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What Might be More Associated with Higher or Lower Blood Pressure in Older Adults? Sarcopenia, Obesity, or Sarcopenic Obesity? A Cross-sectional Retrospective Study

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Abstract

Objective: In old age, body composition changes. While the muscle tissue tends to decrease, adipose tissue increases. The term sarcopenic obesity (SO) refers to a combination of sarcopenia and obesity. SO is a geriatric syndrome that has been newly defined and understood the importance. Its relationship to blood pressure is unclear. The study aims to determine which sarcopenia, obesity or SO is more associated with higher or lower blood pressure.

Materials and Methods: Non-hypertensive and not receiving antihypertensive therapy patients who underwent bioelectrical impedance analysis (BIA) and 24-hour ambulatory blood pressure measurements for body composition were included in this retrospective study. Comprehensive geriatric assessment, socio-demographic and laboratory data were recorded. Sarcopenia was diagnosed according to the European Working Group on Sarcopenia in Older People-2 criteria. Fat percentage measured by BIA was used for obesity (38% and 27% for females and males).

Results: Of 167 patients with a mean age of 75.45±8.12 years, 70.6% (n=121) were women. The ratios of sarcopenia, obesity and SO were 14.5% (n=24), 27.8% (n=46) and 42.4% (n=71), respectively. In the sarcopenic group, systolic blood pressure (SBP), daytime mean arterial pressure (MAP), and pulse pressure (PP) were the lowest. The obese group had the highest SBP, MAP, and the lowest daytime pulse rate (PR). SO the group had the lowest MAP at night and the highest daytime PR. After adjusting for confounders, for SO, being female, having high nighttime mean arterial pressure and high daytime PR had a higher odds ratio (respectively, OR 3.271, 0.976, 1.32; p<0.001, 0.046, 0.012).

Conclusion: Obesity might be more related to blood pressure and mean arterial pressure elevation. Sarcopenia and SO might be related to hypotension, low PP, and low mean arterial pressure in older adults.

Keywords: Sarcopenia, sarcopenic obesity, blood pressure, older adults, comprehensive geriatric assessment

Introduction

The older adult population is increasing around the world. As of 2021, already, there are more than 1 billion people aged 60 years or older. This number is expected to double to 1.5 billion by 2050 (1). Body composition in old age changes compared to young people. The muscle ratio decreases while fat ratio increases. Studies show that muscle mass decreases by about 6% per decade. Body fat also increases until the seventh year of life and then decreases (2). Sarcopenia is a geriatric syndrome, referring to low muscle mass, strength, and performance. In the diagnosis of sarcopenia, many different groups have introduced definitions. One of these groups is the European Working Group

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on Sarcopenia in Older People (EWGSOP-2). The definition criteria of sarcopenia were updated by this group in 2018 and cases with low muscle strength were taken as probable sarcopenias. The diagnosis of sarcopenia is confirmed when both muscle strength and mass are low (3). Sarcopenia causes decreased physical performance, increased physical disability, hospitalization, and institutionalization, decreased quality of life, and increased healthcare costs, falls, and mortality in older adults (4,5). Sarcopenia causes metabolic changes that lead to insulin resistance by several different mechanisms in older adults (changes in the neuroendocrine system (insulin resistance, altered anabolic hormone secretion, decreased sex hormones), physical inactivity, decrease in skeletal muscle mass, and decrease in physical activity and energy expenditure) (6-9). In older adults, these conditions can induce disease pathogenicity and cause blood pressure changes.

Obesity and being overweight were associated with higher blood pressure and mortality in the adult group. However, studies examining the effects of overweight and obesity on CVD and mortality in older adults are conflicting. Some studies have even suggested that overweight and obesity, as measured by BMI, are associated with a lower risk of death. This is known as the "obesity paradox" (6).

The term sarcopenic obesity (SO) refers to a combination of sarcopenia and obesity. SO is a geriatric syndrome that is relatively newly defined compared to sarcopenia, and its importance is newly understood. In older adults, sarcopenia, and obesity synergistically increase the effects of each other. The combination of these two epidemic situations causes limitation of functionality in older adults. Both have inflammatory pathways of similar pathogenicity (10). Recent studies have shown that SO is associated with an increased risk of physical disability, cardiovascular morbidity, and mortality compared with sarcopenia or obesity alone (10-13). Previous studies have examined the effects of sarcopenia and obesity on blood pressure (14,15). However, studies examining the effect of the coexistence of these two conditions are limited. Despite increasing research on the association between SO and cardiovascular risk factors, only a limited number of studies to date have evaluated the association between SO and CVD risk in older adults.

The study aims to determine which sarcopenia, obesity or SO is more associated with higher or lower blood pressure.

Materials and Methods

Study design and patient selection

A total of 167 patients who underwent Bioelectrical Impedance Analysis (BIA) and 24-hour ambulatory blood pressure measurements (24 hours-PPM) were included in this cross-sectional retrospective study. The patients included in the study were selected from among the patients whose data were collected between July 2015 and February 2019. The patients were those who had a previous 24-hour blood pressure measurement, did not have a history of hypertension, and did not receive antihypertensive treatment. Sociodemographic findings, comprehensive geriatric assessment tests, and laboratory data of the patients indicated in Table 1 were obtained from their electronic files. Patients whose files were missing (not suitable for BIA, ABPM not complete for 24 hours, laboratory values missing, comprehensive geriatric assessment tests could not be performed or missing) were not included in the study. The patient selection algorithm is summarized in Figure 1. The patients were divided into four groups according to the measurement results. 1. group: Non-sarcopenic, non-obese, normal group, 2. group only sarcopenic, 3. group: Only obesity and 4. group SO. Comparisons were made between the four groups. The STROBE checklist for cross-sectional studies was filled out.

