Original Article

Association of socioeconomic factors and dietary intake with sarcopenic obesity in the Korean older population

Won Jang PhD[1,2] and Hyesook Kim PhD[1,2]

[1]*Department of Food and Nutrition, Wonkwang University, Iksan, Korea*
[2]*Institute for Better Living, Wonkwang University, Iksan, Korea*

Background and Objectives: This study investigated the relationship between socioeconomic factors, dietary intake, and sarcopenic obesity among older adults in Korea. **Methods and Study Design:** Data from the seventh Korean National Health and Nutrition Examination Survey (2016-2018) were analyzed. The study included 3,690 participants (1,645 men and 2,045 women) aged 65 years and older. Sarcopenic obesity was defined as the coexistence of low muscle strength (handgrip strength <28 kg in men and <18 kg in women) and abdominal obesity (waist circumference >90 cm in men and >85 cm in women). Socioeconomic factors assessed included age, living status, residential area, employment, education, and family income level. Dietary intake was evaluated using the nutrient adequacy ratio and mean adequacy ratio derived from 24-h dietary recall data. Multiple logistic regression was used to identify factors associated with sarcopenic obesity. **Results:** The prevalence rates of sarcopenic obesity were 6.5% in men and 17.4% in women. Low education levels were significantly associated with a higher prevalence of sarcopenic obesity in women, whereas lower family income levels were associated with an increased risk of sarcopenic obesity in men. In women, a lower mean adequacy ratio was significantly associated with a higher risk of sarcopenic obesity. **Conclusions:** Lower family income and education level are associated with a higher prevalence of sarcopenic obesity. Additionally, overall nutritional adequacy is inversely related to the prevalence of sarcopenic obesity, particularly in women.

Key Words: sarcopenic obesity, older adults, socioeconomic status, nutrition, MAR

INTRODUCTION

The average life expectancy of the global population has been increasing over the last decade and will continue to rise over the next two decades as a result of medical advancements and improvements in living standards.[1] However, because the extension of life expectancy does not necessarily lead to an increase in healthy life expectancy, there is increasing focus on the prevention and management of age-related functional decline in older individuals, which have both been shown to be important in promoting healthy longevity.[1] The general aging process involves a change in body composition, specifically a decrease in muscle mass and an increase in body fat, even in the absence of changes in body weight.[2] These age-related changes in body composition lead to several physical and physiological changes that affect physical function and disease risk.[3] Sarcopenia is characterized by gradual loss of skeletal muscle mass and function, leading to poor physical performance, poor quality of life, negative metabolic effects, cardiovascular disease, falls, and increased mortality.[3] The coexistence of sarcopenia and obesity, known as sarcopenic obesity (SO), can have synergistic and detrimental effects on health outcomes compared to sarcopenia or obesity alone.[4,5] SO occurs in 5-10% of the world's older population,[6] and it has been associated with various negative outcomes, such as impaired physical function, disability, and mortality.[7]

Socioeconomic status (SES) is a measure of an individual's or group's position within a social hierarchy, and it is based on family income, educational attainment, and occupation.[8] There is a growing recognition of the relationship between SES and health.[8,9] Low socioeconomic levels are associated with accelerated aging and poor health outcomes.[9] Recent findings suggest a higher risk of sarcopenia in lower SES older adults.[10–12] It is also reported that low educational achievement and occupational class are associated with decreased muscle strength.[12] In addition, many studies have reported a relationship between SES and obesity.[13–16] A landmark review of studies on SES and obesity published prior to 1989 supported the contention that obesity was a disease of the socioeconomic elite in developing societies.[13] The prevalence of obesogenic environments in rich societies, unhealthy food options, and a sedentary lifestyle have been identified as important drivers of this disparity.[13–15] However, recent studies showed that the burden of obesity tends to shift toward the groups with lower SES as a country's economy increases.[16] Higher educational outcomes and better

Corresponding Author: Dr Hyesook Kim. Department of Food and Nutrition, Wonkwang University, 460 Iksan-daero, Iksan 54538, Korea
Tel: +82-63-850-6896; Fax: +82-63-850-6896
Email: hskim81@wku.ac.kr
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employment opportunities in higher SES groups can contribute to healthier lifestyles and behaviors, reducing obesity risk.[16] Conversely, information on the relationship between SES and SO is insufficient and inconsistent.[17,18] One study of Koreans reported a significant correlation between occupation and SO.[17] By contrast, a study of the Spanish population reported no association between SES and SO.[18]

Several studies have shown that dietary factors such as diet quality, protein intake levels, dairy products, vegetables, and fruits are associated with SO.[19–22] To prevent the accumulation of body fat and to maintain muscle mass in older adults, appropriate amounts of energy and protein are required.23,24 Antioxidant nutrients, such as vitamins C and E,[25,26] as well as anti-inflammatory nutrients, such as omega-3 fatty acids,[27] may also decrease the risk of SO through mechanisms that reduce oxidative stress and inflammation.

