J Korean Soc Phys Med, 2023; 18(3): 11-19
https://doi.org/10.13066/kspm.2023.18.3.11

Online ISSN: 2287-7215
Print ISSN: 1975-311X

Research Article

Open Access

Exploring Incidence and Potential Risk Factors of Sarcopenic Obesity Among Middle-Aged Women Residing in a Community

Jongseok Hwang, PT, Ph.D. · Il-Young Moon, PT, Ph.D.[1†]

Institute of Human Ecology, Yeungnam University
[1]Wonju Severance Christian Hospital

Received: May 26 2023 / Revised: May 26 2023 / Accepted: June 1 2023

| Abstract |

PURPOSE: This study evaluated the incidence of sarcopenic obesity (SO) and examined the specific risk factors in a community-dwelling middle-aged population of women.

METHODS: The present study involved analyzing data from a cross-sectional study that included 1,693 community-dwelling women aged between 40 and 49 years. Various risk factors were investigated, including age, height, weight, body mass index, waist circumference, skeletal muscle mass index, smoking and drinking behaviors, systolic and diastolic blood pressure, fasting glucose levels, as well as triglyceride and cholesterol levels. To ensure the accuracy and validity of the results, a complex sampling technique was employed for data analysis. Each sample weight was calculated through a three-step process by estimating base weight, adjusting it for non-response, and modulating it for post-stratification.

RESULTS: The incidence of SO was 4.26% (95% CI: 3.20-5.67%). The clinical risk factors for SO were age, height, weight, body mass index, waist circumference, skeletal muscle mass index, systolic blood pressure, diastolic blood pressure, and levels of fasting glucose, triglycerides, and total cholesterol ($p < .05$).

CONCLUSION: This study explores the prevalence and risk factors of SO among community-dwelling women. It adds to the existing literature on SO and identifies potential risk factors in middle-aged women.

Key Words: Odds ratios, Prevalence, Risk factors, Sarcopenic obesity

Ⅰ. Introduction

Sarcopenic obesity (SO) is a clinical condition characterized by the coexistence of sarcopenia and obesity [1]. Sarcopenia is a condition associated with an age-related decline in muscle mass, strength, and/or physical function, and obesity is characterized by the excessive accumulation of fat mass. Decreased physical function and impaired metabolic function result in a poor quality of life, and raise

†Corresponding Author : Il-Young Moon
ansdlfdud@naver.com, https://orcid.org/0000-0001-6457-8125

the risk of mortality in individuals with SO [2].

There has been a substantial increase in the aging population in Asia, and Korea stands out as a country with the largest proportion of older individuals. The elderly population in Korea will constitute around 40% of the total population by 2050, which is a significant rise from 15% in 2022. This demographic shift would translate into a surge in the number of elderly citizens, with estimates reaching nineteen million compared to the current five million [3]. Consequently, there is likely to be an increase in the incidence of age-related complications, including sarcopenia, which could pose a significant threat to Korean society. Additionally, the prevalence of obesity in Korea has been consistently increasing since 2009, especially among the elderly female population [4]. The rise in the obese population among the elderly, along with the growth in the elderly population as a whole, suggests that the risk of SO in Korea is also increasing. Thus, it has become important to prevent SO among elderly Koreans.

The combination of obesity and low muscle mass has a negative impact on health and contributes to the development of chronic diseases and disability. This could lead to longer hospital stays, which is a burden for health initiatives and policymaking. Research indicates that individuals with SO have poorer health outcomes compared to those who only have low muscle mass or obesity [5,6]. Additionally, diagnosing and identifying the clinical consequences of this condition can be difficult because obesity can interfere with the generation and maintenance of muscle mass [7].

Although SO is an important condition with poor health outcomes, healthcare professionals and primary care clinicians often lack the knowledge and diagnostic tools required for its diagnosis. Due to time constraints, primary care clinicians typically spend less than ten minutes per patient visit and may only consider referring a patient for diagnosis and treatment of SO if they suspect that the individual may have this condition. The clinicians' limited knowledge about SO as a disease increases the likelihood of missing the diagnosis [8]. Understanding the key risk factors associated with early detection and prevention is vital to ensure early diagnosis of SO. Failure to diagnose and intervene early in cases of SO can result in poor functional recovery, reduced quality of life, and a waste of government healthcare resources [9].

