ORIGINAL ARTICLE
Endocrinology, Nutrition & Metabolism

JKMS

http://dx.doi.org/10.3346/jkms.2012.27.7.748 • J Korean Med Sci 2012; 27: 748-755

Prevalence Rate and Associated Factors of Sarcopenic Obesity in Korean Elderly Population

Byungkwan Hwang[1,2], Jae-Young Lim[1], Joongyub Lee[3], Nam-Kyong Choi[3], Yoon-Ok Ahn[2], and Byung-Joo Park[2]

[1]Department of Rehabilitation Medicine, Seoul National University Hospital; [2]Department of Preventive Medicine, Seoul National University College of Medicine; [3]Medical Research Collaborating Center, Seoul National University and Seoul National University Hospital, Seoul, Korea

Received: 12 January 2012
Accepted: 2 May 2012

Address for Correspondence:
Byung-Joo Park, MD
Department of Preventive Medicine, Seoul National University College of Medicine, 103 Daehak-ro, Jongno-gu, Seoul 110-799, Korea
Tel: +82.2-740-8325, Fax: +82.2-747-4830
E-mail: bjpark@snu.ac.kr

This study was conducted to estimate the prevalence rates and to explore associated factors of sarcopenic obesity (SO) in 2,221 Koreans over 60 yr-of age from the Fourth Korea National Health and Nutrition Examination Survey (2009). Participants were assessed by dual energy X-ray absorptiometry. Appendicular skeletal muscle mass divided by body weight was used to define sarcopenia and waist circumference was used to define obesity. We estimated the prevalence rates of SO according to age-groups, sex and region. In addition, each group was compared by demographic characteristics, metabolic status, nutrition, and physical activity. The prevalence rates of SO were 6.1% (95% confidential interval [CI] = 6.1-6.2) for men and 7.3% (95% CI = 7.3-7.3) for women, respectively. SO was positively associated with no current working and the number of combined medical conditions. High serum insulin level was positively associated with SO, whereas vitamin D was negatively associated with SO in both men and women. In conclusion, the prevalence rates of SO are 6.1% in men and 7.3% in women. SO is associated with insulin resistance, inappropriate nutrition, and low physical activity.

Key Words: Sarcopenia; Obesity; Aging; Prevalence; Epidemiology

INTRODUCTION

The age-related reduction of muscle mass is the predominant change of body composition in elderly people. In 1989, Rosenberg defined this progressive loss of muscle mass as sarcopenia (1). Sarcopenia leads to impaired physical functioning, including impaired activities of daily living, falls and gait disturbance. Consequently, sarcopenia increases the dependency of living and decreases the quality of life in elderly people (2, 3). In the year 2000, the estimated healthcare cost of sarcopenia in the United States was as high as 18.5 billion dollars (4).

Age-related body composition change includes the loss of muscle mass and an increase of body fat (5). Particularly, central obesity increases with age. Central obesity is correlated with insulin resistance and considered as an important risk factor of metabolic syndrome (6). This body composition change influences functional limitation and cardiovascular risk (7). Thus, the concept of sarcopenic obesity (SO) was proposed, as the recognition of the relationship between sarcopenia and obesity (8).

Previously, there were only two studies reporting the prevalence of SO in the Korean elderly population (9, 10). However, these two reports had limitations to apply entire Korean population because their study subjects could not guarantee the representativeness. In addition, associated factors of SO have not been studied well in Korean elderly people, although such knowledge was crucial for developing public health programs for the elderly persons.

In 2009, the Fourth Korea National Health and Nutrition Examination Survey (KNHANES IV) measured muscle mass of 2,221 representative Korean adults who were 60 yr old or more, using dual energy x-ray absorptiometry (DXA) (11). The present study used this data to estimate the prevalence of SO and to find out associated factors for SO in Korean elderly persons.

MATERIALS AND METHODS

Study database and participants

The Ministry of Health and Welfare and Korea Institute for Health and Social Affairs has conducted the KNHANES since 1998 (11). The KNHANES has generated nationwide and representative statistical data by self-administered questionnaires of health status, health behaviors, and nutritional status. In KNHANES IV, participants were selected by a stratified, multistage probability sampling design for the selection of household units. The selection was made from sampling units based on geographical area, gender, and age using household registries. In addition, KNHANES IV employed the concept of rolling survey sampling during 2007-2009. Each rolling sample was able to represent the

pISSN 1011-8934
eISSN 1598-6357

entire Korean population and had independent and homogenous characteristics.