Dietary factors and socioeconomic factors are closely related.[14] Therefore, a comprehensive evaluation of socioeconomic and dietary factors can provide valuable insights to counteract SO in older adults. However, there is a lack of in-depth research on the association of SO with SES determinants and dietary factors. Therefore, this study aimed to examine the interrelationship of SES determinants and dietary factors with SO in a representative sample of older Korean adults.

METHODS

Study design and participants

This study used data from the 2016–2018 Korea National Health and Nutrition Examination Survey (KNHANES VII) conducted by the Korea Centers for Disease Control and Prevention (KCDC), now known as the Korea Disease Control and Prevention Agency (KDCA). KNHANES is an ongoing, cross-sectional, nationally representative survey with a complex, multistage, stratified, and probability cluster sampling design.28 It includes a health questionnaire, a health examination, and a nutrition survey (collected by the 24-h recall method). The first and second years of KNHANES VII were exempt from institutional review board (IRB) review and approval according to the Bioethics Act, while the third year (2018) received approval from the IRB at the Korea Disease Control and Prevention Agency (IRB No. 2018-01-03-P-A). Data from the KNHANES VII can be accessed and downloaded from the KNHANES website (https://knhanes.kdca.go.kr/knhanes/sub03/sub03_02_05.do, accessed on July 16, 2023). Detailed information about the survey is also provided on the home page of the website. Participants in the 2016–2018 survey totaled 24,269. The present analysis was limited to adults aged 65 years or older who completed the survey (n = 4,804). Participants with incomplete data on SO classification were excluded (n = 326). Those with missing dietary intake data, energy intakes below 500 kcal and over 5,000 kcal, and unusual intake on the previous day were also excluded (n = 503). We also excluded participants with missing data on other covariates, such as demographic information, smoking, alcohol consumption, and physical activity (n = 289). Thus, 3,690 participants (1,645 men and 2,045 women) were included in the study.

SO classification

To date, there are no unified clinical criteria for SO diagnosis.[29] In this study, SO was defined as both low muscle strength and abdominal obesity. In KNHANES, handgrip strength (HGS) was measured to evaluate muscle strength. HGS was evaluated using a TKK 5401 digital grip strength dynamometer (Takei Scientific Instruments Co., Ltd, Tokyo, Japan), which was used a total of six times, three times for each hand, and measured alternately. In this study, the maximum value of the three trials of the dominant hand was used as the final HGS value. Low HGS was defined as <28 kg for men and <18 kg for women, according to the consensus report of the Asian Working Group for Sarcopenia (AWGS).[30] Waist circumference was measured at the midpoint between the bottom of the rib cage and the top of the iliac crest. Abdominal obesity was defined as a waist circumference ≥90 cm for men and ≥85 cm for women, following Korean-specific cutoffs for abdominal obesity defined by the Korean Society for the Study of Obesity (KSSO).[31]

Dietary quality assessment

Dietary intake information was obtained from the 24-h recall data collected by the KNHANES VII.[29] Skilled and well-trained dietary interviewers conducted a 24-h recall through face-to-face interviews. The participants reported all food and beverages consumed the previous day, including food names, types of ingredients, and amount of food intake per meal. Based on this data, the average amounts of certain nutrient intakes were calculated and compared with the DRIs for Koreans,[32] including energy, protein, calcium, phosphorus, iron, vitamin A, thiamin, riboflavin, niacin, and vitamin C. To assess nutritional adequacy, the nutritional adequacy ratio (NAR) and mean adequacy ratio (MAR) were calculated. The NAR of certain nutrients was calculated by comparing the amount of the participant's nutrient intake with the recommended intake. The maximum score was designated as 1.0, and all scores over 1.0 were considered to be 1.0. The MAR, which reflects the adequacy of the overall diet, was calculated by averaging each nutrient's NAR score. A cutoff point of 0.75 was applied to MAR to define overall micronutrient adequacy.[33]

Assessment of sociodemographic and health-related variables

Information on sociodemographic characteristics was obtained from the general questionnaire and health interview questionnaire data collected by KNHANES VII. The sociodemographic characteristics included gender (men, women), age (65–74 years, ≥75 years), living status (living alone, living with others), residential area (urban, rural), education level (≤elementary school, ≥middle school), household income level (the lowest quartile, ≥middle–low), and occupation (employed, unemployed). Information about health-related variables was obtained from the anthropometric survey, and the health interview surveyed BMI (kg/m^2), smoking status (current smoker, non-current smoker), high-risk alcohol consumption (yes, no), and physical activity (yes, no). High-risk drinking was defined for men as seven or more glasses of beer, wine, or Soju at one time, and five or more glasses for women, and drinking more than twice per week.