SO is more prevalent among women as compared to men [10,11]. In an observational study of 2,917 adults by Newman et al. [10] in the United States, women were found to have a higher prevalence of SO compared to men, with rates of 14.5% and 11.5%, respectively. Stenholm et al. [11] assessed 1,189 individuals in the Netherlands and reported incidence rates of 5.1% for men and 5.9% for women. In other words, women were found to be more susceptible to SO than men.

The identification of risk factors and the effective management of SO in the female population continue to present challenges. These challenges are particularly pronounced when comparing the available research on SO in this population to the well-established studies conducted on men [12-14].

In addition, the majority of research studies conducted on SO have primarily centered around individuals who are 50 years and older [6,15-17]. However, emerging evidence indicates that sarcopenia and obesity can initiate as early as the 40s [18-23]. Given the importance of early prevention strategies for age-related muscle loss, it has become essential to identify the risk factors in middle-aged women.

The objective of this study was to evaluate the prevalence and risk factors associated with SO in a community-dwelling female population aged 40 to 49 years. The research hypotheses proposed two potential outcomes. Firstly, the study hypothesized that there would be a specific incidence of SO in middle-aged women residing in the community. Secondly, the study assumed that there would be specific risk factors associated with the development of SO in this age group of women.

Ⅱ. Methods

1. Research Subjects and Data Sampling

The data used in this study was collected from the Korea National Health and Nutrition Examination Surveys (KNHANES), which are conducted by the Korea Centers for Disease Control and Prevention (KCDC). To ensure representative nationwide sampling, a stratified, clustered, multistage probability sampling design was employed.

Between 2008 and 2011, a total of 37,753 individuals participated in the survey. However, for this particular study, 34,123 individuals were excluded from the analysis because they did not fall within the age range of 40 to 49 years. This resulted in a final sample size of 3,630 participants. The study excluded 1,937 participants who did not undergo a dual-energy X-ray absorptiometry (DEXA) examination or did not provide responses to the health survey. Ultimately, the final analysis focused on a subset of 1,693 women aged between 40 and 49 years. Based on their skeletal muscle mass index score, the participants were divided into two groups. The SO group included 62 individuals, while the normal group comprised the remaining 1,693 individuals. For inclusion in the SO group, the women participants had to meet two criteria: (1) age between 40 and 49 years, and (2) the presence of both sarcopenia and obesity. In contrast, the normal group consisted of women participants who met the following criteria: (1) age between 40 and 49 years, and (2) not suffering from either sarcopenia or obesity. Exclusion criteria were (1) pregnant women, and (2) individuals who had undergone a diagnostic procedure involving the use of a contrast agent in the week prior to the survey. Ethical considerations were also taken into account. The study received approval from the institutional review board of the KCDC, and all participants provided informed written consent.

2. Research Variables

The study incorporated a range of variables for analysis. These variables included age, height (measured in centimeters), weight (measured in kilograms), body mass index (BMI), waist circumference (WC), skeletal muscle index (SMI), smoking and drinking status, fasting glucose (FG), triglyceride and total cholesterol (TC) levels, and systolic (SBP) and diastolic blood pressure (DBP).

WC was measured by determining the circumference at the midpoint between the bottom of the ribcage and the top of the iliac crest during full expiration. The blood tests were conducted after an eight-hour fast, and systolic and diastolic blood pressures were measured using a mercury sphygmomanometer after a ten-minute rest in a chair. Participants were divided into three groups based on their smoking and drinking status, namely, non-users, ex-users, or current users. These variables were included to assess their relationship with SO and to examine potential associations with other health markers in the study population.

3. Diagnosis of SO

A diagnosis of SO is made when both sarcopenia and obesity are present as defined below:

Sarcopenia has been officially recognized as a muscle disorder by the World Health Organization (WHO) with a specific code (M62.84) from the 10th revision of the International Classification of Diseases (ICD-10). It is diagnosed based on the measurement of the appendicular skeletal muscle mass (ASM). The assessment of ASM was carried out using DEXA with the QDR4500A machine (Hologic, Inc., Bedford, MA, USA). The SMI was calculated by dividing the ASM (measured in kilograms) by the BMI expressed in kilograms per square meter (kg/m^2). The Foundation for the National Institutes of Health (FNIH) Sarcopenia Project guidelines were followed to establish the criteria for the sarcopenia diagnosis. As per these guidelines, sarcopenia in women was defined as an SMI of less than 0.521 [24]. By employing this methodology, the study ensured accurate diagnosis of

sarcopenia within the examined population, relying on the specific SMI thresholds provided by the Foundation for the National Institutes of Health Sarcopenia Project.

