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

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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...
entire Korean population and had independent and homogeneous 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)    | Women (n = 1,257) | P value | Men (n = 1,003) | Women (n = 1,266) | 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/m²)                   | 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 (yr)                   | 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          | 26.6          |         |
|                            | 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.
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 women (Table 3).

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

| Metabolic/nutritional characteristics | Men* | Women† | P value | Men* | Women† | 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)             | 176.5 ± 34.9 | 162.2 ± 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 | 163.0 ± 79.9 | 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 (mg/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 | 0.799 | 23.8 ± 18.4 | 21.7 ± 18.3 | 0.337 |
| Ca intake (mg)                        | 467.2 ± 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 ± 7.1 | 0.760 |
| Na intake (mg)                        | 4712.8 ± 3292.9 | 4620.0 ± 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 (µg/RE)              | 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, 5 cases in fasting glucose, 3 cases in insulin, total cholesterol, HDL, LDL, P, triglyceride, 124 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, LDL, vitamin D level, 57 cases in HbA1c, 5 cases in fasting glucose, 3 cases in insulin, total cholesterol, HDL, LDL, P, triglyceride, 124 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; HDL, high-density lipoprotein; LDL, low-density lipoprotein; PTH, parathyroid hormone.

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

| Groups | Category | Sarcopenic obesity |
|--------|----------|--------------------|
| 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-
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, 2.38-16.64). 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 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-

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.
supplementation of vitamin D should be investigated.

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 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-

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

| Metabolic/nutritional factors | OR (95% CI)† | OR (95% CI)† | Men | Women | Men | Women |
|-----------------------------|-------------|-------------|-----|-------|-----|-------|
| Fasting glucose             | 1.00        | 1.00        | 1.00| 1.00  |
| 2nd                         | 1.03 (0.41-2.61)  | 1.00 (0.37-1.70)  | 1.00| 1.00  |
| 3rd                         | 2.35 (1.06-5.19)  | 3.36 (1.03-10.94) | 3.19 (1.64-6.69) | 10.10 (4.13-29.86) |
| 3rd                         | 1.83 (0.76-4.38)  | 7.50 (3.86-16.64) | 3.44 (1.73-6.82) | 1.00 (0.29-1.30) |
| Serum insulin level         | 1.00        | 1.00        | 1.00| 1.00  |
| 2nd                         | 4.23 (1.35-13.29) | 4.23 (1.35-13.29) | 1.96 (0.80-4.79) | 1.96 (0.80-4.79) |
| 3rd                         | 3.36 (1.03-10.94) | 3.36 (1.03-10.94) | 3.78 (1.64-8.69) | 3.78 (1.64-8.69) |
| 4th                         | 10.10 (4.13-29.86) | 10.10 (4.13-29.86) | 7.50 (3.86-16.64) | 7.50 (3.86-16.64) |
| Serum vitamin D level       | 1.00        | 1.00        | 1.00| 1.00  |
| 2nd                         | 0.99 (0.44-2.20)  | 0.99 (0.44-2.20)  | 0.77 (0.39-1.51) | 0.77 (0.39-1.51) |
| 3rd                         | 0.83 (0.37-1.87)  | 0.83 (0.37-1.87)  | 0.65 (0.32-1.34) | 0.65 (0.32-1.34) |
| 4th                         | 0.32 (0.11-0.91)  | 0.32 (0.11-0.91)  | 0.41 (0.19-0.89) | 0.41 (0.19-0.89) |
| Triglyceride                | 1.00        | 1.00        | 1.00| 1.00  |
| 2nd                         | 1.52 (0.61-3.83)  | 1.52 (0.61-3.83)  | 0.71 (0.25-2.02) | 0.71 (0.25-2.02) |
| 3rd                         | 1.91 (0.78-4.68)  | 1.91 (0.78-4.68)  | 3.68 (1.69-8.02) | 3.68 (1.69-8.02) |
| 4th                         | 2.10 (0.83-5.27)  | 2.10 (0.83-5.27)  | 3.33 (1.53-7.28) | 3.33 (1.53-7.28) |
| HDL level                   | 1.00        | 1.00        | 1.00| 1.00  |
| 2nd                         | 0.61 (0.29-1.30)  | 0.61 (0.29-1.30)  | 0.81 (0.44-1.48) | 0.81 (0.44-1.48) |
| 3rd                         | 0.61 (0.29-1.30)  | 0.61 (0.29-1.30)  | 0.62 (0.32-1.20) | 0.62 (0.32-1.20) |
| 4th                         | 0.32 (0.13-0.80)  | 0.32 (0.13-0.80)  | 0.61 (0.32-1.18) | 0.61 (0.32-1.18) |
| Parathyroid hormone         | 1.00        | 1.00        | 1.00| 1.00  |
| 2nd                         | 2.17 (0.73-6.44)  | 2.17 (0.73-6.44)  | 0.89 (0.41-1.92) | 0.89 (0.41-1.92) |
| 3rd                         | 1.25 (0.37-4.21)  | 1.25 (0.37-4.21)  | 1.45 (0.69-3.04) | 1.45 (0.69-3.04) |
| 4th                         | 3.14 (1.10-8.96)  | 3.14 (1.10-8.96)  | 1.11 (0.51-2.41) | 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; ²P value < 0.05.
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, inappropiate nutrition, and low physical activity.