Statistical analysis

All statistical analyses were performed using the SAS software (version 9.4; SAS Institute, Inc., Cary, NC, USA). Due to the complex sampling design of the KNHANES study, the sample weights, stratification variable (k strata), and cluster variable (primary sampling unit) were included in our analysis. Differences in the distribution of characteristics between the SO and non-SO (NSO) groups were analyzed using the SURVEY FREQ procedure for categorical variables or the SURVEY MEAN procedure for continuous variables. The significant differences in the consumption of nutrient intake, according to the SO status, were investigated using the SURVEY REG procedure. Multiple SURVEYLOGISTIC analysis was performed to estimate the ORs and 95% CIs for SO across socioeconomic factors and the MAR. Adjustments were performed for potential confounding variables, selected based on prior knowledge from the scientific literature and whether they were related to the independent and dependent variables. The confounders included age, family income, education level, physical activity, and total energy intake. There was no significant multicollinearity among these variables. All reported probability tests were two-sided, with a p-value <0.05 considered statistically significant.

RESULTS

General characteristics of participants

Of the 3,690 participants, 12.6% (6.5% of the men and 17.4% of the women) had SO, and 87.4% (93.5% of the men and 82.6% of the women) were classified as NSO (data not shown). The general characteristics of the participants according to SO are summarized in Table 1. The participants with SO were significantly older (p<0.001 for both men and women), less educated (p=0.031 for men and p<0.001 for women), and had lower family income (p<0.001 for men and p=0.003 for women) than those with NSO. In men, the SO group included more people living alone (p<0.001) and with no occupation (p=0.007) than the NSO group. In the women, the SO group was less likely to engage in physical activity (p=0.030) than the NSO group.

There was no difference in the area of residence, smoking and drinking habits.

Comparison of NAR and MAR between SO and NSO

Table 2 compares the NAR and MAR between the SO and NSO groups. An intergroup comparison of the NAR showed that the NSO group had more appropriate NARs in all nutrients compared to the SO group in both men and women. The NAR of protein (p=0.047) and vitamin C (p=0.030) in men, and the NAR of protein (p<0.001), vitamin A (p=0.026), C (p=0.020), and riboflavin (p=0.014) in women, were significantly higher in the NSO group than in the SO group. A significant difference in the average of the MAR score between the NSO and SO groups was seen only in women (p<0.001). The proportion of participants with a MAR higher than 0.75 was significantly higher in both men (p=0.028) and women (p<0.001) in the NSO group than in the SO group.

Socioeconomic factors and dietary factors related to SO

The association between SO and various factors, estimated by multivariable logistic regression, is shown in Table 3. Due to the close interrelationship between socioeconomic factors, the results of adjusting the effects of each socioeconomic factor showed that age had an independent significant effect on SO prevalence in both genders [OR (95% CI) = 2.79 (1.70-4.59) in men, 2.52 (1.89-3.34) in women]. Low education levels significantly increased the prevalence of SO [OR (95% CI) = 1.88 (1.31-2.70)] in women, and the lower family income levels had a significant association with increased OR of SO in men [OR (95% CI) = 1.77 (1.02-3.05)]. However, after adjusting for confounding factors, there was no significant correlation between living status, residential area, or employment and the risk of SO prevalence in either gender. The association between the dietary quality evaluated by MAR and SO risk was found only in women. Low MAR levels in women significantly increased the prevalence of SO [OR (95% CI) = 1.44 (1.09-1.92)].

DISCUSSION

In this study, data from the nationally representative KNHANES VII (2016-2018) were used to examine the association between SES, dietary factors, and SO among older adults. This cross-sectional study identified low family income levels in men, low education levels in women, and increased age of both genders as socioeconomic risk factors for SO. Furthermore, we found an independent association between MAR, which reflects the adequacy of the overall diet, and SO in older women after adjusting for various SES factors related to SO. However, this association was not observed in older men.