The KNHANES included database of demographic characteristics (age, region, income, education, occupation, marital status, current smoking, and alcohol drinking), metabolic status (glycated hemoglobin, fasting glucose, insulin, total cholesterol, high-density lipoprotein, low-density lipoprotein, triglyceride, parathyroid hormone, and serum vitamin D), nutrition (carbohydrate, protein, lipid, mineral, and vitamin intake), and physical activity (frequencies of resistance and flexibility exercise, and walking time per day).

Definition of sarcopenic obesity

In 2009, whole body DXA (Discovery-W; Hologic, Waltham, MA, USA) was performed for each participant to measure total and regional body fat and lean body mass. Appendicular skeletal muscle mass (ASM) was calculated as the sum of muscle mass in bilateral upper and lower limbs.

We defined an elderly person to be 60 yr of age or older. In this study, sarcopenia in Korean was defined as appendicular skeletal muscle mass divided by body weight (%) more than 2 standard deviation (SD) below mean value of sex-specific young normal people (20-39 yr-of-age). This definition was called as modified skeletal muscle mass index (SMI), which was modified from the original definition of Janssen et al. (2). Two SDs of sex-specific young normal people, as cutoff points, were 29.53% in men and 23.20% in women, respectively.

The definition of SO combines the definitions of sarcopenia and obesity. Waist circumference (WC) was chosen as an index of obesity because waist circumference might have better power to predict mortality than body mass index (BMI) in elderly people. Janssen et al. (12) suggested BMI is inversely related to mortality because low BMI might reflect malnutrition, which plays an important role in mortality. We accepted the Korean abdominal obesity criteria (WC ≥ 90 cm in men and ≥ 85 cm in women) (13). Waist circumference was measured at the midpoint between the lower margin of the last palpable rib and the top of the iliac crest at the end of a normal expiration with the arms relaxed at the sides.

Prevalence rates and associated factors of sarcopenic obesity in the Korean elderly population

We divided Korean elderly people into 2 groups using as-above definition; normal and SO. For comparison, we excluded obesity without sarcopenia and sarcopenia without obesity. We estimated prevalence of SO according to age-groups, sex and region. In addition, we explored potential risk factors among the various related factors after adjusting for age.

Statistical analysis

All analyses were conducted using SPSS software version 17.0 (SPSS, Chicago, IL, USA). We estimated prevalence of SO after applying weight. We applied weight value in order to reflect entire Korean elderly population. A sample weight was assigned to each sample by the following 3 steps: calculating base weight, adjusting for non-responses and post-stratification adjustment to match the total number of the previous census population.

In addition, we compared demographic, metabolic characteristics, nutrition, and physical activity between normal and SO. Elderly age-groups were divided into 3 groups; 60-69 yr-of-age, 70-79 yr-of-age and ≥ 80 yr-of-age. In the KNHANES IV, Korea was divided into 12 different administrative regions. We classified those regions into urban and rural groups. Urban areas included Seoul, Gyeonggi-do, Busan, Daegu, Incheon, Gwangju, Daejeon, and Ulsan. Rural areas included Gangwon-do, Chungcheongbuk-do, Chungcheongnam-do, Gyeongsangbuk-do, Gyeongsangnam-do, Jeollabuk-do, Jeollanam-do, and Jeju-do. Income was divided into 4 quartiles, based on monthly household-equalized income. Education was classified as ≤ elementary school, ≤ middle school and ≥ high school. Occupation was divided into current working and no current working. Marital status was classified by the presence/absence of spouse. Current smoking was categorized as yes or no. Alcohol drinking was classified by frequency of drinking (none, < 4 days/week, ≥ 4 days/week). Combined medical condition included hypertension, diabetes mellitus, dyslipidemia, stroke, coronary heart disease, liver cirrhosis, chronic obstructive pulmonary disease, cancer (stomach, liver, colon, breast, cervix, lung, and other cancers), osteoporosis, and arthritis. While categorical variables were analyzed by chi-square test, continuous variables were analyzed by independent t test.

Finally, the associated factors for SO was investigated using multiple logistic regression analysis. Continuous variables were divided into 4 quartiles for evaluating linear trends. We considered each of the associated factors separately, after adjusting age.

Ethics statement

This study was approved by the institutional review board of Seoul National University Hospital (IRB No. E-1201-035-394). Informed consent was waived by the board.

