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Research Article

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Prevalence, Anthropometric Risk Factors, and Clinical Risk Factors in Sarcopenic Women in Their 40s

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| Abstract |

PURPOSE: This study examined the anthropometric and clinical risk factors and the prevalence of sarcopenia in women aged 40 to 49 years.

METHODS: The study design is a cross-sectional research and a total of 2,055 participants were included. The participants were divided into two groups based on their skeletal muscle mass index score. One hundred and twenty-six individuals were assigned to a sarcopenia group, and 1,939 were assigned to a normal group. The following variables were analyzed: age, height, weight, body mass index, waist circumference, skeletal muscle mass index anthropometric measure, systolic blood pressure, diastolic blood pressure, blood laboratory tests, fasting glucose, triglyceride, total cholesterol, and smoking and drinking smoking statuses.

RESULTS: The prevalence of sarcopenia was 6.5% (95% CI: 5.33−7.92). Anthropometric variables, such as height, BMI, and waist circumference, showed significance differences between the two groups ($p < .05$), except for weight variable ($p > .05$). In terms of blood pressure and blood lab tests, the systolic blood pressure, diastolic blood pressure, fasting glucose, triglyceride, and total cholesterol were all significant risk factors for sarcopenia in the two groups. ($p < .05$).

CONCLUSION: This study identified risk factors and the prevalence of sarcopenia among community-dwelling middle-aged women.

Key Words: Odd ratios, Prevalence, Risk factors, Sarcopenia

Ⅰ. Introduction

Sarcopenia is characterized by the age-related reduction of the skeletal muscle mass, leading to diminished muscle strength, function, and quality of life [1]. Although the precise mechanism of sarcopenia is not completely understood, various studies have suggested that hormonal changes, immobility, age-related muscle changes, nutrition, and neurodegenerative factors may contribute to its development. Elderly individuals aged 65 years and above are more susceptible to sarcopenia [2]. Skeletal muscle loss starts at the age of 40, with a yearly decline of 1−2%, which increases to 3% per year after the age of 65 [3].

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The proportion of elderly individuals in Asia is increasing rapidly, and Korea is facing the highest rate of aging globally. In 2021, 16.5% of the Korean population was aged 65 years or older, which is expected to surge to 39.8% by 2050 [3]. As a result, age-related ailments, such as sarcopenia, will have a more significant effect in Korea and Asia than in other countries.

Multiple studies have found that the prevalence of sarcopenia is higher in females than in males. Dam et al., who screened 10,063 individuals, reported a prevalence of 11.80% in women and 5.10% in men [4,5]. Hunt et al. examined 1,921 Japanese individuals living in the community and reported a prevalence of sarcopenia of 16.56% in females and 10.34% in males [5].

A large population of older adults are at risk of sarcopenia, particularly females in Korea. The early detection in female sarcopenia patients is still challenging compared to the extensive studies on sarcopenia in males [6-9]. Despite the potential negative consequences associated with sarcopenia and the increasing female elderly population, healthcare professionals, including physical therapists and primary care clinicians, face challenges in diagnosing sarcopenia because of inadequate knowledge and diagnostic tools. With limited time per patient visit, primary care clinicians must assess the likelihood of a patient having sarcopenia before considering referral for diagnosis and treatment. Furthermore, the lack of awareness of sarcopenia as a disease among clinicians increases the risk of missed diagnoses [10]. Understanding the characteristics of key risk factors related to early detection and prevention is essential to address this challenge effectively [11]. The timely detection of symptomatic individuals can significantly impact early diagnosis and intervention, as delayed or missed diagnoses can lead to complications, such as poor functional recovery, reduced quality of life, and wasted healthcare resources.

On the other hand, most sarcopenia studies focused on individuals over 50 years of age, even though age-related muscle loss can begin in the 40s. Identifying the risk factors for muscle loss earlier is essential to preventing and treating this condition. Thus, this study examined the risk factors and prevalence of sarcopenia in middle-aged women between 40 and 49 years of age. The hypothesis was that the specific risk factors were unique to this age group.