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REFERENCES

1. Rosenberg IH. Sarcopenia: origins and clinical relevance. J Nutr 1997; 127: 990S-1S.
2. 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: 889-96.
3. Rolland Y, Czerwinski S, Abellan Van Kan G, Morley JE, Cesari M, Onder G, Woo J, Baumgartner R, Pillard F, Boirie Y, et al. Sarcopenia: its assessment, etiology, pathogenesis, consequences and future perspectives. J Nutr Health Aging 2008; 12: 433-50.
4. Janssen I, Shepard DS, Katzmarzyk PT, Roubenoff R. The healthcare costs of sarcopenia in the United States. J Am Geriatr Soc 2004; 52: 80-5.
5. Zoico E, Di Francesco V, Gurahnik JM, Mazzali G, Bortolani A, Guariento S, Sergi G, Bosello O, Zamboni M. Physical disability and muscular strength in relation to obesity and different body composition indexes in a sample of healthy elderly women. Int J Obes Relat Metab Disord 2004; 28: 234-41.
6. Kahn R, Buse J, Ferramnni E, Stern M. The metabolic syndrome: time for a critical appraisal. Joint statement from the American Diabetes Association and the European Association for the Study of Diabetes. Diabetologia 2005; 48: 1684-99.
7. Visser M, Langlois J, Gurahnik JM, Cauley JA, Kronmal RA, Robbins J, Williamson JD, Harris TB. High body fatness, but not low fat-free mass, predicts disability in older men and women: the Cardiovascular Health Study. Am J Clin Nutr 1998; 68: 584-90.
8. Roubenoff R. Sarcopenic obesity: does muscle loss cause fat gain? Lessons from rheumatoid arthritis and osteoarthritis. Ann N Y Acad Sci 2000; 904: 553-7.
9. 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.
10. Kim TN, Park MS, Yang SJ, Yoo HJ, Kang HJ, Song W, Seo JA, Kim SG, Kim NH, Baik SH, et al. Prevalence and determinant factors of sarcopenia in patients with type 2 diabetes: the Korean Sarcopenic Obesity Study (KSOIS). Diabetes Care 2010; 33: 1497-9.
11. Korea Centers for Disease Control and Prevention. The Fourth Korea National Health and Nutrition Examination Survey (KNHANES IV), 2009. Available at http://knhanes.cdc.go.kr/ [accessed on 2 April 2011].
12. Janssen I, Katzmarzyk PT, Ross R. Body mass index is inversely related to mortality in older people after adjustment for waist circumference. J Am Geriatr Soc 2005; 53: 2112-8.
13. Lee SY, Park HS, Kim DJ, Han JH, Kim SM, Cho GJ, Kim DY, Kwon HS, Kim SR, Lee CB, et al. Appropriate waist circumference cutoff points for central obesity in Korean adults. Diabetes Res Clin Pract 2007; 75: 72-80.
14. Hedayaati KK, Dittmar M. Prevalence of sarcopenia among older community-dwelling people with normal health and nutritional state. Ecol Food Nutr 2010; 49: 110-28.
15. Woo J, Leung I, Sham A, Kwok T. Defining sarcopenia in terms of risk of physical limitations: a 5-year follow-up study of 3,153 chinese men and women. J Am Geriatr Soc 2009; 57: 2224-31.
16. Tichet J, Vol S, Goze D, Salle A, Berrut G, Ritz P. Prevalence of sarcopenia in the French senior population. J Nutr Health Aging 2008; 12: 202-6.
17. Baumgartner RN, Koehler KM, Gallagher D, Romero L, Heymsfield SB, Ross RR, Garry PJ, Lindeman RD. Epidemiology of sarcopenia among the elderly in New Mexico. Am J Epidemiol 1998; 147: 755-63.
18. Visser M. Towards a definition of sarcopenia: results from epidemiologic studies. J Nutr Health Aging 2009; 13: 713-6.
19. Newman AB, Kupelian V, Visser M, Simonsick E, Goodpaster B, Nevitt M, Kritchevsky SB, Tyaslovsk FA, Rubin SM, Harris TB. Sarcopenia: alternative definitions and associations with lower extremity function. J Am Geriatr Soc 2003; 51: 1602-9.
20. Choi S, Yon M, Lee MS, Oh SI, Park SC. Social characteristics of the oldest old in longevity belt in Korea. Gerontologist 2004; 44: 576-7.
21. Roth SM, Zmuda JM, Cauley JA, Shea PR, Ferrell RE. Vitamin D receptor genotype is associated with fat-free mass and sarcopenia in elderly