Obesity is described as the abnormal or excessive accumulation of fat in the body, which can have detrimental effects on health. It is typically identified by certain criteria, such as having a BMI equal to or greater than 25 kg/m^2, and central obesity, which is determined by a WC exceeding 80 cm among Asian women [25].

4. Data Analysis

The statistical analysis in this study involved presenting the mean and standard deviation as measures of central tendency and variability for each variable. Data analysis was performed using SPSS 22.0, a software developed by the IBM Corporation in Armonk, NY, USA. Weight values were applied in this study to accurately represent the entire population of Korea. Each participant was assigned a sample weight through a three-step process: (1) calculating a base weight, (2) adjusting for non-responses, and (3) post-stratification adjustment to match the population distribution from the previous census. A complex sampling analysis technique was utilized for all data analyses, taking into account the weighted nature of the sample. To compare variables between the SO and normal groups, independent t-tests were conducted for parametric variables, while Chi-square tests were employed for non-parametric variables. Additionally, multiple logistic regression analyses were performed, incorporating adjusted covariates, to predict SO and determine the odds ratio (OR) of the SO risk factors for women. The significance level for all variables was set at 0.05, adhering to the predetermined alpha level for statistical significance.

Ⅲ. Results

1. Prevalence of SO

The weighted value of SO was estimated to be 4.26% (95% CI: 3.20-5.67%). The unweighted occurrence of SO was found to be 3.66%, while the normal group accounted for 96.34% of the subjects. The prevalence of SO is presented in Table 1.

2. Clinical Risk Factors

Age, height, weight, BMI, WC, SMI, SBP, DBP, drinking status, levels of FG, triglycerides, and TC demonstrated statistical significance as risk factors ($p < .05$). On the other hand, the smoking status variable was not statistically significant ($p > .05$) (Table 2).

Table 1. Prevalence of sarcopenic obesity among community-dwelling women

	SO group (n = 62)	Normal group (n = 1,631)	Total (N = 1,693)
Un-weighted (%)	3.66	96.34	100
Weighted (%)	4.26 (3.20-5.67)	95.74 (94.33-96.81)	100

Weighed values present the 95% confidence interval.

Table 2. Clinical risk factors related to sarcopenic obesity

	SO group (n = 62)	Normal group (n = 1,631)	p
Age (years)	45.33 ± 2.92	44.38 ± 2.96	.012
Height (cm)	151.77 ± 3.74	158.27 ± 4.87	.000
Weight (kg)	68.46 ± 8.47	58.02 ± 9.10	.000
BMI (kg/m^2)	29.67 ± 3.11	23.14 ± 3.33	.000
WC (cm)	91.97 ± 7.89	76.48 ± 8.89	.000

Table 2. (Continued)

	SO group (n = 62)	Normal group (n = 1,631)	p
SMI (kg/m^2)	.48 ± .03	.65 ± .07	.000
SBP (mmHg)	122.30 ± 15.31	112.01 ± 14.74	.000
DBP (mmHg)	79.33 ± 10.08	74.16 ± 10.08	.000
Drinking status (%) (current-/ex-/non-drinker)	59.58 / 24.13 / 16.29	57.45 / 16.00 / 26.54	.003
Smoking status (%) (current-/ex-/non-smoker)	4.48 / 3.29 / 92.22	6.82 / 1.60 / 91.57	.197
FG (mg/dL)	127.24 ± 67.35	103.49 ± 68.99	.008
Triglycerides (mg/dL)	195.34 ± 33.58	185.47 ± 32.47	.020
TC (mg/dL)	122.30 ± 15.31	112.01 ± 14.74	.000

SO: Sarcopenic obesity; BMI: body mass index; WC: waist circumference; SMI: skeletal muscle mass index; SBP: systolic blood pressure; DBP: diastolic blood pressure; FG: fasting glucose; TC: total cholesterol.
Values are expressed as the mean ± standard deviation. The independent t-test and chi-square test were used in the analysis.