Ⅱ. Methods

1. Participants

The current research relied on data collected from the Korea National Health and Nutrition Examination Surveys, a survey designed to monitor health-risk behaviors in the population, and conducted by the Centers for Disease Control and Prevention. The data used a stratified, clustered, multistage probability sampling design. A total of 37,753 individuals participated in the survey between 2008 and 2011. Of these, 34,123 individuals were excluded from the study because they were below 40 or above 49 years old, leaving 3,630 participants. One thousand five hundred and seventy-five subjects were excluded from the study because there was no available data on their health surveys and dual X-ray absorptiometry. In addition, 2,055 women aged between 40 and 49 years old were included in the final analysis. The participants were divided into two groups based on their skeletal muscle mass index score: 126 and 1,939 individuals assigned to a sarcopenia and normal group, respectively. The institutional review board of the Center for Disease Control and Prevention approved the study, and all participants provided informed written consent.

2. Diagnosis of Sarcopenia

Sarcopenia is a medical condition with an ICD-10-CM code of M62.84 diagnosed based on measuring the appendicular skeletal muscle mass. Dual X-ray absorptiometry (DEXA, QDR4500A, Hologic, Inc. Bedford, MA, USA) was used to assess the appendicular skeletal muscle mass (ASM). The skeletal muscle mass

index (SMI) was calculated as the ratio of ASM (in kg) to BMI (in kg/m^2). Sarcopenia was defined as having an SMI of less than .789 in men and less than .521 in women based on the criteria established by the Foundation for the National Institutes of Health Sarcopenia Project [12]. This methodology was used to diagnose sarcopenia in the study population.

3. Variables

1) Anthropometric Variables

Anthropometric measurements were obtained. All subjects participating in the study were asked to remove their shoes, socks, hat, and hairpins and wear light clothing. The height and weight were measured using calibrated automatic body measurement equipment, with the measurements recorded to the nearest .1 cm or kg. The body mass index (BMI) was then calculated by dividing the weight (kg) by height squared (m^2). The waist circumference (WC) was measured to the nearest .1 cm in a horizontal plane at the midline between the last rib and the iliac crest at the end of a normal expiration [13].

2) Blood Pressure and Blood Lab Tests Variables

A trained practitioner measured the systolic blood pressure (SBP) and diastolic blood pressure (DBP) using a mercury sphygmomanometer, with the blood pressure cuff positioned at heart level while subjects were seated after at least five minutes of rest. The blood lab test included the fasting glucose (FG), triglyceride, and total cholesterol (TC) levels, which were analyzed and measured on a LABOSPECT 008AS platform (Hitachi High-Tech Co., Tokyo, Japan). The blood samples were collected from the non-dominant arm after an overnight fast of at least eight hours. The collected blood was mixed immediately with a coagulation promoter and centrifuged in a mobile examination vehicle. All tests were analyzed within 24 hours of sample collection.

3) Drinking Smoking Variables

The smoking and drinking status data were collected by a survey. Cigarette smokers and alcohol drinkers were categorized into three domains: non-user, ex-user, or current user. These measurements and variables are important for evaluating the various aspects of health and disease risk in the study population.

4. Data Analysis

This study presents all statistical values as the mean and standard deviation for each measurement. The study used complex sampling analysis, representing Korean national-wide analysis incorporating the individual weights provided by KNHANES. SPSS 22.0 window version (IBM Corporation Armonk, NY, USA) was used for statistical analysis. The data used a stratified, clustered, multistage probability sampling design. Independent t-tests and chi-square analyses were employed to compare the chemical parameters of the sarcopenia and non-sarcopenia participants, and multiple logistic regression was used to calculate the odds ratio of sarcopenia. The statistical significance level was set at $p = .05$.

Ⅲ. Results

1. Prevalence

The prevalence of sarcopenia, as weighted values, was 6.5% (95% CI: 5.33–7.92), as shown in Table 2. The unweighted sarcopenia prevalence was 6.1% (Table 1).

Table 1. Prevalence of sarcopenia

	Sarcopenia (N = 126)	Normal (N = 1,939)	Total (N = 2,055)
Un-weighted (%)	6.1	93.9	100
Weighted (%)	6.5 (5.33-7.92)	93.5 (92.08-94.67)	100

Weighed values present the 95% confidence interval.

