction (OR = 3.03), independently of confounding factors [41]. Multimorbidity and polypharmacy were independent predictors of decreased functional capacity in our research, as well as in some other studies. For example, in cross-sectional analysis by Tachall et al. [42], polypharmacy was associated with increased risk of problems with performing ADL (OR = 1.87) and IADL (OR = 3.52), regardless of age and other clinical variables. Ćwirlej-Sozańska et al. [43] observed a higher risk of functional limitations in persons taking ≥4 medications; each chronic disease increased the risk of deficits in IADL by 18%.

In our study, SO was observed more than twice as often in men as in women (19.5% vs. 9.6%). Similarly, in the FIBRA-RJ study, which included 270 community-dwelling older adults from Brazil (189 women and 81 men; mean age 77.5 ± 5.9 years), SO was identified in 29.3% of participants and was more than four times as prevalent in men than in women (63.0% vs. 14.7%) [44]. The higher

occurrence of SO in men may be explained by sex-specific differences in body fat distribution and lifestyle changes associated with aging. Men are more likely to accumulate visceral adipose tissue, which exerts stronger metabolic and proinflammatory effects, potentially accelerating muscle loss and promoting the development of the SO phenotype [45–47]. Moreover, a pronounced reduction in physical activity, commonly observed in men after retirement, may further exacerbate muscle decline while fat mass remains stable or even increases [48].

Despite apparent impairment in muscle mass and strength, the sarcopenia phenotype was associated with disability to perform instrumental, but not basic, activities of daily living in our study sample. These results are perfectly in line with the consensus review by the Global Leadership Initiative in Sarcopenia (GLIS) experts, stating that although sarcopenia may have a moderate association with disability in IADL, the data about its relationship with ADL are inconsistent and significantly vary between studies [49]. The GLIS experts emphasized that the ability to perform instrumental activities of daily living may be a more sensitive index of functional consequences of sarcopenia, as IADL have a more complex character, requiring not only physical capacity, but also a good level of coordination, executive functions, and cognitive skills [49]. While we aimed at the assessment of body composition phenotypes in our analysis, it should be noted that the key components of sarcopenia: reduced lower and upper limb muscle strength were independent and strong risk factors for functional disability (reduced lower limb muscle strength was associated with a threefold increase in limitations in ADL and a fourfold - in IADL; reduced upper limb muscle strength - with a twofold increase in IADL disability) [49].

Participants with an obesity phenotype had relatively good muscle strength and functional capacity, comparable to those observed in subjects with a normal phenotype. These findings suggest that moderate excess in fat tissue does not necessarily lead to functional impairment, provided a reduction in muscle mass and strength does not accompany it. Therefore, the assessment of risk of functional disability in elderly persons should be based on body composition, defined as the proportion of fat and muscle components, and not on anthropometric parameters (e.g., BMI) alone. Our findings add to the „obesity paradox” - a conception that a moderate excess in body mass in elderly persons may serve as a metabolic reserve and may be associated with a favorable prognosis [50,51]. This hypothesis has recently been supported by the results of a study performed in New Zealand, which included nearly 200,000 institutionalized older adults. Obese and overweight persons (BMI 25.0-34.9 kg/m²) had better abilities to perform activities of daily living than individuals with normal weight, while underweight (BMI <18.5 kg/m²) was strongly associated with functional disability [52].

Participants with normal phenotype had the best functional and health status among all phenotype groups. We use the term „normal phenotype” instead of „healthy phenotype” to emphasize its equivocal clinical profile. Some individuals with normal phenotype had decreased muscle mass or strength, which may indicate a preclinical phase of sarcopenia. The number of chronic diseases and medications taken regularly in this group were very close to those found in persons with sarcopenia, which suggests that not all people with normal body composition phenotype can be classified as healthy aging. Many of them may be subject to normal aging, and multimorbidity and polypharmacy may occur in them independently of body composition or functional capacity.

Our study has some limitations. Firstly, the cross-sectional character of analysis makes it impossible to draw any conclusions on a possible causal relationship. Data concerning physical activity, dietary habits, and other potential risk factors for disability were not available and were not included in the survey. Finally, body composition analysis with the BIA method, despite its wide use, has lower precision compared to DXA and other reference methods [53–55]. Our study also has strong points. One-time analysis of four distinct body composition phenotypes enables a comprehensive assessment of the relationship between these phenotypes and functional capacity. Classification of body composition phenotypes was by the most recent diagnostic criteria, including the definition of sarcopenic obesity by ESPEN/EASO recommendations. Finally, the study sample consisted of community-dwelling elderly persons, which gives better insight into the functional capacity of this

population, being an important target for social policy, than surveys including institutionalized persons.

By investigating the relationship between body composition phenotypes and functional ability in ADL and IADL, we provide evidence with direct implications for clinical assessment, prevention, and rehabilitation in aging populations. Our findings highlight the importance of assessing muscle mass, strength, and adiposity patterns to enable the early identification of individuals at risk and guide personalized interventions aimed at maintaining independence and preventing disability. These findings support the implementation of body composition screening as a routine procedure in geriatric care.

5. Conclusions

Sarcopenic obesity was associated with a higher risk of limitations in both basic and instrumental activities of daily living, and sarcopenia, with deficits in IADL only. Obesity phenotype had no important influence on functional capacity. Further studies are necessary to shed more light on the impact of this phenotype on the everyday functioning of elderly persons. Potentially, factors such as the degree of obesity may be relevant.

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