RESULTS

Characteristics of the study participants

The anthropometric characteristics of all participants in this study are shown in Table 1. Mean age was 69.4 ± 6.6 yr old in men and 69.8 ± 6.8 yr old in women. Mean modified SMI was 33.4% ± 2.9% in men and 26.6% ± 2.8% in women. SO group was older than normal group. In addition, the occupation (current working) and the number of combined medical conditions were different between normal and SO in both men and women. Current smoking, frequency of resistance exercise and walking

Table 1. Anthropometric characteristics of study participating Korean elderly population*

Anthropometric characteristics	Study population			Young references		
	Men (n = 964) Mean ± SD	Women (n = 1,257) Mean ± SD	*P* value	Men (n = 1,003) Mean ± SD	Women (n = 1,266) Mean ± SD	*P* value
Age (yr)	69.4 ± 6.6	69.8 ± 6.8	0.119	30.7 ± 5.5	31.0 ± 5.5	0.218
Height (cm)	165.2 ± 5.8	151.2 ± 5.9	< 0.001	173.5 ± 5.9	160.2 ± 7.1	< 0.001
Weight (kg)	62.6 ± 9.7	55.4 ± 8.8	< 0.001	72.5 ± 11.6	56.8 ± 9.9	< 0.001
WC (cm)	84.5 ± 9.0	83.0 ± 9.4	< 0.001	82.8 ± 9.4	73.9 ± 9.8	< 0.001
BMI (kg/m^2)	23.3 ± 3.0	24.2 ± 3.3	< 0.001	24.1 ± 3.5	22.1 ± 3.6	< 0.001
Total body fat (kg)	13.6 ± 5.4	18.3 ± 6.0	< 0.001	15.1 ± 6.5	17.4 ± 6.2	< 0.001
ASM (kg)	20.9 ± 3.1	14.5 ± 2.0	< 0.001	24.6 ± 5.4	15.6 ± 3.2	< 0.001
SMI (%)	33.4 ± 2.9	26.6 ± 2.8	< 0.001	35.7 ± 3.1	28.4 ± 2.6	< 0.001

The data were analyzed by independent t test. *Study subjects were adults ≥ 60 yr of age in the Fourth Korea National Health and Nutrition Examination Survey. Young references were sex-specific young normal people (20-39 yr-of-age). WC, waist circumference; BMI, body mass index; ASM, appendicular skeletal muscle mass; SMI, modified skeletal muscle mass index.

Table 2. Demographic characteristics of study participating Korean elderly population

Demographic characteristics	Category	Men*			Women†		
		Normal (n = 676)	SO‡ (n = 58)	*P* value	Normal (n = 717)	SO‡ (n = 86)	*P* value
Age	60-69	54.4	41.4	0.029	50.9	36.0	0.065
	70-79	37.9	44.8		38.9	54.7	
	≥ 80	7.7	13.8		10.2	9.3	
Region	Urban area	56.7	58.6	0.772	51.7	58.1	0.262
	Rural area	43.3	41.4		48.3	41.9	
Income	1st quartile	42.3	49.1	0.148	49.2	47.1	0.391
	2nd quartile	26.4	28.1		24.5	34.1	
	3rd quartile	18.7	15.8		15.6	12.9	
	4th quartile	12.7	7.0		10.6	5.9	
Education	≤ Elementary	50.4	41.4	0.468	80.4	88.4	0.096
	≤ Middle	18.3	27.6		8.2	4.7	
	≥ High	31.3	31.0		11.4	7.0	
Occupation	Current working	52.3	27.6	< 0.001	34.8	15.1	< 0.001
	Not working	47.7	72.4		65.2	84.7	
Marital status	Spouse	90.8	94.8	0.297	54.7	41.2	0.018
	No spouse	9.2	5.2		45.3	58.8	
Smoking	No	17.0	28.9	0.046	88.6	85.3	0.426
	Yes	83.0	71.1		11.4	14.7	
Alcohol	None	44.4	44.6	0.715	71.9	74.7	0.490
	< 4 days/week	39.6	42.9		25.6	24.1	
	≥ 4 days/week	15.9	12.5		2.5	1.2	
Combined medical conditions	None	37.9	10.3	< 0.001	19.2	2.3	< 0.001
	1 condition	33.3	34.5		34.2	25.6	
	2 conditions	21.0	32.8		26.1	32.6	
	≥ 3 conditions	7.8	22.4		20.5	39.5	
Resistance exercise	No	73.0	86.2	0.032	89.9	89.5	0.822
	1-2 times/week	3.4	1.7		1.8	1.2	
	≥ 3 times/week	23.6	12.1		8.3	9.3	
Flexibility exercise	No	59.0	65.5	0.198	67.1	70.9	0.281
	1-2 times/week	9.1	12.1		10.2	12.8	
	≥ 3 times/week	31.9	22.4		22.7	16.3	
Walking time per day	< 30 min	39.2	49.0	0.050	55.6	57.6	0.425
	30 min-1 hr	24.1	29.4		26.2	30.3	
	≥ 1 hr	36.6	21.6		18.1	12.1	