Table 2. Anthropometric variables and skeletal muscle mass index

	Sarcopenia (N = 126)	Normal (N = 1,939)	p
Age (years)	45.28 ± 2.94	44.40 ± 2.95	.001
Height (cm)	150.02 ± 4.45	158.42 ± 4.94	.000
Weight (kg)	59.43 ± 11.31	58.49 ± 8.60	.248
BMI (kg/m^2)	26.29 ± 4.21	23.29 ± 3.12	.000
WC (cm)	83.17 ± 10.80	77.32 ± 8.53	.000
SMI (kg/m^2)	0.48 ± 0.02	0.64 ± 0.07	.000

Values are expressed as the mean ± standard deviation. The independent t-test was exploited.
BMI, body mass index; WC, waist circumference; SMI, skeletal muscle mass index.

2. Risk Factor

1) Anthropometric Variables

The risk factors are in height, weight, BMI, WC, and have a statistically significant between the two groups ($p < .05$), unlike weight variable ($p > .05$). Table 3 lists the risk factors in the anthropometric measures (Table 2).

2) Blood pressure and blood lab tests variables

SBP and DBP were statistically significant between the two groups ($p < .05$). FG, triglyceride, and TC showed significant differences between the two groups ($p < .05$) (Table 3).

3) Alcohol consumption and smoking variables

The alcohol consumption and smoking statuses were similar ($p > .05$) (Table 4).

Table 3. Blood pressure and blood lab tests variables

	Sarcopenia (N = 126)	Normal (N = 1,939)	p
SBP (mmHg)	118.817 ± 15.09	112.23 ± 14.59	.000
DBP (mmHg)	77.437 ± 10.152	74.30 ± 10.03	.001
FG (mg/dL)	101.55 ± 35.75	94.11 ± 18.87	.000
Triglyceride (mg/dL)	120.79 ± 70.01	105.96 ± 77.94	.039
TC (mg/dL)	192.84 ± 35.17	185.65 ± 32.17	.017

Values are expressed as the mean ± standard deviation. The independent t-test was exploited.
SBP, systolic blood pressure; DBP, diastolic blood pressure; FG, fasting glucose; TC, total cholesterol.

Table 4. Drinking and smoking variables

	Sarcopenia (N = 126)	Normal (N = 1,939)	p
Drinking status (%) (current-/ex-/non-drinker)	75.93 / 12.12 / 11.93	74.74 / 13.41 / 11.84	.507
Smoking status (%) (current-/ex-/non-smoker)	9.73 / 3.05 / 87.207	7.29 / 2.02 / 90.67	.936

A Chi-square test was used to compare the two groups.

Table 5. Multiple logistic regression for odds ratios of sarcopenia

Variables	Odd ratios (95% of CI)	p
Height	5.60 (1.34–23.31)	.000
BMI	12.99 (3.38–49.87)	.000
WC	2.75 (2.03–3.71)	.000
SMI	15.73 (11.58–21.36)	.000
SBP	.19 (.16–.23)	.000
DBP	1.80 (1.38–2.35)	.000
FG	1.31 (1.07–1.60)	.007
Triglyceride	1.12 (1.083–1.17)	.000
TC	1.55 (1.47–1.63)	.000

Odd ratio values are present as the 95% confidence interval (CI). Multiple logistic regression was exploited.
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.

3. Odd Ratios for Risk Factors

The variables of height, BMI, WC, SMI, SBP, DBP, FG, triglyceride, and TC demonstrated statistically significant differences between the two groups ($p < .01$). The corresponding values were 5.60 (1.34–23.31), 12.99 (3.38–49.87), 2.75 (2.03–3.71), 15.73 (11.58–21.36), .19 (.16–0.23), 1.80 (1.387–2.35), 1.31 (1.07–1.60), 1.12 (1.083 –1.17), and 1.55 (1.47–1.63) (Table 5).

Ⅳ. Discussion

This study examined the prevalence and risk factors of sarcopenia in middle-aged people residing in the community. The aging population in Korea and Asia is increasing rapidly, leading to a higher prevalence of sarcopenia, particularly in females. Despite the potential negative consequences of sarcopenia, healthcare professionals, including physical and occupational therapists, face challenges in diagnosing the disease because of inadequate knowledge and diagnostic tools, leading to missed diagnoses and complications. The study variables, including anthropometric measurements, blood pressure, blood lab test variables, drinking status, and smoking status, are inexpensive, convenient, and accessible for detecting potential sarcopenia patients. Understanding the risk factors for early detection and prevention of sarcopenia is crucial. The identified risk factors for sarcopenia in the population included circumference, systolic blood pressure, diastolic blood pressure, fasting glucose, triglyceride, and total cholesterol levels.