Definition of sarcopenia, obesity, and SO

The diagnosis of sarcopenia was made according to the revised European consensus on the definition and diagnosis from the "EWGSOP-2" (3). These revised diagnostic criteria, which were updated in 2018, mainly use three components: Muscle strength, muscle quantity, and physical performance.

1- Muscle strength: In our study, the handgrip test was used to measure muscle strength. For the evaluation of muscle strength, handgrip strength was measured with an electronic hand dynamometer (GRIP-D, grip strength dynamometer, produced by Takei, Made in Japan). The measurement was made with the arm flexed at 90 degrees from the elbow. The person grasped the force-applied part of the dynamometer with the dominant hand and applied power to the dynamometer with all their might. Measurements were made three times with an interval of one minute. An average of three measurements was taken. The unit of results is kilograms. According to EWGSOP-2 recommendations, local cut-off values were used (grip strengths of <22 kg for females and <32 kg for males) (16).

2- Muscle quantity: Skeletal muscle mass was evaluated by BIA. The measurement was made in the supine position before breakfast after the participant had removed all metal objects. The four electrodes of the device, two each on the right foot and right hand of the person, were attached with the device's adhesive tape. The gender, age, height, and body weight of the individual were entered into the device. Measurements were made at a frequency of 50 kHz. The resistance value in ohms, one of the data items obtained as a result of the analysis, was used to calculate the skeletal muscle mass. The resistance value measured during analysis was used in the following formula to calculate skeletal muscle mass, as suggested by Janssen et al. (17): [(height^2/resistance value in BIA measurement x 0.401) +