Values are presented as percent in cases. The data were analyzed using chi-square test and linear by linear association. *Missing cases are 13 cases in income, 11 cases in education, 12 cases in occupation, 5 cases in marital status, 187 cases in smoking, 32 cases in alcohol, 1 case in resistance exercise, 8 cases in flexibility exercise and 140 cases in walking exercise; †Missing cases are 13 cases in income, 8 cases in education, 8 cases in occupation, 5 cases in marital status, 143 cases in smoking, 40 cases in alcohol, 2 cases in resistance exercise, 8 cases in flexibility exercise and 169 cases in walking exercise; ‡Sarcopenic obesity in Koreans is defined as appendicular skeletal muscle mass divided by body weight (%) more than 2 SD below sex-specific young normal mean and waist circumference greater than the Korean abdominal obesity criteria (waist circumference ≥ 90 cm in men and ≥ 85 cm in women) from the Fourth Korea National Health and Nutrition Examination Survey. SO, sarcopenic obesity.

http://dx.doi.org/10.3346/jkms.2012.27.7.748

Table 3. Metabolic characteristics and nutritional intake of study participating Korean elderly population

Metabolic/nutritional characteristics	Men*			Women†		
	Normal (n = 640)	SO‡ (n = 54)	*P* value	Normal (n = 686)	SO‡ (n = 83)	*P* value
HbA1c (%)	7.2 ± 1.6	6.9 ± 1.2	0.554	7.4 ± 1.4	7.2 ± 1.1	0.567
Fasting glucose (mg/dL)	102.1 ± 29.6	104.7 ± 22.2	0.538	99.0 ± 23.1	104.8 ± 19.6	0.030
Insulin (μIU/mL)	9.1 ± 5.1	12.5 ± 7.4	0.002	10.0 ± 5.8	14.8 ± 12.7	0.001
Total cholesterol (mg/dL)	178.5 ± 34.9	182.2 ± 35.4	0.462	190.7 ± 37.1	196.0 ± 38.7	0.216
HDL (mg/dL)	45.9 ± 10.6	42.7 ± 9.8	0.042	47.6 ± 10.3	46.3 ± 10.2	0.249
LDL (mg/dL)	107.0 ± 31.4	103.5 ± 33.6	0.719	113.4 ± 33.5	116.5 ± 34.4	0.737
Triglyceride (mg/dL)	141.4 ± 112.6	153.9 ± 97.9	0.471	133.4 ± 82.6	163.6 ± 70.9	0.005
PTH (pg/mL)	68.7 ± 28.2	77.5 ± 28.4	0.068	70.4 ± 34.2	75.0 ± 39.1	0.330
Vitamin D (ng/mL)	20.7 ± 7.4	17.9 ± 6.1	0.016	18.3 ± 7.2	15.8 ± 6.0	0.009
Carbohydrate intake (g)	307.4 ± 117.0	280.6 ± 88.5	0.100	261.7 ± 107.5	251.3 ± 93.1	0.409
Protein intake (g)	62.7 ± 30.8	58.3 ± 23.3	0.300	49.2 ± 26.0	44.7 ± 22.1	0.142
Lipid intake (g)	30.4 ± 24.3	29.5 ± 19.8	0.790	23.8 ± 18.4	21.7 ± 18.3	0.337
Ca intake (mg)	487.2 ± 346.4	490.5 ± 564.8	0.949	391.0 ± 267.8	511.6 ± 1475.1	0.467
P intake (mg)	1109.1 ± 465.7	1016.7 ± 361.5	0.156	889.2 ± 402.1	807.3 ± 336.8	0.080
Iron intake (mg)	13.7 ± 11.4	12.6 ± 9.1	0.502	11.1 ± 9.1	11.4 ± 17.1	0.760
Na intake (mg)	4712.8 ± 3292.9	4620.1 ± 2728.1	0.841	3517.7 ± 2674.8	3235.9 ± 2370.5	0.367
K intake (mg)	2838.8 ± 1603.5	2728.3 ± 1314.1	0.623	2345.3 ± 1337.7	1947.5 ± 1038.8	0.002
Vitamin A intake (μgRE)	729.2 ± 974.3	554.2 ± 374.8	0.007	617.9 ± 744.7	623.3 ± 774.3	0.951
Vitamin C intake (mg)	92.2 ± 83.4	83.5 ± 61.4	0.451	83.9 ± 72.0	67.6 ± 76.0	0.057