The prevalence rates of SO in this study were 6.5% for men and 17.4% for women. However, it is noteworthy that the clinical diagnostic criteria for classifying muscle reduction differ across studies[29] because the measurement methods for skeletal muscle mass and muscle strength have not been standardized worldwide. According to research by Lim et al.[32] using data from KNHANES IV, a high prevalence rate of 23.3% for SO was reported when diagnosing sarcopenia using dual-energy X-ray absorptiometry. KNHANES VII only measured a few indicators related to muscle loss, with HGS being the sole indicator of sarcopenia. While a comprehensive evaluation of skeletal muscle mass reduction and overall muscle performance is necessary, HGS has been shown to independently predict muscle-related health outcomes because it is closely related to the strength of other muscle groups and thus can be a useful indicator of overall strength.[34]

Our findings revealed that low-income levels in men, low educational attainment in women, and increasing age are independently associated with SO. Educational attainment, in particular, is considered a predictor of future employment types and has a significant influence on obesity and sarcopenia.[35] Higher levels of education often lead to more employment opportunities, higher incomes, and greater knowledge of health-affecting behaviors.[36] In Korea, older adults have limited opportunities for higher

Table 1. Sociodemographic characteristics of elderly men and women in the 2016-2018 KNHANES based on sarcopenic obesity status

	Male				Female			
	All (n=1645)	NSO (n=1536)	SO (n=109)	*p*-value	All (n=2045)	NSO (n=1714)	SO (n=331)	*p*-value
Age (years)	72.3 ± 0.1	72.1 ± 0.2	75.3 ± 0.6	<0.001	73.2 ± 0.1	72.7 ± 0.1	75.6 ± 0.2	<0.001
BMI (kg/m^2)	23.7 ± 0.1	23.6 ± 0.1	25.9 ± 0.3	<0.001	24.6 ± 0.1	24.1 ± 0.1	27.0 ± 0.2	<0.001
Waist circumference (cm)	86.7 ± 0.3	86.0 ± 0.3	95.2 ± 0.4	<0.001	84.3 ± 0.1	82.8 ± 0.3	91.7 ± 0.3	<0.001
Hand grip strength (kg)	33.0 ± 0.2	33.7 ± 0.2	23.4 ± 0.5	<0.001	19.5 ± 0.1	20.5 ± 0.1	14.6 ± 0.2	<0.001
Low household income (n, %)	663 (38.9)	596 (37.1)	67 (64.7)	<0.001	1056 (52.0)	858 (50.2)	198 (60.4)	0.003
Low education level, (n, %)	659 (38.2)	604 (37.4)	55 (49.5)	0.031	1456 (70.8)	1178 (67.7)	278 (85.8)	<0.001
Current smokers (n, %)	278(16.7)	264 (17.0)	14 (12.9)	0.386	40 (1.9)	32 (1.9)	8 (1.6)	0.686
Heavy drinker (n, %)	131 (8.3)	124 (8.3)	7 (8.8)	0.891	18 (0.7)	16 (0.7)	2 (0.5)	0.592
Living alone (n, %)	217 (12.0)	195 (11.2)	22 (24.4)	0.001	630 (27.8)	513 (27.0)	117 (31.5)	0.119
Employed (n, %)	684 (41.1)	652 (42.1)	32 (25.8)	0.007	548 (25.0)	482 (26.0)	66 (20.5)	0.072
City dweller (n, %)	1207 (77.6)	1139 (77.9)	68 (72.7)	0.237	1485 (76.9)	1254 (77.8)	231 (72.2)	0.117
Physical activity (n, %)	586 (36.6)	555 (37.1)	31 (29.5)	0.162	556 (26.8)	502 (28.3)	54 (19.6)	0.030

NSO, non sarcopenic obesity; SO, sarcopenic obesity
Data are presented as mean ± standard error or proportion (%)

Table 2. NAR and MAR of the participants according to sarcopenic obesity

	Male				Female			
	All (n=1645)	NSO (n=1536)	SO (n=109)	*p*-value	All (n=2045)	NSO (n=1714)	SO (n=331)	*p*-value
Age (years)	72.3 ± 0.1	72.1 ± 0.2	75.3 ± 0.6	<0.001	73.2 ± 0.1	72.7 ± 0.1	75.6 ± 0.2	<0.001
BMI (kg/m^2)	23.7 ± 0.1	23.6 ± 0.1	25.9 ± 0.3	<0.001	24.6 ± 0.1	24.1 ± 0.1	27.0 ± 0.2	<0.001
Waist circumference (cm)	86.7 ± 0.3	86.0 ± 0.3	95.2 ± 0.4	<0.001	84.3 ± 0.1	82.8 ± 0.3	91.7 ± 0.3	<0.001
Hand grip strength (kg)	33.0 ± 0.2	33.7 ± 0.2	23.4 ± 0.5	<0.001	19.5 ± 0.1	20.5 ± 0.1	14.6 ± 0.2	<0.001
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Values are expressed as mean ± standard error or numbers of participants (percentage distribution).
†NAR = nutrient intake of an individual/recommended dietary allowance (RDA) of the nutrient.
‡MAR = sum of the NAR for each nutrient/number of nutrients.
§The *p*-value was obtained from PROC SURVEYREG procedure. The $p < 0.05$ was considered to be significant.
¶Adjusted for age, residential area, living status, family income, education level, alcohol consumption, physical activity and total energy intake (except for energy itself).
††The *p*-value was obtained from $\chi 2$ test in complex sample data analysis.