Table 1. Demographic and clinical data of groups

	Normal	S only	O only	SO	All	p
N (%)**	26 (15.3)	24 (14.5)	46 (27.8)	71 (42.4)	167	
Age ± SD	75.45±8.12[bcd]	80.94±7.03[ac]	71.75±5.63	80.31±6.36	77.34±7.64	**<0.001***
Gender [n (%)]¶						
Female	8 (5.2)[bcd]	14 (8.9)[a]	35 (21.4)[a]	58 (35.1)[a]	121 (70.6)	**<0.001***
Male	16 (10.1)	9 (5.6)	10 (6.5)	11 (7.3)	46 (29.4)	
Number of drugs used (min-max) (CI 95%)	5.84 (2-9) (5.18-6.51)	5.84 (3-10) (4.91-6.81)	5.57 (3-11) (4.95-6.18)	6.53 (2-14) (5.82-7.24)	6.06 (3-25) (5.68-6.44)	0.201
Body mass index (kg/m^2)# (CI 95%)	23.64±2.65 (22.77-24.52)[bc]	21.28±3.20 (20.20-21.22)[acd]	32.10±3.05 (31.37-32.84)[abd]	24.95±4.55 (24.07-25.83)[bc]	26.21±5.35 (25.54-26.88)	**<0.001**
Fat mass percentage (%) # (CI 95%)	27.56±5.94 (23.78-31.34)[cd]	22.36±4.75 (18.99-25.76)[cd]	38.29±14.87 (32.52-44.06)[abd]	44.56±4.21 (43.61-45.51)[abc]	39.86±10.72 (37.98-41.73)	**<0.001**
Comorbidities¶						
Diabetes mellitus n (%)	11 (6.5)	10 (5.9)	26 (15.5)	27 (16.1)	74 (44)	0.132
Cerebrovascular event n (%)	7 (4.2)	4 (2.3)	5 (2.9)	10 (5.9)	26 (15.5)	**0.115**
Congestive heart failure n (%)	9 (5.6)	12 (7.3)[d]	17 (10.5)	18 (10.9)[b]	57 (34.3)	**0.049**
Depression n (%)	5 (2.9)[d]	3 (1.8)[d]	12 (7.2)d	41 (24.5)[abc]	61 (36.4)	**<0.001**
CGA#						
Katz ADL (CI 95%)	4.93±1.20 (4.48-5.38)	3.95±2.36 (2.95-4.95)[sd]	5.23±1.28 (4.91-5.55)[bd]	4.24±2.14 (3.81-4.67)[bc]	4.52±1.91 (4.27-4.78)	**<0.001**
LB-IADL (CI 95%)	10.5±4.96 (8.64-12.35)[d]	8.83±6.74 (6.98-12.68)[c]	13.71±4.20 (12.41-14.76)[bd]	7.88±5.92 (6.69-9.08)[ac]	10.27±5.95 (9.51-11.03)	**<0.001**
MMSE (CI 95%)	21.36±5.56 (19.28-23.44)[d]	25.04±5.52 (22.70-27.37)[d]	21.82±4.72 (20.64-23.00)[d]	17.77±8.29 (16.10-19.44)[abc]	20.33±7.14 (19.43-21.23)	**<0.001**
MNA-SF (CI 95%)	11.23±1.43 (10.69-11.76)[b]	10.29±1.65 (9.59-10.99)[acd]	11.95±1.49 (11.57-12.32)[b]	11.35±2.00 (10.94-11.75)[b]	11.32±1.80 (11.08-11.56)	**<0.001**
GDS-SF (CI 95%)	3.66±1.82 (2.98-4.37)[d]	5.54±3.87 (3.90-7.17)	5.56±2.85 (4.84-6.27)	5.80±3.21 (5.15-6.45)[a]	5.54±3.10 (5.12-5.95)	**0.029**
Handgrip strength (kg) (CI 95%)	20.68±6.44 (18.62-22.75)[bd]	13.92±7.16 (11.55-16.29)[ac]	21.23±8.82 (19.11-23.35)[bd]	13.66±4.83 (12.73-14.58)[ac]	16.88±7.43 (15.93-17.82)	**<0.001**
Waist circumference (cm) (CI 95%)	90.31±9.97 (87.03-93.59)[c]	83.61±10.08 (80.22-86.99)[c]	108.04±6.7 (106.46-109.62)[abd]	91.33±13.13 (88.75-93.91)[bc]	94.70±13.78 (92.91-96.43)	**<0.001**
Hip circumference (cm) (CI 95%)	97.73±7.72 (95.26-100.20)[c]	92.47±7.04 (89.59-95.34)[c]	117.44±12.8 (114.47-120.42)[abd]	95.26±10.96 (93.06-97.47)[c]	101.41±14.8 (99.56-103.25)	**<0.001**
Mid-arm circumference (cm) (CI 95%)	24.47±2.80 (23.52-25.42)[c]	22.44±4.37 (20.91-23.96)[cd]	29.79±2.90 (29.06-30.52)[abd]	25.07±4.04 (24.18-25.86)[bc]	25.86±4.42 (25.29-26.43)	**<0.001**
Laboratory values#						
Fasting blood glucose (mg/dL) (CI 95%)	111.59±54.32 (93.48-129.70)[c]	112.81±39.32 (98.27-127.35)[c]	134.91±51.97 (121.05-148.77)[abd]	108.08±35.92 (100.38-115.78)[c]	117.10±46.16 (111.04-123.16)	**<0.001**
LDL (mmol/L) (CI 95%)	113.64±47.64 (97.76-129.53)	99.93±32.33 (88.47-111.40)[d]	118.94±33.58 (109.79-128.10)	123.32±27.49 (117.73-128.92)[b]	117.12±34.31 (112.75-121.49)	**0.017**
Calcium (mg/dL) (CI 95%)	9.53±0.69 (9.30-9.76)	9.17±0.87 (8.85-9.49)[d]	9.33±0.65 (9.15-9.51)	9.63±0.54 (9.52-9.74)[b]	9.46±0.66 (9.38-9.54)	**0.003**
Total protein (g)/L (CI 95%)	7.00±0.57 (6.81-7.19)	6.83±0.56 (6.62-7.04)[c]	7.28±0.89 (7.03-7.52)[b]	7.02±0.54 (6.91-7.13)	7.07±0.54 (6.99-7.16)	**0.009**
Albumin (g/L) (CI 95%)	3.91±0.53 (3.73-4.09)[b]	3.49±0.6 (3.28-3.71)[acd]	4.07±0.41 (3.97-4.18)[b]	3.96±0.33 (3.90-4.03)[b]	3.93±0.46 (3.88-3.99)	**<0.001**
Sedimentation rate (CI 95%)	21.16±12.05 (7.17-25.15)[bc]	39.79±28.41 (28.13-48.19)[ad]	32.36±29.04 (21.77-39.06)[ad]	20.01±13.32 (17.24-22.77)[bc]	26.40±22.11 (23.58-29.22)	**<0.001**
Leukocyte (WBC) ($x10^9$/L) (CI 95%)	6.89±2.31 (6.10-7.68)	7.03±2.63 (6.14-7.91)	6.90±1.76 (6.46-7.34)	6.84±1.99 (6.45-7.22)	6.92±2.08 (6.66-7.13)	0.906
CRP (mg/L) (CI 95%)	25.61±63.9 (13.01-58.58)[d]	31.79±32.49 (14.77-36.45)	14.32±33.39 (6.30-22.35)	13.85±20.60 (9.86-17.89)[a]	19.17±36.14 (14.66-23.68)	**0.013**
25-Hydroxy vitamin D (µg/L) (CI 95%)	21.01±18.68 (14.40-27.63)[b]	28.53±14.32 (23.44-33.62)[a]	14.66±20.30 (12.15-17.18)[b]	14.41±8.34 (12.79-16.02)[b]	17.35±13.09 (15.74-18.96)	**<0.001**

**Percentages are given in proportion to the total number of patients, One-Way ANOVA test was used for continuous variables# (mean ± SD), chi-square test was used for ordinal or binary variables¶ (%), bonferroni post-hoc tests were performed. CI: Confidence interval, SD: Standard deviation, Normal: Robust, non-sarcopenic-non-obes group, S: Sarcopenic only group, O: Obes only group, SO: Sarcopenic obesity group, ADL: Activities of daily living, IADL: Instrumental activities of daily living, MMSE: Mini-mental state examination, GDS-SF: Geriatric depression scale short form, MNA-SF: Mini nutritional assessment-short form, LDL: Low density lipoprotein, CRP: C-reactive protein results in bold (p<0.005) are statistically significant, [a]: Significant difference to normal, [b]: Significant difference to SP, [c]: Significant difference to OB, [d]: Significant difference to SO

(gender x 3.825) + (age x -0.071)] + 5.102 (height in meters, resistance in ohms, part 1 for male and 0 for female). The value obtained with this formula was divided by the square meter of the participant's height to obtain the absolute skeletal muscle mass. An absolute skeletal muscle mass value of <7.4 kg/m^2 in women and <9.2 kg/m^2 in men corresponds to decreased skeletal muscle mass (16).