Values are presented as mean ± SD. The data were analyzed by independent t test. *Missing cases are 7 cases in carbohydrate, protein, lipid, Ca, P, iron, Na, K, vitamin A, vitamin C intake, 577 cases in HbA1c, 5 cases in fasting glucose, 3 cases in in insulin, total cholesterol, HDL, 571 cases in LDL, 124 cases in triglyceride, 109 cases in PTH, and 123 cases in vitamin D level; †Missing cases are 3 cases in carbohydrate, protein, lipid, Ca, P, iron, Na, K, vitamin A, vitamin C intake, 663 cases in HbA1c, 14 cases in fasting glucose, 13 cases in insulin, total cholesterol, HDL, 654 cases in LDL, 95 cases in triglyceride, 266 cases in PTH, and 200 cases in vitamin D level; ‡Sarcopenic obesity in Koreans is defined as appendicular skeletal muscle mass divided by body weight (%) more than 2 SD below sex-specific young normal mean and waist circumference greater than the Korean abdominal obesity criteria (waist circumference ≥ 90 cm in men and ≥ 85 cm in women) from the Fourth Korea National Health and Nutrition Examination Survey. SO, sarcopenic obesity; HbA1c, Glycated hemoglobin; HDL, high-density lipoprotein; LDL, low-density lipoprotein; PTH, parathyroid hormone.

time per day in SO men were lower than ones in normal men, whereas the proportion of marital status without spouse in SO women was higher than in normal women (Table 2).

In the aspects of metabolic status, serum insulin level in SO men and women was higher than one in normal group, whereas vitamin D in SO men and women were lower than one in normal group. Otherwise, HDL level/vitamin A intake in SO men and potassium in SO women were lower than ones in control, whereas triglyceride in SO women was higher than one in normal group (Table 3).

Prevalence rates of sarcopenic obesity

The prevalence of SO displayed an age-related increasing pattern in men, but one in women did not show increasing pattern with aging. Specifically, the prevalence rate of over 80 yr-old (11.9%, 95% confidential interval [CI], 11.7-12.0%) was higher than those of 60-69 yr-of-age (4.3%, 95% CI, 4.3-4.4%) and 70-79 yr-of-age (8.1%, 95% CI, 8.1-8.2%) in men, while this difference was less pronounced in women (Table 4). The prevalence rates of elderly women were 5.4% (95% CI, 5.4-5.5%) in 60-69 yr-of-age, 9.5% (95% CI, 9.5-9.6%) in 70-79 yr-of-age, and 7.5% (95% CI, 7.4-7.6%) in over 80 yr-old. From the viewpoint of region, there was no statistically significant different in the prevalence of SO between urban and rural area.

Table 4. Prevalence rates of sarcopenic obesity* according to age, sex, and regions in Korean elderly population

Groups	Category	Sarcopenic obesity	
		Men	Women
Age†	60-69	4.3% (4.3-4.4)	5.4% (5.4-5.5)
	70-79	8.1% (8.1-8.2)	9.5% (9.5-9.6)
	≥ 80	11.9% (11.7-12.0)	7.5% (7.4-7.6)
Region‡	Urban	6.2% (6.2-6.2)	8.1% (8.0-8.1)
	Rural	6.1% (6.0-6.1)	6.1% (6.1-6.2)
Total	≥ 60 yr of age	6.1% (6.1-6.2)	7.3% (7.3-7.3)

*Sarcopenia in Koreans is defined as appendicular skeletal muscle mass divided by body weight (%) more than 2 SD below sex-specific young normal mean. Obesity in Koreans is defined as waist circumference greater than the Korean abdominal obesity criteria (waist circumference ≥ 90 cm in men and ≥ 85 cm in women) from the Fourth Korea National Health and Nutrition Examination Survey. Definition of sarcopenic obesity combines those of sarcopenia and obesity; †Values are presented as prevalence rate (95% confidential interval) in same age-groups after adjusting weight; ‡Values are presented as prevalence rate (95% confidential interval) in same living regions after adjusting weight.