Table 3. Association of sarcopenic obesity with socioeconomic status and MAR

Variables	Male		Female	
	Model 1† [OR(95%CI)]	Model 2‡ [OR(95%CI)]	Model 1 [OR(95%CI)]	Model 2 [OR(95%CI)]
Age				
65–74 years	1 (ref)	1 (ref)	1 (ref)	1 (ref)
≥75 years	3.73 (2.35–5.91)	2.79 (1.70-4.59)	3.15 (2.41–4.11)	2.52 (1.89-3.34)
Living status				
Living with others	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Living alone	2.09 (1.25–3.51)	1.63 (0.96-2.75)	1.24 (0.95–1.63)	0.97 (0.72-1.31)
Residence				
Urban	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Rural	1.35 (0.85–2.14)	0.85 (0.53-1.35)	1.30 (0.89–1.89)	1.02 (0.69-1.52)
Employment				
Employed	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Unemployed	1.91 (1.13–3.23)	1.33 (0.77-2.29)	1.38 (0.98–1.94)	1.22 (0.84-1.77)
Education				
≥Middle school	1 (ref)	1 (ref)	1 (ref)	1 (ref)
≤Elementary school	1.49 (0.95–2.33)	1.15 (0.70-1.89)	2.61 (1.84–3.37)	1.88 (1.31-2.70)
Household income				
≥Middle low	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Low	2.72 (1.76–4.19)	1.77 (1.02-3.05)	1.51 (1.14–2.00)	1.00 (0.72-1.38)
Smoking status				
Non-current smoker	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Current smoker	1.64 (0.89-3.00)	1.86 (1.00-3.48)	1.18 (0.50-2.75)	1.27 (0.50-3.21)
High-risk alcohol consumption				
Non-heavy drinker	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Heavy drinker	1.23 (0.54-2.81)	0.93 (0.39-2.21)	1.51 (0.67-6.18)	1.28 (0.30-5.46)
Physical activity				
Yes	1 (ref)	1 (ref)	1 (ref)	1 (ref)
No	1.39 (0.86-2.24)	1.09 (0.66-1.80)	1.93 (1.32-2.84)	1.44 (0.96-2.17)
MAR				
<0.75	1 (ref)	1 (ref)	1 (ref)	1 (ref)
≥0.75	1.66 (1.06-2.59)	1.28 (0.80-2.06)	1.81 (1.37-2.38)	1.44 (1.09-1.92)

ORs and 95% CI were calculated using a multiple logistic regression
†Model 1, unadjusted
‡Model 2, adjusted for variables listed in columns (except for variables themselves)

education, especially women, who have significantly lower educational opportunities compared to men. More than 70% of women with low education levels received less than 6 years of education, nearly half of the educational attainment of men. Hence, education is believed to have a more pronounced effect on SO in women than in men. Additionally, income levels are crucial factors associated with nutritional imbalance and malnutrition, which are linked to obesity and muscle loss in older adults.[35,37] Generally, obesity is more common in individuals with a higher SES in low- and middle-income countries, while in high-income countries, obesity is more frequent in people who are poor.[37] Several studies have examined the relationship between SES and sarcopenia[10,11,36] or obesity,[13,14,37] but research on the association between SES and SO is scarce, and results have been inconsistent. Contrary to our findings that physical activity is not independently associated with SO, as are SES factors, such as living status, residential areas, employment status, smoking habit, and drinking habit, Moreno et al.[18] reported no association between SO and socioeconomic factors, including education and income levels, in the Spanish population. Additionally, in a multi-continent study by Tyrobolas et al.,[38] socioeconomic factors, such as wealth and education level, were not correlated with SO. Instead, a low physical activity level was identified as a strong predictor of SO.[38] Kim et al.[17] found that the development of SO in men was related to lifetime occupation, with white-collar workers being most affected due to lower levels of occupational physical activity compared to blue-collar and low-level workers in agribusiness. The inconsistencies in findings regarding the relationship between SO risk and socioeconomic factors may be attributed to differences in the heterogeneity of the study populations and the definition of SO.[38] Nevertheless, this study is meaningful in that it provides some evidence for a relationship between several SES factors and SO.