3- Physical performance: Muscle performance was evaluated by walking speed measured on a 4-meter track. The start and endpoints of the track were marked so that the person could see them well. After the walking time was measured with an electronic stopwatch, walking speed was calculated in m/sec with the formula 4 m/walking time (sec). Walking speed <0.8 m/sec was evaluated in favor of decreased muscle performance (3).

Those with low muscle strength were defined as probable sarcopenia. A diagnosis of confirmed sarcopenia was made in those with low skeletal muscle in addition to low muscle strength. In addition, those with low physical performance were diagnosed with severe sarcopenia.

Obesity was defined according to the percentage of fat mass (FM) obtained from the BIA analysis. According to FM, the cut-off scores for obesity are 38% and 27% for women and men, respectively (18). SO was defined as the coexistence of obesity and sarcopenia.

Twenty-four hour ambulatory blood pressure monitoring and examined parameters

Measurements of blood pressure and heart rate were made with a 24-hour ambulatory blood pressure measuring device (Mobil-O-Graph Blood Pressure 24-h monitor). The Mobil-O-Graph 24 h (24-hour monitoring) monitor (I.E.M. GmbH, Stolberg, Germany) is a certified monitor for 24-hour blood pressure monitoring (19). The device was designed to operate every 20 minutes between 07 in the morning and 23 in the evening, and every 30 minutes at night. Before the measurement, the patient's date of birth, height, weight, and smoking status was defined in the software program of the device. Patients were allowed to rest for at least 10 minutes before the measurement. They were informed that they should not drink caffeinated beverages within 30 minutes before the measurement. A cuff suitable for arm circumference measurements was used as a brachial cuff in the measurements. The cuff was attached to the upper arm above the brachial artery mark. The patient's bedtime and wake-up times were noted by the patient and their relatives, and the information on the device was loaded into the software while being read. With this device, the parameters whose comparative results are given in Table 2 could be examined (19).

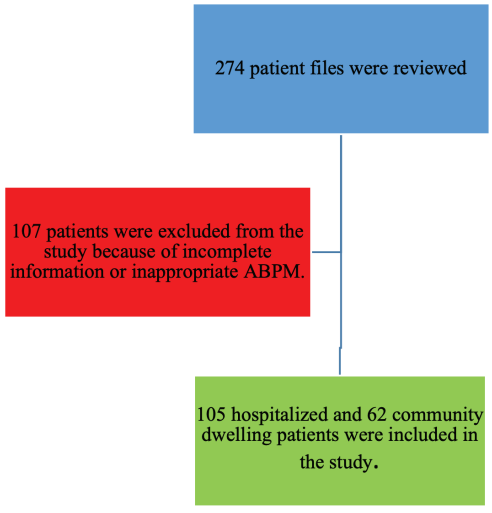

Figure 1. Flow chart of the study participants

Laboratory values

Biochemical parameters were studied using spectrophotometric, C-reactive protein turbidımetric, hormonal tests using ECLIA method and vitamin D levels using HPLC method in Ankara University İbn-i Sina Hospital laboratories. As laboratory values (unit- normal range): Fasting blood glucose (mg/dL 74-100), calculated Glomerular Filtration Rate (hGFR) (mL/min/1.73 m^2>60), calcium (mg/dL 8.8-10.6), total protein (g/L 66-83), albumin (g/L 35-52), leukocyte (WBC) (x10^9/L 4.5-11), hemoglobin (Hb) (g/dL 11.7-16.1), vitamin B12 (pg/mL 126.5-505), TSH (µIU/mL 0.38-5.33), CRP (mg/L 0.0-5.0) and 25-hydroxy vitamin D (µg/L 10-60) values were recorded.

Comprehensive geriatric assessments

Activities of daily living (ADL) were evaluated with the Katz ADL index. This index evaluates dressing, bathing, going to the toilet, getting out of bed, eating, and continence functions over 6 points (20). Instrumental activities of daily living (IADL) were evaluated with the Lawton-Brody IADL scale. On this scale, activities such as using the phone, shopping, preparing meals, housework, laundry, urban transportation, and using drugs properly are evaluated over eight points (21). Cognitive functions were investigated with the mini-mental state examination (MMSE). Low scores on this test, which is evaluated as a total of thirty points, indicate cognitive dysfunction (22). The 15-question short validated form of the geriatric depression score (GDS) was used (23). GDS scores of 5 and above indicate depression. Nutritional status was investigated with a mini-nutritional assessment short-form (MNA). This test, which has proven Turkish validity and reliability, is a test of 14 points. 0-7 points indicate malnutrition, 8-11 points indicate malnutrition risk and 12-14 points indicate normal nutrition (24).

Anthropometric measurements

Body weight, height, body mass index (BMI), waist circumference (WC), hip circumference (HC), and mid-arm circumference (MAC) were measured. A standard measuring device accurate to

0.1 kg and 0.1 cm was used. BMI was calculated as body weight in kilograms divided by the square of height in meters. WC was measured around the smallest abdominal point or midway between the lowest rib and the iliac crest in obese individuals. HC was measured horizontally at the point of greatest lateral extension on the hips or buttocks. MAC measurement was measured between the acromion and the olecranon with the arm raised and internally rotated. All measurements were made by trained personnel.