Associated factors of sarcopenic obesity

We investigated the relationship between SO and various demographic and metabolic factors. Multivariate analysis showed ≥ 3 combined medical conditions (men: odds ratio [OR], 10.47, 95% CI, 3.79-28.87, women: OR, 15.48, 95% CI, 3.64-65.80) and no current working (men: OR, 2.62, 95% CI, 1.42-4.83, women: OR, 2.86, 95% CI, 1.55-5.30) were associated with a significantly increased likelihood for SO in men and women (Table 5). How-

Table 5. Associations of various lifestyle factors with sarcopenic obesity* among Korean elderly population

Demographic characteristics	Category	Men OR (95% CI)†	Women OR (95% CI)†
Region	Urban	1.00	1.00
	Rural	0.85 (0.49-1.48)	0.69 (0.44-1.10)
Income	1st quartile	1.00	1.00
	2nd quartile	1.07 (0.55-2.09)	1.81 (1.06-3.09)‡
	3rd quartile	0.90 (0.40-2.03)	1.08 (0.53-2.22)
	4th quartile	0.62 (0.20-1.88)	0.65 (0.25-1.72)
Education	≤ Elementary school	1.00	1.00
	≤ Middle school	2.17 (1.10-4.31)‡	0.64 (0.22-1.86)
	≥ High school	1.49 (0.77-2.88)	0.68 (0.28-1.65)
Occupation	Current working	1.00	1.00
	Not working	2.62 (1.42-4.83)‡	2.86 (1.55-5.30)‡
Marital status	Spouse	1.00	1.00
	No spouse	0.48 (0.14-1.58)	1.57 (0.96-2.57)
Smoking	No	1.00	1.00
	Yes	0.50 (0.25-1.01)	1.31 (0.62-2.75)
Alcohol	None	1.00	1.00
	< 4 days/week	1.22 (0.67-2.22)	1.03 (0.60-1.78)
	≥ 4 days/week	0.84 (0.35-2.02)	0.37 (0.05-2.87)
Combined medical conditions	None	1.00	1.00
	1 condition	3.94 (1.55-9.99)‡	6.06 (1.40-26.19)‡
	2 conditions	5.48 (2.14-14.07)‡	10.18 (2.38-43.55)‡
	≥ 3 conditions	10.47 (3.79-28.87)‡	15.48 (3.64-65.80)‡
Resistance exercise	No	1.00	1.00
	1-2 times/week	0.50 (0.07-3.85)	0.73 (0.09-5.71)
	≥ 3 times/week	0.47 (0.21-1.07)	1.34 (0.61-2.96)
Flexibility exercise	No	1.00	1.00
	1-2 times/week	1.37 (0.58-3.26)	1.29 (0.64-2.59)
	≥ 3 times/week	0.70 (0.36-1.35)	0.77 (0.41-1.43)
Walking duration (time/day)	< 30 min	1.00	1.00
	30 min-1 hr	0.98 (0.50-1.93)	1.17 (0.66-2.09)
	≥ 1 hr	0.51 (0.24-1.07)	0.68 (0.31-1.51)

The data were analyzed by logistic regression. *Sarcopenic obesity in Koreans is defined as appendicular skeletal muscle mass divided by body weight (%) more than 2 SD below sex-specific young normal mean and waist circumference greater than the Korean abdominal obesity criteria (waist circumference ≥ 90 cm in men and ≥ 85 cm in women) from the Fourth Korea National Health and Nutrition Examination Survey; †Values are presented as prevalence odds ratio (95% confidential interval) with adjustment for age; ‡P value < 0.05.

ever, physical activity-related factors such as the frequency of resistance exercise did not show a statistically significant association in both men and women. On the other hand, middle school education or less (OR, 2.17, 95% CI, 1.10-4.31) was associated with an increased likelihood of SO in men.

High serum insulin level increased the risk of SO in men and women (men: OR of the fourth quartile, 10.10, 95% CI, 3.41-29.86, women: OR of the fourth quartile, 7.50, 95% CI, 3.38-16.64). Dose-response relationship was observed between serum insulin level and SO in men and women (Table 6). Serum vitamin D level decreased the likelihood of SO in men and in women (men: OR of the fourth quartile, 0.32, 95% CI, 0.11-0.91, women: OR of the fourth quartile, 0.41, 95% CI, 0.19-0.89). Fasting glucose level (OR of the fourth quartile, 3.44, 95% CI, 1.73-6.82) and triglyceride level (OR of the fourth quartile, 3.33, 95% CI, 1.53-7.28) increased likelihood of SO in women, whereas parathyroid hormone level did in men (OR of the fourth quartile, 3.14, 95% CI, 1.10-8.96). Carbohydrate intake in men (OR of the fourth quartile, 0.37, 95% CI, 0.14-0.97) and potassium intake in women (OR of the fourth quartile, 0.47, 95% CI, 0.24-0.93) decreased the likelihood of SO.