3. Multiple Logistic Regression for Odds Ratio (OR)

Table 3 shows the OR with a 95% confidence interval (CI) for SO in women, based on multiple logistic regression analysis. Statistically significant differences were observed between the two groups for variables including age, height, weight, BMI, WC, SMI, SBP, DBP, and FG levels ($p < .05$). The relevant values were 1.81(1.16-3.03), .44(.28-.70), 142.92(72.15-283.10), 11.30(8.70-14.57), 1.74(1.45-2.09), .10(.08-.19), 2.55(2.06-3.16), 9.97(7.35-13.53), and 1.08 (1.05-1.11), respectively.

Table 3. Multiple logistic regression for estimating the odds ratios of sarcopenic obesity (SO)

Variables	Odds ratios (95% of CI)	p
Age	1.81 (1.16-3.03)	.019
Height	.44 (.28-.70)	.000
Weight	142.92 (72.15-283.10)	.000
BMI	11.30 (8.70-14.57)	.000
WC	1.74 (1.45-2.09)	.000
SMI	.10 (.08-.19)	.000
SBP	2.55 (2.06-3.16)	.000
DBP	9.97 (7.35-13.53)	.000
FG	1.08(1.05-1.11)	.000

SO: Sarcopenic obesity; BMI: body mass index; WC: waist circumference; SMI: skeletal muscle mass index; SBP: systolic blood pressure; DBP: diastolic blood pressure; FG: fasting glucose.

Ⅳ. Discussion

The present study investigated SO prevalence and risk factors in community-dwelling middle-aged women in Korea. The weighted prevalence of SO was 4.26% (95%CI: 3.20-5.67%). The clinical risk factors for SO were age, height, weight BMI, WC, SMI, SBP, DBP, drinking status, FG, triglycerides, and TC.

The prevalence of middle-aged women with SO was 4.26% (95%CI: 3.20-5.67%). This finding is in line with a study by Moreira et al. [26], who investigated a group of 491 middle-aged women from Northeast Brazil and reported a prevalence of 7.1% for SO.

Elevated FG levels have been identified as a risk factor for SO in women, consistent with findings from several studies [27-29] For instance, Du et al. [29] conducted a study in East China, involving approximately 600 adults

living in the community and found that women with SO had higher glycemic levels compared to those without SO. Similarly, another study on 565 people, conducted by Lim et al. reported that women with SO exhibited higher FG levels compared to women without SO [27]. Additionally, Lu et al. [28] conducted a study on a target population in Taiwan that reported higher FG levels in individuals with SO compared to those without SO. Skeletal muscle plays a crucial role in regulating glucose levels following a meal. After ingestion, the skeletal muscle is responsible for absorbing a substantial amount of glucose through various mechanisms involving both insulin-dependent and insulin-independent processes. These entail the transportation of glucose from the bloodstream to the muscle, its passage through different cellular barriers, and its distribution within the muscle cells. The uptake of glucose by the muscle is facilitated by glucose transporters, which are regulated by intracellular glucose metabolism and rely on the glucose concentration gradient [30]. Consequently, impaired carbohydrate metabolism can impede glucose uptake by skeletal muscles, thereby impacting postprandial glucose levels.

Elevated triglyceride levels were observed to be a risk factor for SO, which is similar to findings from previous SO studies [28,29]. Du et al. [29] conducted a study on community-dwelling adults and found that individuals with SO had higher triglyceride levels compared to the normal group, while no significant differences were observed between the SO and normal groups among women. Similarly, in a study by Lu et al. involving Taiwanese community-dwelling adults with an average age of 63.6, significant elevations in triglyceride levels were observed in the SO group compared to the normal group [28].

Elevated total cholesterol serves as a risk factor for women with SO, a finding supported by several studies [28,31,29]. In a cross-sectional study conducted in eastern China [29], it was observed that female participants with SO exhibited higher total cholesterol levels compared to those in the normal group. Consistently, Lu et al. [31] also reported elevated cholesterol levels in the SO group compared to the normal group. Another investigation by Perna et al. [31] focused on over 600 Italian subjects and found that the SO group demonstrated significantly higher total cholesterol levels in their blood compared to the healthy group. One possible explanation is that the elevated triglycerides and total cholesterol values, as well as the increased total cholesterol levels, could be attributed to insulin resistance [32] and higher levels of inflammatory cytokines [33].