Anthropometric measures, specifically waist circumference, have been consistently identified as a risk factor for sarcopenia. Several studies reported consistent findings that the waist circumference is a risk factor for sarcopenia in men and women [14-16]. A population-based cohort study conducted in the US National Health and Nutrition Survey found a larger waist circumference in adults with sarcopenia [15]. Similarly, a cohort study conducted among individuals with sarcopenia in Brazil revealed a larger waist circumference than in the normal population [16]. Another study conducted in Japan among community-dwelling individuals suggested that those with sarcopenia had larger waist circumferences than non-sarcopenic individuals [14]. The possible theoretical rationale for the higher waist circumference in adults with sarcopenia is that the relationship between enhanced fat mass and lower muscle mass is mutually interdependent [17]. Sarcopenic individuals often experience problems with muscle power and function caused by muscle loss, resulting in reduced physical activity levels, such as difficulties in sitting-to-stand and walking long distances indoors and outdoors [18]. This decreased physical activity is strongly associated with decreased total daily energy expenditure and increased fat stores, particularly in the visceral and abdominal areas, leading to an enlargement of the waist volume [18]. Therefore, the relationship between decreased muscle mass and increased fat mass in sarcopenia is bidirectional and mutually reinforcing [19].

The study results support the hypothesis that systolic blood pressure (SBP) and diastolic blood pressure (DBP) are risk factors for women, which is consistent with previous studies on this population. Lu et al. reported that the SBP and DBP in the sarcopenia group in Taiwan were higher than in the normal group [20]. A British cohort study on SO with 4252 participants found that the SBP and DBP in the sarcopenia group were significantly higher than in the normal group [21]. Androga et al. [22] reported that hypertension in the SO group was greater than in the normal group. Skeletal muscle loss due to metabolic alterations and muscle mass loss may underlie the higher SBP and DBP in individuals with sarcopenia, resulting in reduced energy expenditure and physical activity, insulin resistance, and arterial stiffness in adults. Furthermore, redundant visceral fat mass accumulation may trigger an inflammatory response, leading to thickening of the blood vessel walls, constriction of vascular passages, and obstruction of blood flow.

Previous research found that elevated fasting glucose levels are associated with an increased risk of sarcopenia in females, which is consistent with the present findings [23-26]. Bersemi et al. conducted a cohort study on 157 community-dwelling individuals with sarcopenia and found that the sarcopenic group exhibited higher fasting glucose levels than the normal group [26]. Ozturk investigated 147 participants and found that sarcopenic patients had difficulties in adjusting the normal range of their blood glucose levels [23]. A plausible underlying mechanism for the observed association between sarcopenia and elevated fasting glucose levels is the role of muscle mass in regulating postprandial glucose metabolism. Skeletal muscle stores approximately 80% of ingested glucose after meals to prevent hyperglycemia in the blood. [27]. On the other hand, low skeletal muscle mass in sarcopenic patients tends to result in lower insulin sensitivity than females, characterized by decreased glucose uptake by the skeletal muscle because of the lower proportions of type I muscle fiber and capillary density that are susceptible to insulin action [28]. Consequently, this decline in muscle mass and impaired insulin sensitivity in females may contribute to reduced uptake of blood glucose by muscles, leading to accelerated hyperglycemia in sarcopenic females. Elevated triglyceride levels are a secondary risk factor in blood lab tests. The results are consistent with previous research [20,29,30]. Yanping Du et al. [20] conducted a cross-sectional study of individuals in East China and reported that females with sarcopenia had higher serum triglyceride levels. Similarly, Lu et al. investigated a population of adults in northern Taiwan. They reported that the sarcopenia group had significantly higher triglyceride levels. Buchmann et al. [29], who examined an population in Berlin, also concluded that the triglyceride levels were higher in the sarcopenia group than in the non-sarcopenic group. Total cholesterol was identified as a third risk factor for sarcopenia, which aligns with earlier [14,30]. Yanping Du et al. [30] reported that females with sarcopenia had higher total cholesterol levels than females in the normal group. Sanada et al. [14] evaluated a population of Japanese individuals and reported that total cholesterol levels were significantly higher in individuals with sarcopenia than in the normal group. These elevated triglycerides and total cholesterol levels in sarcopenia patients may be attributed to underlying mechanisms, such as insulin resistance [31], and increased inflammatory cytokines [32].