DISCUSSION

The current study used representative national data and estimated the prevalence rate of SO in Korean elderly population. Our results showed the prevalence rate of sarcopenic obesity in men was higher than that in the Korean Sarcopenic Obesity Study (6.1% vs 5.1%). However, the prevalence rate in women was lower than that in the Korean Sarcopenic Obesity Study (7.3% vs 12.5%). The difference may have reflected the different methods of subject recruitment and the definition of sarcopenic obesity (10).

Since 1998, the reported prevalence rates of SO in the elderly have been widely diverse, ranging from 0.8%-20.3% (2, 14-17). This is because a widely-accepted definition of sarcopenia is still lacking (18). In particular, the appendicular skeletal mass divided by height square, widely used to define sarcopenia, has been criticized because body fat was not taken into consideration. Thus, its applications could have been limited because of underestimating sarcopenia in overweight or obese subjects (2, 5, 18, 19). Therefore, we accepted modified definition from Jans-

http://dx.doi.org/10.3346/jkms.2012.27.7.748

Table 6. Associations of metabolic and nutritional factors with sarcopenic obesity* among Korean elderly population

Metabolic/nutritional factors	Quartile	Men OR (95% CI)†	Women OR (95% CI)†	Metabolic/nutritional factors	Quartile	Men OR (95% CI)†	Women OR (95% CI)†
Fasting glucose	1st	1.00	1.00	Carbohydrate intake	1st	1.00	1.00
	2nd	1.03 (0.41-2.61)	1.97 (0.96-4.02)		2nd	0.79 (0.37-1.70)	1.37 (0.73-2.57)
	3rd	2.35 (1.06-5.19)‡	2.36 (1.17-4.78)‡		3rd	1.14 (0.56-2.33)	0.96 (0.49-1.88)
	4th	1.83 (0.76-4.38)	3.44 (1.73-6.82)‡		4th	0.37 (0.14-0.97)‡	0.87 (0.43-1.74)
Serum insulin level	1st	1.00	1.00	Protein intake	1st	1.00	1.00
	2nd	4.23 (1.35-13.29)	1.96 (0.80-4.79)		2nd	0.93 (0.42-2.06)	0.97 (0.52-1.81)
	3rd	3.36 (1.03-10.94)‡	3.78 (1.64-8.69)‡		3rd	1.39 (0.66-2.92)	0.92 (0.48-1.76)
	4th	10.10 (3.41-29.86)‡	7.50 (3.38-16.64)‡		4th	0.82 (0.35-1.91)	0.76 (0.39-1.49)
Serum vitamin D level	1st	1.00	1.00	Lipid intake	1st	1.00	1.00
	2nd	0.99 (0.44-2.20)	0.77 (0.39-1.51)		2nd	1.50 (0.69-4.27)	0.57 (0.30-1.09)
	3rd	0.83 (0.37-1.87)	0.65 (0.32-1.34)		3rd	1.13 (0.50-2.58)	0.56 (0.29-1.08)
	4th	0.32 (0.11-0.91)‡	0.41 (0.19-0.89)‡		4th	1.39 (0.62-3.15)	0.74 (0.40-1.37)
Triglyceride	1st	1.00	1.00	Potassium intake	1st	1.00	1.00
	2nd	1.52 (0.61-3.83)	0.71 (0.25-2.02)		2nd	2.30 (1.03-5.11)‡	0.43 (0.22-0.86)‡
	3rd	1.91 (0.78-4.68)	3.68 (1.69-8.02)‡		3rd	1.73 (0.75-4.02)	0.74 (0.41-1.33)
	4th	2.10 (0.83-5.27)	3.33 (1.53-7.28)‡		4th	1.06 (0.41-2.71)	0.47 (0.24-0.93)‡
HDL level	1st	1.00	1.00	Vitamin A intake	1st	1.00	1.00
	2nd	0.61 (0.29-1.30)	0.81 (0.44-1.48)		2nd	0.46 (0.19-1.11)	0.48 (0.24-0.95)‡
	3rd	0.61 (0.29-1.30)	0.62 (0.32-1.20)		3rd	1.18 (0.58-2.40)	0.66 (0.34-1.26)
	4th	0.32 (0.13-0.80)	0.61 (0.32-1.18)		4th	0.68 (0.31-1.50)	0.78 (0.42-1.44)
Parathyroid hormone	1st	1.00	1.00				
	2nd	2.17 (0.73-6.44)	0.89 (0.41-1.92)				
	3rd	1.25 (0.37-4.21)	1.45 (0.69-3.04)				
	4th	3.14 (1.10-8.96)‡	1.11 (0.51-2.41)				

The data were analyzed by logistic regression. *Sarcopenic obesity in Koreans is defined as appendicular skeletal muscle mass divided by body weight (%) more than 2 SD below sex-specific young normal mean and waist circumference greater than the Korean abdominal obesity criteria (waist circumference ≥ 90 cm in men and ≥ 85 cm in women) from the Fourth Korea National Health and Nutrition Examination Survey; †Values are presented as prevalence odds ratio (95% confidential interval) with adjustment for age; ‡P value < 0.05.

sen et al. because its definition was known to reflect metabolic impairment better than other indices (9, 10).