Another risk factor we found was alcohol consumption status. This outcome is in line with several earlier studies [34,35]. Daskalopoulou et al. [34] analyzed the bioclinical and lifestyle factors in adults with SO and concluded that alcohol consumption was a risk factor for SO. A meta-analysis conducted by Steffl. [35] also reported that alcohol consumption was a risk factor for SO. A plausible reason is that the effects of alcohol are mediated by a decrease in protein synthesis, which is influenced by impaired activity of the protein kinase called the mechanistic target of rapamycin (mTOR). In this overview, we present recent developments in mTOR signal transduction and examine the similarities and differences in how alcohol affects this vital metabolic regulator in the skeletal muscle and the heart, considering both acute and chronic alcohol intake. Although the impact of alcohol on global protein breakdown through the ubiquitin-proteasome pathway is unclear, emerging data suggest that alcohol enhances autophagy in the muscle [36].

Hypertension, both high SBP and DBP are risk factors for SO. This result is consistent with several research outcomes reported earlier [28,37]. A northwest Chinese cohort study [37] demonstrated that SBP in women with SO was elevated (136.69 mmHg) compared to women in the normal SBP group (130.58 mmHg). Additionally, the DBP among women in the SO group was also higher than that of the normal group, with respective values of 83.63

mmHg and 76.65 mmHg. Likewise, the individuals in the SO group had higher DBP levels, measuring 80.6 mmHg, in comparison to the normal group, which exhibited a DBP of 76.2 mmHg. Lu et al. [28] investigated 600 Taiwanese community-dwelling adults and observed that the SO group exhibited SBP levels of 132.3 mmHg or higher, while the normal population had SBP levels of 125.7 mmHg. The DBP in the SO group was elevated, with a measurement of 80.6 mmHg, in contrast to 76.2 mmHg in the normal group.

There are several potential underlying reasons for these findings. First, muscle loss is closely associated with metabolic changes and is linked to decreased energy expenditure and physical inactivity, leading to insulin resistance and arterial stiffness [38-40]. Additionally, increased visceral fat mass triggers an inflammatory response, thickens blood vessel walls, obstructs blood flow, and narrows vascular passages [41]. A lower level of skeletal muscle mass and a higher level of adipose tissue are significant causative factors leading to hypertension in women [42]. The combination of low muscle mass and an increased accumulation of adipose tissue in the visceral area may contribute to higher SBP and DBP in women with SO.

The findings of this study offer valuable insights into the occurrence and specific risk factors of SO among adults, specifically women residing in the community. The study utilizes representative data from the Korean population and employs the gold standard DEXA measurement technique to accurately diagnose SO. However, it is important to recognize the study's limitations, which should be taken into consideration in future research. The cross-sectional design of the study limits its ability to establish a definitive causal relationship. To enhance the research's validity, a longitudinal design involving repeated measurements of the same individuals at different time points would strengthen the findings. Furthermore, due to the scarcity of studies focusing on middle-aged women with SO, it becomes challenging to make meaningful comparisons with other studies in the discussion section regarding the prevalence and other risk factors within this age group.

Ⅴ. Conclusion

This study provides the prevalence and clinical risk factors for SO among Korean community-dwelling middle-aged women. The prevalence of SO in females was 4.26% (95% CI: 3.20-5.67%). The clinical risk factors for SO were age, height, weight, BMI, WC, SMI, SBP, DBP, drinking status, levels of FG, triglycerides, and TC. Future studies employing a longitudinal design that involves measuring the same individuals at multiple time points would greatly enhance this study's credibility and would provide more robust evidence, thus strengthening the validity of its findings.

References

[1] Donini LM, Busetto L, Bischoff SC, et al. Definition and diagnostic criteria for sarcopenic obesity: ESPEN and EASO consensus statement. Obesity Facts. 2022;15(3):321-35.

[2] Donini LM, Busetto L, Bauer JM, et al. Critical appraisal of definitions and diagnostic criteria for sarcopenic obesity based on a systematic review. Clin Nutr. 2020;39(8): 2368-88.