The strength of the present research is the investigation of the risk factors, particularly in females within the representative population of individuals in their 40s, in which the age group has gone through a decline in skeletal muscle mass [33-36]. These findings enable the early detection and treatment of sarcopenia. On the other hand, the current study has several limitations that should be considered for future research. First, the nature of a cross-sectional design, although including a substantial sample size of 2,055 participants representative of the entire population through statistical weighting, may have limited the ability to establish the causal

relationships for the identified risk factors. For example, while elevated glycemia, triglyceride, and total cholesterol levels may predict sarcopenia, sarcopenia might cause a higher blood test level. Therefore, further research will be needed to understand the relationship between these predictors and sarcopenia. Future studies could explore longitudinal or randomized case-control study designs to enhance the robustness of the findings. In addition, the study did not consider sarcopenic obesity, which is a condition where individuals have both low muscle mass and high body fat. Therefore, sarcopenic obesity, which may affect the changes in fasting glucose, total cholesterol levels, and triglyceride levels, should be considered when interpreting the study results.

Ⅴ. Conclusion

This paper presents a pioneering investigation that sheds light on the clinical risk factors associated with sarcopenia in females in their 40s. The estimated prevalence of sarcopenia in this demographic was 6.5%, with a confidence interval ranging from 5.33% to 7.92%. The study identified several significant risk factors for sarcopenia, including the waist circumference, systolic and diastolic blood pressure, fasting glucose levels, triglyceride, and total cholesterol levels. Healthcare professionals can better identify and detect potential sarcopenia patients by acknowledging the prevalence and risk factors. Further research will be needed to understand the relationship between these predictors and sarcopenia. In addition, longitudinal or randomized case-control study designs will be needed to enhance the robustness of the findings.

References

[1] Rosenberg IH. Sarcopenia: origins and clinical relevance. J Nutr. 1997;127(5 Suppl):990S-1S.

[2] Wang C, Bai L. Sarcopenia in the elderly: basic and clinical issues. Geriatr Gerontol Int. 2012;12(3):388-96.

[3] Kulik CT, Ryan S, Harper S, et al. Aging populations and management. Academy of Management Briarcliff Manor, NY. 2014. pp.929-35.

[4] Dam TT, Peters KW, Fragala M, et al. An evidence-based comparison of operational criteria for the presence of sarcopenia. J Gerontol A Biol Sci Med Sci. 2014;69(5):584-90.

[5] Htun NC, Ishikawa-Takata K, Kuroda A, et al. Screening for Malnutrition in Community Dwelling Older Japanese: Preliminary Development and Evaluation of the Japanese Nutritional Risk Screening Tool (NRST). J Nutr Health Aging. 2016;20(2):114-20.

[6] Han K, Park YM, Kwon HS, et al. Sarcopenia as a determinant of blood pressure in older Koreans: findings from the Korea National Health and Nutrition Examination Surveys (KNHANES) 2008-2010. PLoS One. 2014;9(1):e86902.

[7] Cawthon PM, Blackwell TL, Cauley J, et al. Evaluation of the usefulness of consensus definitions of sarcopenia in older men: Results from the Observational Osteoporotic Fractures in Men Cohort Study. J Am Geriatr Soc. 2015;63(11):2247-59.

[8] Pereira FB, Leite AF, de Paula AP. Relationship between pre-sarcopenia, sarcopenia and bone mineral density in elderly men. Archives of Endocrinology Metabolism. 2015;59(1):59-65.

[9] Laurent MR, Dedeyne L, Dupont J, et al. Age-related bone loss and sarcopenia in men. Maturitas. 2019;122:51-6.

[10] 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.

[11] 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.

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

[13] Hwang J, Park S. Sex differences of sarcopenia in an elderly asian population: the prevalence and risk factors. Intern J of Environ Res and Pub Health. 2022;19(19):11980.