There was no difference of prevalence rates between urban and rural area. However, this study could not differentiate longevity-belt regions from other areas in Korea (20). Also, if dividing Korea into 12 administrative regions, SO persons in any one region were too small to reveal statistical significance. Therefore, further studies are needed to reveal any actual regional differences and the prevalence rate in longevity-belt regions in Korea.

Many factors could contribute to SO. Specifically, these included a reduction in dietary protein, decreased physical activity, and recently emerging issue, metabolic syndrome. Our study also showed high serum insulin and glucose level, which was a subcomponent of metabolic syndrome was positively associated with SO. Therefore, insulin resistance should be considered as a significant risk factor for SO.

In this study, low vitamin D level was distinctive in SO persons. Low vitamin D was associated with low extremity power and performance because vitamin D level positively influences on muscle strength and muscle mass (21). Also, vitamin D levels have been associated with sarcopenia in older Koreans, regardless of obesity (22). Therefore, vitamin D deficiency could influence the reduction of muscle mass, but the effect on SO after supplementation of vitamin D should be investigated.

To date, only dietary modification and exercise have been proven to prevent sarcopenia. In this study, after adjusting for age, increased carbohydrate, protein, and minerals (potassium and phosphate) intake did not decrease the likelihood of SO. However, even though there was no statistical meaningful difference, the total amount of nutrition in SO subjects was less than one in normal people. This means general malnutrition might play a pivotal role in SO. In particular, aging was correlated with poor appetite, reduced gastric emptying, early satiety, and decreased anabolic response to protein (23). Therefore, elderly people should be encouraged to take at least 0.8 g/kg/day protein to ensure the synthesis of an appropriate amount of protein in muscles (24). Even though Andrews et al. suggested protein supplementation after resistance exercise does not influence lean body mass (25), digestibility and bioavailability of protein should be considered. For example, milk containing fast protein (i.e., whey) and slow protein (i.e., casein) results in producing more protein than iso-nitrogenous soy beverage in human body (26). Koreans typically consume more protein from vegetable-sources than meat-sources (11). Therefore, the role of protein might be more important than one in our study. Therefore, further studies should be investigated for the proper amount and interaction of carbohydrate and protein.

In addition, resistance exercise has been the most effective and safe way to prevent SO (27). Resistance exercise increases the synthesis of protein and induces muscle hypertrophy, regard-

less of age (28). In addition, resistance exercise induces anabolic hormone such as growth hormone, increases neural adaptation and decreases interleukin-6 (29). However, our study showed the frequency of resistance exercise and duration of walking were not statistically significant to reduce the risk of SO in Korean elderly people. These results conflict with previous studies. However, the excessively low participation rate of exercise in Korean elderly people would decrease statistical power. Moreover, the presence of current working was associated with SO. Mostly, current working in Korean elderly was physically demanding working in this survey. Therefore, daily active physical activity should be encouraged for reducing SO, regardless of exercise regimens.

Our study had several limitations that must be considered. First, the cross-sectional design did not identify a causal relationship or changes over time. For example, we could not figure out whether no-current working causes SO or SO causes no-current working. Second, there was no objective measure to estimate muscle strength and physical performance. Thus, we could not evaluate the definition that best represented muscle quality. In 2010, the European Working Group on Sarcopenia in Older People (EWGSOP) developed a practical clinical definition and diagnostic criteria for age-related sarcopenia (30). Further studies should be required to measure muscle strength and physical performance to estimate sarcopenia and SO in accordance with EWGSOP's criteria. However, the large-scale national data used in the current study had the advantages of representing the entire Korean elderly population. Also, the present study was the first study to evaluate associated factors for SO in Korean elderly population.

In conclusion, the prevalence rates of SO are 6.1% in men and 7.3% in women, respectively. SO is associated with insulin resistance, inappropriate nutrition, and low physical activity.

ACKNOWLEDGMENTS

The authors thank Ji-eun Yang for help with advices on statistical analysis and Woojin Kim for her assistance in critical reading of the manuscript in English.

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