http://jkms.org
men. J Gerontol A Biol Sci Med Sci 2004; 59: 10-5.

22. Kim MK, Baek KH, Song KH, Kang MI, Park CY, Lee WV, Oh KW. Vitamin D deficiency is associated with sarcopenia in older Koreans, regardless of obesity: the Fourth Korea National Health and Nutrition Examination Surveys (KNHANES IV) 2009. J Clin Endocrinol Metab 2011; 96: 3250-6.

23. Dixon CL, Woerner DR, Tokach RJ, Chapman PL, Engle TE, Tatum JD, Belk KE. Quantifying the aging response and nutrient composition for muscles of the beef round. J Anim Sci 2012; 90: 996-1007.

24. Breen L, Phillips SM. Skeletal muscle protein metabolism in the elderly: interventions to counteract the ‘anabolic resistance’ of ageing. Nutr Metab (Lond) 2011; 8: 68.

25. Andrews RD, MacLean DA, Riechman SE. Protein intake for skeletal muscle hypertrophy with resistance training in seniors. Int J Sport Nutr Exerc Metab 2006; 16: 362-72.

26. Wilkinson SB, Tarnopolsky MA, Macdonald MJ, Macdonald JR, Armstrong D, Phillips SM. Consumption of fluid skim milk promotes greater muscle protein accretion after resistance exercise than does consumption of an isonitrogenous and isoenergetic soy-protein beverage. Am J Clin Nutr 2007; 85: 1031-40.

27. Peterson MD, Gordon PM. Resistance exercise for the aging adult: clinical implications and prescription guidelines. Am J Med 2011; 124: 194-8.

28. Griffin L, Cafarelli E. Resistance training: cortical, spinal, and motor unit adaptations. Can J Appl Physiol 2005; 30: 328-40.

29. Lauretani F, Russo CR, Bandinelli S, Bartali B, Cavazzini C, Di Iorio A, Corsi AM, Rantanen T, Guralnik JM, Ferrucci L. Age-associated changes in skeletal muscles and their effect on mobility: an operational diagnosis of sarcopenia. J Appl Physiol 2003; 95: 1851-60.

30. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, Martin FC, Michel JP, Rolland Y, Schneider SM, et al. Sarcopenia: European consensus on definition and diagnosis: report of the European Working Group on Sarcopenia in Older People. Age Ageing 2010; 39: 412-23.