SO is associated with various nutritional factors related to skeletal muscle mass and fat mass.[3,24] Our results align with previous evidence suggesting that dietary factors, including overall dietary quality and the intake of protein and antioxidant nutrients, are associated with SO.[19,39] Regarding the overall quality of the diet, we found that a lower MAR score was associated with a higher prevalence of SO in women. Similarly, another study found that older men and women in Korea with higher diet quality, as evaluated by MAR, had a lower prevalence of SO compared to those with lower MAR scores.[39] Optimal protein intake is considered a critical nutritional factor for muscle-related health. In line with studies demonstrating the importance of an adequate intake of high-quality protein rich in essential amino acids in reducing the risk of SO,[19,24,40] our study found that the SO group had insufficient protein intake compared to the NSO group. Previous studies have suggested that protein intake beyond the recommended daily intake is needed to promote muscle protein synthesis and mitigate muscle loss.[24,40] Aside from protein, antioxidant nutrients play a vital role in the development and progression of SO by mitigating the catabolic effects of oxidative stress on skeletal muscle. Therefore, meeting the recommended intake of these nutrients can have a beneficial effect in preventing or managing SO.[26] In this regard, our study showed that antioxidant vitamins, such as vitamin A, vitamin B-2, and vitamin C, were higher in the NSO group than in the SO group in women.

This study had some limitations. First, because this study had a cross-sectional design, we could not determine the causality between SES, dietary factors, and SO. Further longitudinal studies are needed to determine the causal associations. Second, the lack of a consensus definition for SO poses an important limitation, as the definitions of obesity and sarcopenia vary considerably. Consequently, diagnosing and understanding the epidemiology of SO becomes challenging. Third, the dietary data collected from a single 24-h dietary recall may not fully capture ordinary dietary intake. However, efforts were made to address this limitation by excluding unusual cases of extreme over- or under-reporting.

In conclusion, our study suggests that a high MAR is associated with a decreased prevalence of SO among older adult women. In addition, low education levels and low financial status positively correlate with SO risk. Therefore, older individuals with low SES should be provided with appropriate education and information on SO, and improving dietary quality through increased intake of high-quality protein and antioxidant-rich foods can have a positive impact on preventing or managing SO. Further research is needed to confirm the clinical significance and causal relationship between social and dietary factors and SO.

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AUTHOR DISCLOSURES

The authors declare no competing interests.