[3] Kulik CT, Ryan S, Harper S, et al. Aging populations and management. Academy of Management Briarcliff Manor, NY. 2014.

[4] Yang YS, Han B-D, Han K, et al. Obesity fact sheet in Korea, 2021: trends in obesity prevalence and obesity-related comorbidity incidence stratified by age from 2009 to 2019. Journal of Obesity & Metabolic Syndrome. 2022;31(2):169.

[5] Roubenoff R. Sarcopenic obesity: the confluence of two epidemics. Obesity. 2004;12(6):887.

[6] Zhang X, Xie X, Dou Q, et al. Association of sarcopenic obesity with the risk of all-cause mortality among adults over a broad range of different settings: a updated meta-analysis. BMC Geriatr. 2019;19(1):1-14.

[7] Prado CM, Siervo M, Mire E, et al. A population-based approach to define body-composition phenotypes. The American journal of clinical nutrition. 2014;99(6): 1369-77.

[8] Reijnierse EM, de van der Schueren MAE, Trappenburg MC, et al. Lack of knowledge and availability of diagnostic equipment could hinder the diagnosis of sarcopenia and its management. PLoS One. 2017;12(10):e0185837.

[9] Mehiret G, Molla A, Tesfaw A. Knowledge on risk factors and practice of early detection methods of breast cancer among graduating students of Debre Tabor University, Northcentral Ethiopia. BMC Womens Health. 2022; 22(1):183.

[10] Newman AB, Kupelian V, Visser M, et al. Sarcopenia: alternative definitions and associations with lower extremity function. J Am Geriatr Soc. 2003;51(11): 1602-9.

[11] Stenholm S, Harris TB, Rantanen T, et al. Sarcopenic obesity-definition, etiology and consequences. Curr Opin Clin Nutr Metab Care. 2008;11(6):693.

[12] Atkins JL, Whincup PH, Morris RW, et al. Sarcopenic obesity and risk of cardiovascular disease and mortality: a population-based cohort study of older men. J Am Geriatr Soc. 2014;62(2):253-60.

[13] Hirani V, Naganathan V, Blyth F, et al. Longitudinal associations between body composition, sarcopenic obesity and outcomes of frailty, disability, institutionalisation and mortality in community-dwelling older men: The Concord Health and Ageing in Men Project. Age and ageing. 2017;46(3):413-20.

[14] Sanada K, Chen R, Willcox B, et al. Association of sarcopenic obesity predicted by anthropometric measurements and 24-y all-cause mortality in elderly men: The Kuakini Honolulu Heart Program. Nutrition. 2018;46:97-102.

[15] Hwang J, Park S. Gender-specific risk factors and prevalence for sarcopenia among community-dwelling young-old adults. Int J Environ Res Pub Heal. 2022;19(12):7232.

[16] Hwang J, Park S. Sex Differences of sarcopenia in an elderly asian population: the prevalence and risk factors. Int J Environ Res Pub Heal. 2022;19(19):11980.

[17] Hwang J, Park S. Gender-specific prevalence and risk factors of sarcopenic obesity in the Korean elderly population: a nationwide cross-sectional study. Int J Environ Res Pub Heal. 2023;20(2):1140.

[18] Lexell J, Downham D, Sjostrom M. Distribution of different fibre types in human skeletal muscles. Fibre type arrangement in m. vastus lateralis from three groups of healthy men between 15 and 83 years. J Neurol Sci. 1986;72(2-3):211-22.

[19] Kehayias JJ, Fiatarone MA, Zhuang H, et al. Total body potassium and body fat: relevance to aging. Am J Clin Nutr. 1997;66(4):904-10.

[20] Janssen I, Heymsfield SB, Wang ZM, et al. Skeletal muscle mass and distribution in 468 men and women aged 18-88 yr. J Appl Physiol. 2000;89(1):81-8.

[21] Janssen I, Heymsfield SB, Ross R. Low relative skeletal muscle mass (sarcopenia) in older persons is associated with functional impairment and physical disability. J Am Geriatr Soc. 2002;50(5):889-96.

[22] Cruz-Jentoft AJ, Bahat G, Bauer J, et al. Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing. 2019;48(1):16-31.