Statistics

The sample size calculation for this study is based on the following assumptions: According to the results of a previous study (9), the baseline SO rate was 25.8% in older adults. The sample size was calculated as 42 in the calculation made by taking the one-side alpha level of 0.10 and the power of 80%. The suitability of variables to normal distribution was examined using visual (histogram and probability graphs) and analytical methods (Kolmogorov-Smirnov). Descriptive analyses were performed using mean and standard deviation for normally distributed variables, and median and maximum-minimum values for non-normally distributed variables. The frequency of categorical variables was expressed as (%). Chi-square (for categorical variables) and One-Way ANOVA (for continuous variables) tests were used for evaluation between groups in Table 1 and 2. Bonferroni post-hoc tests were performed. Logistic regression analysis was performed to identify conditions that may be associated with sarcopenia and SO risk. Variables that were significant between comparisons were examined as Model 1 and before univariate logistic regression was analyzed. Those that were significant in the univariate analysis were included in the multivariate analysis. After adjusting for confounders, result analysis was performed with Model 3.

Ethics approval and consent to participate: Approval for the study was obtained from the Local Ethics Committee of the Ankara City Hospital with document number E1/1883/2021.

Results

The mean age of the 167 patients included in the study was 75.45±8.12 years. One-hundred twenty-one (70.6%) of them were women. The normal group without sarcopenia consisted of 23 (13.3%), probable sarcopenia 50 (30.1%), confirmed sarcopenia 21 (12.9%), and severe sarcopenia 73 (43.8%). The rates of sarcopenia only, obesity only and SO were 14.5% (n=24), 27.8% (n=46) and 42.4% (n=71), respectively. Demographic and clinical information of the patients is given in Table 1 comparatively. Comprehensive geriatric assessment tests showed a significant difference between the groups. The Katz ADL and MNA scores were the lowest in the sarcopenic group. In the SO group, Lawton-Brody IADL and MMSE scores were the lowest, and the GDS score was the highest. Handgrip strength was also found to be the lowest in the SO group.

The 24-hour ambulatory blood pressure, heart rate, and pulse pressure monitoring results of the groups are shown in Table 2. Daytime and nighttime systolic blood pressure, daytime mean

Table 2. Twenty-four hour blood pressure and pulse rate data of the study groups

# (CI 95%)	Normal	S only	O only	SO	All	p
Daytime SBP (mmHg)	124.21±16.79 (118.68-128.73)	117.63±17.50 (111.71-123.56)[c]	128.23±9.91 (125.85-130.61)[bd]	121.35±13.40 (118.75-123.94)[c]	123.16±14.21 (121.38-124.94)	**0.001**
Night SBP (mmHg)	124.44±17.08 (118.83-130.06)	116.55±17.17 (110.74-122.36)[c]	125.71±13.20 (122.53-128.88)[bd]	117.97±14.04 (115.25-120.68)[c]	120.91±15.29 (119.00-122.81)	**0.001**
Daytime DBP (mmHg)	70.32±10.22 (66.67-73.08)[c]	72.69±11.16 (68.91-76.47)	76.63±7.41 (74.85-78.41)[ad]	72.77±8.08 (71.20-74.33)[c]	73.41±9.00 (72.29-74.54)	**0.002**
Night DBP (mmHg)	68.65±11.08 (65.03-72.28)	70.27±12.34 (66.10-74.45)	72.53±8.72 (70.44-74.63)	69.29±9.09 (67.53-71.05)	70.24±9.87 (69.00-71.47)	0.130
Mean arterial pressure (daytime)	95.18±13.04 (90.89-99.47)	93.00±13.98 (88.26-97.73)[c]	100.21±7.66 (98.37-102.05)[bd]	94.99±9.88 (93.07-96.90)[c]	96.18±10.81 (94.83-97.54)	**0.002**
Mean arterial pressure (night)	94.57±13.56 (90.12-99.03)[d]	91.75±13.68 (87.11-96.38)[d]	97.23±10.57 (94.69-99.77[d]	91.24±10.96 (89.12-93.37)[abc]	93.49±11.93 (92.04-94.98)	**0.008**
Pulse rate (daytime)	72.84±10.37 (69.43-76.25)	76.55±13.60 (71.97-81.16)	72.79±9.59 (70.49-75.10)[d]	77.98±11.58 (75.73-80.22)[c]	75.54±11.45 (74.11-76.97)	**0.010**
Pulse rate (night)	65.21±9.29 (62.15-68.26)	69.86±11.49 (65.97-73.75)	67.36±11.80 (64.52-70.19)	70.76±12.90 (68.26-73.26)	68.83±12.03 (67.33-70.33)	0.058
Pulse pressure (daytime)	50.87±13.07 (46.58-55.17)[b]	41.75±15.25 (36.59-46.91)[a]	48.37±12.62 (45.34-51.41)	47.61±10.33 (45.61-49.82)	47.45±12.55 (45.92-49.03)	**0.012**
Pulse pressure (night)	53.27±14.35 (48.58-57.95)[b]	41.68±16.70 (36.02-47.33)[ac]	50.11±15.24 (46.44-53.77)[b]	47.98±12.12 (45.63-50.32)	48.47±14.49 (46.67-50.26)	**0.004**

One-Way ANOVA test was used for continuous variables# (mean ± SD), Bonferroni post-hoc tests were performed. CI: Confidence interval, SD: Standard deviation, Normal: Robust, non-sarcopenic-non-obes group, S: Sarcopenic only group, O: Obes only group, SO: Sarcopenic obesity group, SBP: Systolic blood pressure, DBP: Diastolic blood pressure

arterial pressure, and daytime and nighttime pulse pressure were lowest in the sarcopenic group. The obese group had the highest daytime and nighttime systolic blood pressure, daytime and nighttime mean arterial pressure, and the lowest daytime pulse rate. In the SO group, mean arterial pressure was the lowest at night and the pulse rate was the highest during the day.