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REFERENCES

1. GBD 2015 Mortality and Causes of Death Collaborators. Global, regional, and national life expectancy, all-cause mortality, and cause-specific mortality for 249 causes of death, 1980-2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet. 2016;388:1459-544. doi: 10.1016/S0140-6736(16)31012-1.
2. Jafari Nasabian P, Inglis JE, Reilly W, Kelly OJ, Ilich JZ. Aging human body: changes in bone, muscle and body fat with consequent changes in nutrient intake. J Endocrinol. 2017;234:R37-51. doi: 10.1530/JOE-16-0603.
3. Zamboni M, Mazzali G, Fantin F, Rossi A, Di Francesco V. Sarcopenic obesity: a new category of obesity in the elderly. Nutr Metab Cardiovasc Dis. 2008;18:388-95. doi: 10.1016/j.numecd.2007.10.002.
4. Roubenoff R. Sarcopenic obesity: the confluence of two epidemics. Obes Res. 2004;12:887-8. doi: 10.1038/oby.2004.107.
5. Lim S, Kim JH, Yoon JW, Kang SM, Choi SH, Park YJ, Kim KW, Lim JY, Park KS, Jang HC. Sarcopenic obesity: prevalence and association with metabolic syndrome in the Korean Longitudinal Study on Health and Aging (KLoSHA). Diabetes Care. 2010;33:1652-4. doi: 10.2337/dc10-0107.
6. Choi KM. Sarcopenia and sarcopenic obesity. Korean J Intern Med. 2016;31:1054-60. doi: 10.3904/kjim.2016.193.
7. Atkins JL, Whincup PH, Morris RW, Lennon LT, Papacosta O, Wannamethee SG. Sarcopenic obesity and risk of cardiovascular disease and mortality: a population-based cohort study of older men. J Am Geriatr Soc. 2014;62:253-60. doi: 10.1111/jgs.12652.
8. Marmot M. Social determinants of health inequalities. Lancet. 2005;365:1099-104. doi: 10.1016/S0140-6736(05)71146-6.
9. Steptoe A, Zaninotto P. Lower socioeconomic status and the acceleration of aging: An outcome-wide analysis. Proc Natl Acad Sci U S A. 2020;117:14911-7. doi: 10.1073/pnas.1915741117.
10. Swan L, Warters A, O'Sullivan M. Socioeconomic inequality and risk of sarcopenia in community-dwelling older adults. Clin Interv Aging. 2021;16:1119-29. doi: 10.2147/CIA.S310774.
11. Dorosty A, Arero G, Chamar M, Tavakoli S. Prevalence of sarcopenia and its association with socioeconomic status among the elderly in Tehran. Ethiop J Health Sci. 2016;26:389-96. doi: 10.4314/ejhs.v26i4.11.
12. Brennan-Olsen SL, Vogrin S, Balogun S, Wu F, Scott D, Jones G et al. Education, occupation and operational measures of sarcopenia: Six years of Australian data. Australas J Ageing. 2020;39:e498-505. doi: 10.1111/ajag.12816.
13. Sobal J, Stunkard AJ. Socioeconomic status and obesity: a review of the literature. Psychol Bull. 1989;105:260-75. doi: 10.1037/0033-2909.105.2.260.
14. McLaren L. Socioeconomic status and obesity. Epidemiol Rev. 2007;29:29-48. doi: 10.1093/epirev/mxm001.
15. Monteiro CA, Moura EC, Conde WL, Popkin BM. Socioeconomic status and obesity in adult populations of developing countries: a review. Bull World Health Organ. 2004;82:940-6.
16. Pampel FC, Denney JT, Krueger PM. Obesity, SES, and economic development: A test of the reversal hypothesis. Soc Sci Med. 2012;74(7):1073-81. doi: 10.1016/j.socscimed.2011.12.028.
17. Kim SH, Kim W, Yang S, Kwon S, Choi KH. Influence of occupation on sarcopenia, sarcopenic obesity, and metabolic syndrome in men over 65 years of age. J Occup Environ Med. 2018;60:e512-7. doi: 10.1097/JOM.000000000000001412.
18. Moreno-Franco B, Pérez-Tasigchana RF, Lopez-Garcia E, Laclaustra M, Gutierrez-Fisac JL, Rodríguez-Artalejo F,