[14] Hwang J, Park S. Gender-specific prevalence and risk Factors of sarcopenic obesity in the korean elderly population: A nationwide cross-sectional study. Intern J of Environ Res and Pub Health. 2023;20(2):1140

[15] 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.

[16] 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.

[17] 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 (1985). 2000;89(1):81-8.

[18] 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.

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

[20] 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.

[21] Kweon S, Kim Y, Jang MJ, et al. Data resource profile: the Korea National Health and Nutrition Examination Survey (KNHANES). Int J Epidemiol. 2014;43(1):69-77.

[22] Sanada K, Miyachi M, Tanimoto M, et al. A cross-sectional study of sarcopenia in Japanese men and women: reference values and association with cardiovascular risk factors. Eur J Appl Physiol. 2010;110(1):57-65.

[23] Brown JC, Harhay MO, Harhay MN. Sarcopenia and mortality among a population-based sample of community-dwelling older adults. J Cachexia Sarcopenia Muscle. 2016;7(3):290-8.

[24] Confortin SC, Meneghini V, Ono LM, et al. Anthropometric indicators as a screening tool for sarcopenia in older adults from Florianopolis, Santa Catarina: EpiFloripa Ageing study. Revista De Nutricao-Brazilian Journal of Nutrition. 2017;30(3):287-96.

[25] Zamboni M, Mazzali G, Fantin F, et al. Sarcopenic obesity: a new category of obesity in the elderly. Nutr Metab Cardiovasc Dis. 2008;18(5):388-95.

[26] Nair KS. Aging muscle. Am J Clin Nutr. 2005;81(5):953-63.

[27] Cesari M, Kritchevsky SB, Baumgartner RN, et al. Sarcopenia, obesity, and inflammation--results from the trial of angiotensin converting enzyme inhibition and novel cardiovascular risk factors study. Am J Clin Nutr. 2005;82(2):428-34.

[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] 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.

[30] Androga L, Sharma D, Amodu A, et al. Sarcopenia, obesity, and mortality in US adults with and without chronic kidney disease. Kidney Intern Rep. 2017;2(2):201-11.

[31] Abidin Ozturk ZA, Turkbeyler IH, Demir Z, et al. The effect of blood glucose regulation on sarcopenia parameters in obese and diabetic patients. Turk J Phys Med Rehabil. 2018;64(1):72-9.

[32] Du Y, Oh C, No J. Associations between sarcopenia and metabolic risk factors: a systematic review and meta-analysis. J Obes & Metab Synd. 2018;27(3):175-85.

[33] Cui M, Gang X, Wang G, et al. A cross-sectional study: Associations between sarcopenia and clinical characteristics of patients with type 2 diabetes. Medicine (Baltimore). 2020;99(2):e18708.

[34] Buscemi C, Ferro Y, Pujia R, et al. Sarcopenia and appendicular muscle mass as predictors of Impaired fasting glucose/type 2 diabetes in elderly women. Nutrients. 2021;13(6):1909.

[35] Lundsgaard AM, Kiens B. Gender differences in skeletal muscle substrate metabolism - molecular mechanisms and insulin sensitivity. Front Endocrinol (Lausanne). 2014;5:195.

[36] Buchmann N, Nikolov J, Spira D, et al. Identifying sarcopenia in metabolic syndrome: data from the Berlin aging study II. J Gerontol A Biol Sci Med Sci. 2016;71(2):265-72.

[37] 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.

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

[39] Schrager MA, Metter EJ, Simonsick E, et al. Sarcopenic obesity and inflammation in the InCHIANTI study. J Appl Physiol (1985). 2007;102(3):919-25.

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

[41] Hashemi R, Shafiee G, Motlagh AD, et al. Sarcopenia and its associated factors in Iranian older individuals: Results of SARIR study. Arch Gerontol Geriatr. 2016;66:18-22.

[42] Santos VRd, Araujo MYC, Cardoso MR, et al. Association of insufficient physical activity with sarcopenia and sarcopenic obesity in individuals aged 50 years or more. Revista de Nutrição. 2017;30:175-84.

[43] Huschtscha Z, Parr A, Porter J, et al. Sarcopenic characteristics of active older adults: a cross-sectional Exploration. Sports Med Open. 2021;7(1):32.