Logistic regression analysis was performed to identify conditions that may be associated with sarcopenia and the risk of SO. Variables that were significant between comparisons in Table 1 and risk factors for blood pressure changes were included in the univariate analysis. Those that were significant in the univariate analysis were included in the multivariate analysis. In the analysis of sarcopenia in Table 3, the values that were significant in previous comparisons were examined as Model 1. After adjusting for age, BMI significant blood pressure values were analyzed in Model 2. Model 3 was established according to Model 1 and Model 2 results. Consequently, age, BMI, daytime SBP, and daytime mean arterial pressure were found to be the most important factors increasing the risk of sarcopenia.

In Table 4, logistic regression analysis was performed in which SO was taken as the dependent variable. In Model 1, clinical and laboratory variables that were significant in previous evaluations were analyzed. In Model 2, after adjusting for gender and other confounders, blood pressure parameters were analyzed. In Model 3, variables that were significant in Model 1 and 2 were analyzed. After adjusting for confounders for SO, being a woman, having a high nighttime mean arterial pressure and a high daytime pulse rate had higher OR. The results are shown in Table 4 and Supplementary Tables 1, 2.

Discussion

We could not find any other study in the literature examining the severity of sarcopenia in older adults and its relationship with 24-hour blood pressure monitoring in separate groups, as only sarcopenia, only obesity, and SO. To our knowledge, this is the first study conducted in this way. In our study, not only muscle mass but also muscle performance was examined in the definition of sarcopenia, and a comprehensive geriatric assessment was made.

The main findings of this study are that obesity may have a greater effect on blood pressure and mean arterial pressure elevation. Sarcopenia and SO may be associated with hypotension, low pulse pressure, low mean arterial pressure in older adults. The rate of CHF, and LDL elevation, which are clinically risk factors for CVD, was more common in the SO group. In the logistic regression analysis for SO, female gender, increased nighttime mean arterial pressure, and increased daytime pulse rate were found to be risk-related factors.

The rates found in our study were 8.9%, 21.4%, and 35.1% for sarcopenia only, obesity only, and SO, respectively, in women. In men it was 5.6%, 6.5% and 7.3%, respectively. In other studies on SO in older adults, the rates range from 0.1% to 85.3% (5,6,13,25-27). Due to the retrospective and cross-sectional design of our study, it is not possible to give the prevalence and therefore the frequency. It can only be used to determine the rate. In addition, the frequency of the female population and inpatients in our study stands out. Prospective studies with homogeneous distribution for gender would be more meaningful to determine complete data and the full efficacy of SO. One of the reasons why SO rates change so much is that a common equation is not used for the definition in the studies. SO definition in this respect is still a big problem. There are calls to create a definition and work with that definition (28,29).

Table 3. Logistic regression analysis for sarcopenia

	ß (odd ratio)	95% CI	p
Model 1			
Age	1.126	(1.073-1.181)	**<0.001***
BMI	0.845	(0.789-0.904)	**<0.001***
Model 2			
Daytime SBP (mmHg)	0.889	(0.809-0.977)	**0.014***
Night SBP (mmHg)	0.992	(0.948-1.039)	0.735
Mean arterial pressure (daytime)	1.122	(1.016-1.239)	**0.024***
Daytime pulse pressure	1.084	(1.002-1.175)	0.055
Night pulse pressure	0.939	(0.876-1.007)	0.079
Model 3			
Age	1.128	(1.074-1.184)	**<0.001***
BMI	0.856	(0.797-0.919)	**<0.001***
Daytime SBP (mmHg)	0.903	(0.839-0.972)	**0.007***
Mean arterial pressure (daytime)	1.112	(1.009-1.225)	**0.033***

CI: Confidence interval, BMI: Body mass index, SBP: Systolic blood pressure

Table 4. Logistic regression analysis for sarcopenic obesity

	ß (odd ratio)	95% CI	p
Model 1			
Gender[a]	3.556	(1.876-6.742)	**<0.001***
Model 2			
Mean arterial pressure (night)	0.0975	(0.953-0.998)	**0.034***
Pulse rate (daytime)	1.038	(1.015-1.063)	**<0.001***
Model 3			
Gender[a]	3.271	(1.695-6.314)	**<0.001***
Mean arterial pressure (night)	0.976	(0.953-1.012)	**0.046***
Pulse rate (daytime)	1.32	(1.007-1.057)	**0.012***

[a]: Be female, CI: Confidence interval

In our study, the highest BMI rate was found in the obese group, and the fat percentage rate was highest in the SO group. One of the most important problems of SO in older adults is the definition of obesity with BMI in the same way as in the general population. However, studies are showing that BMI is insufficient to define the impaired body composition in older adults and it is not an appropriate method, especially in sarcopenic individuals (6,26). In a review that summarizes how the definitions are made, it has been shown that both the definition of sarcopenia and the definition of obesity are made in different ways and that there is no internationally accepted limit value (29).