Guallar-Castillón P. Socioeconomic determinants of sarcopenic obesity and frail obesity in community-dwelling older adults: The Seniors-ENRICA Study. Sci Rep. 2018;8:10760. doi: 10.1038/s41598-018-28982-x.
19. Muscariello E, Nasti G, Siervo M, Di Maro M, Lapi D, D'Addio G, Colantuoni A. Dietary protein intake in sarcopenic obese older women. Clin Interv Aging. 2016;11:133-40. doi: 10.2147/CIA.S96017.
20. Son J, Yu Q, Seo JS. Sarcopenic obesity can be negatively associated with active physical activity and adequate intake of some nutrients in Korean elderly: Findings from the Korea National Health and Nutrition Examination Survey (2008-2011). Nutr Res Pract. 2019;13:47-57. doi: 10.4162/nrp.2019.13.1.47.
21. Sahni S, Mangano KM, Hannan MT, Kiel DP, McLean RR. Higher protein intake is associated with higher lean mass and quadriceps muscle strength in adult men and women. J Nutr. 2015;145:1569-75. doi: 10.3945/jn.114.204925.
22. Yoo S, Kim DY, Lim H. Sarcopenia in relation to nutrition and lifestyle factors among middle-aged and older Korean adults with obesity. Eur J Nutr. 2020;59:3451-60. doi: 10.1007/s00394-020-02179-3.
23. Steffl M, Bohannon RW, Sontakova L, Tufano JJ, Shiells K, Holmerova I. Relationship between sarcopenia and physical activity in older people: a systematic review and meta-analysis. Clin Interv Aging. 2017;12:835-45. doi: 10.2147/CIA.S132940.
24. Houston DK, Nicklas BJ, Ding J, Harris TB, Tylavsky FA, Newman AB, Lee JS, Sahyoun NR, Visser M, Kritchevsky SB; Health ABC Study. Dietary protein intake is associated with lean mass change in older, community-dwelling adults: the Health, Aging, and Body Composition (Health ABC) Study. Am J Clin Nutr. 2008;87:150-5. doi: 10.1093/ajcn/87.1.150.
25. Pérez-Torres I, Castrejón-Téllez V, Soto ME, Rubio-Ruiz ME, Manzano-Pech L, Guarner-Lans V. Oxidative stress, plant natural antioxidants, and obesity. Int J Mol Sci. 2021;22:1786. doi: 10.3390/ijms22041786.
26. Brioche T, Lemoine-Morel S. Oxidative stress, sarcopenia, antioxidant strategies and exercise: molecular aspects. Curr Pharm Des. 2016;22:2664-78. doi: 10.2174/1381612822666 160219120531.
27. Troesch B, Eggersdorfer M, Laviano A, Rolland Y, Smith AD, Warnke I , Weimann A, Calder PC. Expert opinion on benefits of long-chain omega-3 fatty acids (DHA and EPA) in aging and clinical nutrition. Nutrients. 2020;12:2555. doi: 10.3390/nu12092555.
28. Kweon S, Kim Y, Jang MJ, Kim Y, Kim K, Choi S, Chun C, Khang YH, Oh K. Data resource profile: the Korea National Health and Nutrition Examination Survey (KNHANES). Int J Epidemiol. 2014;43:69-77. doi: 10.1093/ije/dyt228.
29. Ciudin A, Simó-Servat A, Palmas F, Barahona MJ. Sarcopenic obesity: A new challenge in the clinical practice. Endocrinol Diabetes Nutr (Engl Ed). 2020;67:672-81. doi: 10.1016/j.endinu.2020.03.004.
30. Chen LK, Woo J, Assantachai P, Auyeung TW, Chou MY, Iijima K et al, Akishita M, Arai H. Asian Working Group for Sarcopenia: 2019 consensus update on sarcopenia diagnosis and treatment. J Am Med Dir Assoc. 2020;21:300-7.e2. doi: 10.1016/j.jamda.2019.12.012.
31. Lee SY, Park HS, Kim DJ, Han JH, Kim SM, Cho GJ , Kim DY, Kwon HS, Kim SR, Lee CB, Oh SJ, Park CY, Yoo HJ. Appropriate waist circumference cutoff points for central obesity in Korean adults. Diabetes Res Clin Pract. 2007;75:72-80. doi: 10.1016/j.diabres.2006.04.013.
32. Lim HS, Park YH, Suh K, Yoo MH, Park HK, Kim HJ, Lee JH, Byun DW. Association between sarcopenia, sarcopenic obesity, and chronic disease in Korean elderly. J Bone Metab. 2018;25:187-93. doi: 10.11005/jbm.2018.25.3.187.
33. Hatløy A, Torheim LE, Oshaug A. Food variety-a good indicator of nutritional adequacy of the diet? A case study from an urban area in Mali, West Africa. Eur J Clin Nutr. 1998;52:891-8. doi: 10.1038/sj.ejcn.1600662.
34. Landi F, Calvani R, Cesari M, Tosato M, Martone AM, Ortolani E et al. Sarcopenia: an overview on current definitions, diagnosis and treatment. Curr Protein Pept Sci. 2018;19:633-8. doi: 10.2174/1389203718666170607113459
35. Kim CR, Jeon YJ, Jeong T. Risk factors associated with low handgrip strength in the older Korean population. PLoS ONE. 2019;14:e0214612. doi: 10.1371/journal.pone.021461 2.
36. 36. de Araújo Amaral C, Amaral TLM, Monteiro GTR, de Vasconcellos MTL, Portela MC. Factors associated with low handgrip strength in older people: data of the Study of Chronic Diseases (Edoc-I). BMC Public Health. 2020;20:395. doi: 10.1186/s12889-020-08504-z.
37. Devaux M, Sassi F. Social inequalities in obesity and overweight in 11 OECD countries. Eur J Public Health. 2013;23:464-9. doi: 10.1093/eurpub/ckr058.
38. Tyrovolas S, Koyanagi A, Olaya B, Ayuso-Mateos JL, Miret M, Chatterji S, Tobiasz-Adamczyk B, Koskinen S, Leonardi M, Haro JM. Factors associated with skeletal muscle mass, sarcopenia, and sarcopenic obesity in older adults: a multi-continent study. J Cachexia Sarcopenia Muscle. 2016;7:312-21. doi: 10.1002/jcsm.12076.
39. Yoo S, Kim DY, Lim H. Sarcopenia in relation to nutrition and lifestyle factors among middle-aged and older Korean adults with obesity. Eur J Nutr. 2020;59:3451-60. doi: 10.1007/s00394-020-02179-3.
40. Eglseer D, Traxler M, Bauer S. Association between the intake of different protein sources and obesity coexisting with low handgrip strength in persons near retirement age. Nutrients. 2022;14:4684. doi: 10.3390/nu14214684.