[23] National Health and Nutrition Examination Survey 2017–March 2020 Prepandemic Data Files Development of Files and Prevalence Estimates for Selected Health Outcomes. In: National Center for Health S, National Health Statistics Reports. Hyattsville, MD.

[24] Studenski SA, Peters KW, Alley DE, et al. The FNIH sarcopenia project: rationale, study description, conference recommendations, and final estimates. J Gerontol A Biol

Sci Med Sci. 2014;69(5):547-58.

[25] World Health Organization. Regional office for the western p. the asia-pacific perspective: redefining obesity and its treatment. Sydney: Health Communications Australia. 2000.

[26] Moreira MA, Zunzunegui MV, Vafaei A, et al. Sarcopenic obesity and physical performance in middle aged women: a cross-sectional study in Northeast Brazil. BMC Public Health. 2016;16:43.

[27] Lim S, Kim JH, Yoon JW, et al. Sarcopenic obesity: prevalence and association with metabolic syndrome in the Korean Longitudinal Study on Health and Aging (KLoSHA). Diabetes Care. 2010;33(7):1652-4.

[28] Lu CW, Yang KC, Chang HH, et al. Sarcopenic obesity is closely associated with metabolic syndrome. Obes Res Clin Pract. 2013;7(4):e301-7.

[29] Du Y, Wang X, Xie H, et al. Sex differences in the prevalence and adverse outcomes of sarcopenia and sarcopenic obesity in community dwelling elderly in East China using the AWGS criteria. BMC Endocr Disord. 2019;19(1):109.

[30] Hulett NA, Scalzo RL, Reusch JEB. Glucose uptake by skeletal muscle within the contexts of type 2 diabetes and exercise: an integrated approach. Nutrients. 2022;14(3).

[31] Perna S, Peroni G, Faliva MA, et al. Sarcopenia and sarcopenic obesity in comparison: prevalence, metabolic profile, and key differences. A cross-sectional study in Italian hospitalized elderly. Aging Clin Exp Res. 2017;29(6):1249-58.

[32] Cleasby ME, Jamieson PM, Atherton PJ. Insulin resistance and sarcopenia: mechanistic links between common co-morbidities. J Endocrinol. 2016;229(2):R67-81.

[33] Schrager MA, Metter EJ, Simonsick E, et al. Sarcopenic obesity and inflammation in the InCHIANTI study. J Appl Physiol. 2007;102(3):919-25.

[34] Daskalopoulou C, Wu YT, Pan W, et al. Factors related with sarcopenia and sarcopenic obesity among low- and middle-income settings: the 10/66 DRG study. Sci Rep. 2020;10(1):20453.

[35] Steffl M, Bohannon RW, Petr M, et al. Alcohol consumption as a risk factor for sarcopenia - a meta-analysis. BMC Geriatr. 2016;16:99.

[36] Kimball SR, Lang CH. Mechanisms underlying muscle protein imbalance induced by alcohol. Annu Rev Nutr. 2018;38:197-217.

[37] Yin T, Zhang JX, Wang FX, et al. The association between sarcopenic obesity and hypertension, diabetes, and abnormal lipid metabolism in chinese adults. Diabetes Metab Syndr Obes. 2021;14:1963-73.

[38] Ferreira I, Snijder MB, Twisk JW, et al. Central fat mass versus peripheral fat and lean mass: opposite (adverse versus favorable) associations with arterial stiffness? the amsterdam growth and health longitudinal study. J Clin Endocrinol Metab. 2004;89(6):2632-9.

[39] Snijder MB, Henry RM, Visser M, et al. Regional body composition as a determinant of arterial stiffness in the elderly: The Hoorn Study. J Hypertens. 2004;22(12): 2339-47.

[40] Dominguez LJ, Barbagallo M. The cardiometabolic syndrome and sarcopenic obesity in older persons. J Cardiometab Syndr. 2007;2(3):183-9.

[41] Goswami B, Reang T, Sarkar S, et al. Role of body visceral fat in hypertension and dyslipidemia among the diabetic and nondiabetic ethnic population of Tripura-A comparative study. J Family Med Prim Care. 2020;9(6):2885-90.

[42] Bredella MA. Sex differences in body composition. Sex and gender factors affecting metabolic homeostasis, Diab Obes. 2017:9-27.