When the results of comprehensive geriatric assessment tests were examined, we found that Katz ADL and MNA scores were low in sarcopenic patients. In addition, we found that instrumental life activities and cognition were adversely affected in those with SO and may be associated with depression. In the study of Öztürk et al. (5), in which they examined the effects of SO on clinical conditions and quality of life, SO was found to be associated with low cognition and life activity scores, similar to the findings in our study. Scores related to instrumental life activities, cognition, and depression were found to be low in the sarcopenic obese group (5). Many studies since Baumgartner et al. (11), the first descriptor of the term SO, have shown that SO is associated with poor physical performance and reduced life activities compared to sarcopenia and obesity alone (6,25,30). There are also studies showing that SO is associated with malnutrition and cognition disorders (4,30,31). It appears that from clinical repercussions SO is associated with a worse condition than sarcopenia alone and obesity alone.

When laboratory data were examined, fasting blood glucose was lowest in the SO group. The highest was in the obesity group. High fasting blood glucose may be related to insulin resistance. Adding sarcopenia to obesity can shift people to the side of malnutrition. When the general laboratory results are examined, it is seen that nutritional values are low and inflammation values are high in the sarcopenic group. This again suggests that sarcopenia is the most prone to malnutrition and inflammation among the groups we examined. One of the common points of studies on the pathogenesis of sarcopenia and obesity suggests that there may be an underlying mild inflammatory condition, with proinflammatory cytokines secreted from adipose tissue and high lipid influx into muscle fibers. Several endocrine-hormonal, metabolic, and lifestyle aspects play a role in the formation of SO and ultimately influence the pathophysiological aspects that may contribute to the development of cardiovascular diseases and neoplasms (10).

It has been emphasized in some studies that SO can be associated with metabolic syndrome, diabetes mellitus, cardiovascular disease, dyslipidemia, and hypertension (6,13,14,28,32,33). It has been suggested that especially the sarcopenia component of SO may be associated with these diseases with many possible pathological mechanisms that have not yet been explained. Among these, neuronal and hormonal changes are mechanisms, as well as being underweight, malnutrition, low protein intake, physical inactivity, and inflammation (10). However, studies on risk factors for CVD and its effects on blood pressure are very limited. Cross-sectional studies have given inconsistent results (6). Some studies have found SO as a factor that increases the risk of CVD (9,14,15). Some studies have shown that there is no difference between a sarcopenic obese group and other groups (34,35). In the "Cardiovascular Health Study" analysis of Stephen and Janssen (36) which examined the relationship between SO and CVD risk over time, the risk of CVD events was not found to be significantly increased. A recent review showed a consistent association between SO and cardiovascular disease risk. It is also a fact that most of the articles compiled in this study are of cross-sectional design, which cannot evaluate a causal relationship. It is also stated that many studies on this subject have been done on Asian people, so the generalization may be limited (37).

In the results of 24-hour blood pressure monitoring, which was the main purpose of our study, in the sarcopenic group daytime and nighttime systolic blood pressure, daytime means arterial pressure, and daytime and nighttime pulse pressure were the lowest. Daytime and nighttime systolic blood pressure, and daytime and nighttime mean arterial pressure were highest and daytime pulse rate was lowest in the obese group. For the SO group, we found that this group had the lowest mean arterial pressure at night and the highest pulse rate during the day. In logistic regression analysis, high age increased BMI, increased daytime systolic blood pressure, and increased mean daytime arterial pressure was found to be factors that may be associated with sarcopenia. In analyses of SO, female gender increased nighttime mean arterial pressure, and increased daytime pulse rate was found to be risk-related factors. The lowest systolic blood pressure values were significantly found in the sarcopenic group. The relationship between sarcopenia and blood pressure has been a subject of interest before and has been studied. Some studies accept sarcopenia as a cardiovascular risk and find that it is associated with high blood pressure (38,39). In contrast, some studies found sarcopenia to be associated with hypotension and orthostatic hypotension (8,40). In a previous study from our group, we found that sarcopenia may be associated with low blood pressure in older adults who have fallen (41). In this new study, in which we examined the relationship between blood pressure and body composition, the female and hospitalized patient groups had a higher rate. These groups are likely to be frail older adults with poor physical performance, frailty, and prone to dependency. This difference between the patient groups may have affected the results.

It is seen that the obese group has relatively high blood pressure values. In light of this information, we may say that the group associated with low systolic blood pressure is the sarcopenia group, and the group associated with high systolic blood pressure is the obese group. Similar to the results in our study, the New Mexico Aging Process Study also showed that the rate of hypertension was higher in non-sarcopenic obese (42). In the case of sarcopenia, physical inactivity can lead to decreased energy and fat accumulation, especially in the abdominal area. This situation may be reflected in the clinic as a decrease in blood pressure. Conversely, it can be argued that abdominal obesity may lead to hypertension through cytokine activation (6,15).

From the mean arterial pressure measurements that were used as one of the predictors of adverse cardiovascular outcomes, the daytime value was the lowest in the sarcopenic group and the highest in the obese group, while the nighttime value was the lowest in the SO group and highest in the obese group. This result may associate high CVD risk with obesity. In the case of SO, the addition of sarcopenia to obesity appears to reduce the risk relatively. The question to be asked here is does the mean arterial pressure, which is known to be affected by arterial stiffness, really decrease in sarcopenia? What mechanism could this have? The answer to these questions may be the decrease in baroreceptor reflexes in sarcopenic patients and the low physical performance of this patient group as mentioned above. Although the values that increase the CVD risk seem to decrease sarcopenia in the results, it should be considered that these results may have different cut-off values in older adults and sarcopenic patients (41,43).

When the results of the relationship between pulse and pulse pressure are examined, the addition of sarcopenia may be associated with a relative risk reduction for CVD compared to obesity alone. In previous studies, it has been argued that high levels of these values are associated with poor cardiovascular prognosis. In older adults, increased systolic pressure may be due to increased stiffness in the aorta and other large arteries (44). However, there are also studies in which it has been determined that low pulse pressure can be an indicator of poor prognosis and mortality, especially in patients with heart failure. Just as the effects of obesity and being overweight on mortality in older adults are paradoxical, there may be a paradox in these cardiovascular markers. Indicators such as blood pressure, mean arterial pressure, pulse rate, and pulse pressure cannot be used as only a sign of arterial health in older adults since most older adults have malnutrition, neurological disorders, and many comorbidities.

These findings have shown that obesity may have more of an effect on raising blood pressure and mean arterial pressure in older adults. Sarcopenia and SO may be associated with decreased blood and pulse pressure and mean arterial pressure in older adults (45). SO is a relatively new definition. To determine the health problems it is associated with, first of all, a consensus should be reached on its definition and the methods to be used in the definition. Prospective studies involving a large number of participants in the geriatric population, especially including and comparing frail adults and also community-dwelling persons will be interesting and valuable.

Study Limitations

Our study had some limitations. First of all, due to the retrospective cross-sectional design of the study, a causal relationship could not be established between blood pressure values and sarcopenia-SO. Secondly, the results cannot be generalized to all geriatric patients because the rate of inpatients was high in the patient group. Further studies using a sample pool more similar to the general population are needed. Lastly, the BIA method could be affected by the hydration status of individuals. In addition, the accumulation of fat in muscle tissue in obese individuals may lead to a missed diagnosis of sarcopenia. Despite all these disadvantages, the BIA method is accepted as a valid, inexpensive, portable, and reliable method for measuring muscle mass with EWGSOP.

Besides some limitations of the study, there are also quite a few strong aspects. The diagnosis of sarcopenia was made according to the new criteria defined in EWGSOP-2. In the diagnosis of sarcopenia, not only muscle mass but also performance was evaluated. The diagnosis of SO is done with the fat percentage measured by BIA for the definition of obesity. The evaluations and comparisons of the patients were made in a versatile way with sociodemographic data, CGA tests, and, lab data. Blood pressures are not instantaneous data, but a 24-hour measurement. In addition, the participants were divided into four different groups and compared. Thus, the most related component to the investigated factors was determined.

Conclusion

We found that obesity may be more related to blood pressure and mean arterial pressure elevation. Sarcopenia and SO may be associated with hypotension, low pulse pressure, and low mean arterial pressure in older adults. The rate of CHF and LDL elevation, which are clinically risk factors for CVD, were more common in the SO group. In the logistic regression analysis for SO, the female gender increased nighttime mean arterial pressure, and increased daytime pulse rate were found to be risk-related factors. SO is a common and easily overlooked clinical syndrome in older people. Our study showed that these patients may also have cardiovascular risk factors. In the geriatric population, screening should be done by focusing not only on sarcopenia but also on SO.

Ethics

Ethics Committee Approval: Ethics approval and consent to participate: Approval for the study was obtained from the Local

Ethics Committee of the Ankara City Hospital with document number E1/1883/2021.

Informed Consent: Retrospective study.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Concept: V.A., R.B., D.M.S., H.S.Ö., Ç.C., A.Y., M.V., Design: V.A., R.B., D.M.S., T.Ö.T., Data Collection or Processing: H.S.Ö., T.Ö.T., V.A., Analysis or Interpretation: H.S.Ö., R.B., T.Ö.T., Ç.C., S.A., M.V., Literature Search: H.S.Ö., V.A., R.B., Ç.C., Writing: H.S.Ö., R.B.

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Supplementary Table 1. Logistic regression analysis for sarcopenia

	ß (odd ratio)	95% CI	p
Model 1			
Age	1.126	(1.073-1.181)	**<0.001***
Gender[a]	1.099	(1.042-1.159)	0.352
Diabetes mellitus	1.009	(0.607-3.184)	0.981
Congestive heart failure	1.390	(0.609-2.675)	0.436
Cerebrovascular event	1.180	(0.427-3.258)	0.479
Depression	0.354	(0.234-2.75)	0.647
Body mass index (kg/m^2)	0.845	(0.789-0.904)	**<0.001***
Fat mass percentage (%)	0.514	(0.165-1.307)	0.752

CI: Confidence interval, [a]: Be female

Supplementary Table 2. Logistic regression analysis for sarcopenic obesity

	ß (odd ratio)	95% CI	p
Model 1			
Age	1.101	(1.044-1.160)	0.647
Gender[a]	3.556	(1.876-6.742)	**<0.001***
Diabetes nellitus	1.137	(0.560-2.311)	0.722
Congestive heart failure	1.016	(0.459-2.250)	0.958
Cerebrovascular event	0.792	(0.302-2.076)	0.635
Body mass index (kg/m^2)	0.769	(0.703-0.840)	0.564
Fat mass percentage (%)	1.073	(1.032-1.117)	0.367

CI: Confidence interval, [a]: Be female