Sarcopenia in Korea: Prevalence and Clinical Aspects

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INTRODUCTION

A progressive decrease in muscle mass and an increase in fat mass are typical body compositional changes associated with aging in humans. In these age-related body compositional changes, sarcopenia is defined as a condition characterized by considerable loss of muscle mass and strength, decreased physical performance, and consequent frailty in the elderly.1 Muscle tissue plays various important roles in the human body; thus, loss of muscle mass can cause diverse functional and metabolic derangements in the elderly. Because of the clinical importance of sarcopenia in the elderly, the number of studies focusing the prevalence, etiology, and clinical issue of sarcopenia has been increasing in many countries, including Korea.2-4 Moreover, consensus papers about defi-
nition, prevalence, and clinical importance of sarcopenia have been published by various working groups, including the International Working Group on Sarcopenia (IWGS), the European Working Group on Sarcopenia in Older People (EWGSOP), and Asian Working Group for Sarcopenia5-7).

Appendicular skeletal muscle mass (ASM) divided by height squared (ASM/ht²) or by weight (ASM/wt) are representative methods used for the definition of sarcopenia8,9). When determining cutoff values for sarcopenia, a mix of criteria of less than 1 standard deviation (SD) or 2 SDs below the mean values of healthy adults, or the lowest quintile of study populations has been used10,11). However, the prevalence and associations with other clinical parameters could be described differently according to the methods used to categorize sarcopenia12-15).

Korea is one of the fastest aging countries, and it has become increasingly evident that sarcopenic status in the elderly is closely related to many clinical consequences including functional limitations, metabolic impairment, and increased cardiovascular risk. This review aims to introduce the representative cohorts for assessing sarcopenia in Korea and their published data, and will highlight the controversies surrounding the definition and prevalence of sarcopenia in Korea.

OPERATIONAL DEFINITION OF SARCOPENIA

The diagnostic criterion of sarcopenia is mainly based on muscle mass. Baumgartner et al.9) first suggested a height squared adjusted ASM index in the New Mexico Elder Health Survey. They also showed a significant association between physical disabilities and sarcopenia defined by that index. However, the relationships were relatively weak for women. This definition was criticized because of the significant positive correlation with body mass index (BMI), suggesting that subjects with greater BMI having a larger amount of fat, are less likely to classified as having sarcopenia10). In this respect, Newman et al.10) suggested an alternative definition adjusted for both height and fat mass, but this method has not been widely used because it is difficult to apply practically. In 2002, Janssen et al.9) presented another method. They defined relative muscle mass index as skeletal muscle mass, which was derived from bioimpedance analysis, divided by weight. In other words, absolute skeletal muscle mass (kg) was converted to percentage skeletal muscle mass (skeletal muscle mass/body weight×100) and termed the skeletal muscle index (SMI). Since Janssen et al.8) proposed their method, “ASM/wt” modified by the index of Janssen et al.9), which is derived from dual energy X-ray absorptiometry (DEXA), has been also used as an alternative method together with the index described by Baumgartner et al.7).

COHORT STUDIES OF SARCOPENIA IN KOREA


The Korean National Health and Nutrition Examination Survey (KNHANES) is a nationwide, population-based, cross-sectional study and has been conducted periodically since 1998 by the Division of Chronic Disease Surveillance of the Korea Centers for Disease Control and Prevention to assess the health and nutritional status of the Korean civilian, noninstitutionalized population. It has been conducted annually since 2008, and approximately around 6,000 to 10,000 individuals are included in annual studies. A stratified, multistage probability sampling design was used for the selection of household units. Whole body and regional body composition were measured by DEXA (Discovery W, Hologic, Waltham, MA, USA) since 2008. Thus, many clinical investigations about sarcopenia and related clinical aspects have been conducted with this cohort.

The etiologies of sarcopenia are multifactorial. Diminishment of anabolic hormone, increased circulating levels of inflammatory cytokines, and lack of exercise with aging have been considered to be possible causative factors for those changes19). Moreover, nutritional deficits have been also considered as one of the contributing factors for those changes19). Kim et al.20) reported that vitamin D levels were significantly lower in sarcopenic subjects compared with nonsarcopenic subjects. In their study, sarcopenia was defined as an ASM adjusted weight index less than 2 SDs below the mean of healthy adults (20–40 years), and prevalence of sarcopenia in participants older than 50 years was 7.8%. A report by Seo et al.21) showed that lower dietary calcium intake was significantly related to a greater risk of sarcopenia. Furthermore, studies using data from KNHANES have shown the cardiometabolic perspectives of sarcopenia indicating impaired metabolism and greater risk of
cardiovascular disease (CVD). Chung et al.22) reported a significant association between sarcopenic obesity and metabolic derangement indicated by a higher prevalence of metabolic syndrome. They also used weight-adjusted ASM as a skeletal muscle mass index, but they defined sarcopenia as ASM divided by weight (ASM/wt) that was less than 1 SD below the mean of healthy adults. Because of the relatively low threshold when defining sarcopenia, the prevalence of sarcopenia was found to be much higher at 42.0% in men and 42.7% in women aged 60 and older. The greater risks of diabetes and metabolic syndrome in sarcopenic subjects were similarly observed in a study reported by Moon23), and the odds for diabetes and metabolic syndrome were significant in nonobese sarcopenic subjects. In this study, the ASM/wt index was used for assessing muscle mass, and ASM/wt less than 2 SDs below the mean of healthy adults was used when determining sarcopenia, and the rate of which was 4.26% in study subjects older than 20 years.

The greater risk of CVDs in subjects with sarcopenia has been observed in several studies. Chin et al.2) reported that CVD prevalence was significantly higher in the sarcopenic elderly than that of nonsarcopenic subjects. Weight-adjusted ASM values less than 1 SD below the mean of healthy young adults were defined as indicating sarcopenia, and the overall prevalence of sarcopenia using this measure was 30.3% in men and 29.5% in women older than 65 years. Moreover, sarcopenia was associated with a greater risk of high blood pressure in both obese and nonobese subjects, and ASM/wt values less than 1 SD below the mean of healthy young adults were used to categorize sarcopenia24).

Importantly, skeletal muscles are essential for locomotion and mobility; thus, it is conceivable that sarcopenia might have dramatic consequences such as impaired performance1). A significant association of sarcopenia with impaired physical activities was also demonstrated in KNAHNES data by Kim et al.25). Although the causal relationship has not yet been fully elucidated yet, a close relationship between sarcopenia and osteoporosis has been suggested, and a greater risk of osteoporosis in the elderly with sarcopenia than in the elderly without sarcopenia was observed in this cohort26). However, in these two studies, muscle mass was analyzed using the ASM index adjusted by height squared, and an ASM/ht² of less than 2 SDs or 1 SD below the sex-specific normal mean for the young reference group was used as a definition for sarcopenia, respectively.

In this manner, both weight adjusted ASM index (ASM/wt) and height squared adjusted ASM index (ASM/ht²) have been used for the definition of sarcopenia, and the prevalence of sarcopenia varies widely according to the method used.

2. Studies in the Korean Longitudinal Study on Health and Aging

The Korean Longitudinal Study on Health and Aging (KLoSHA) is an ongoing population-based observational study initiated in September 2005 for residents aged 65 or older in Seongnam city, one of the satellites of the Seoul Metropolitan district. Participants were selected using age and sex-stratified random sampling from a roster of people aged 65 and older in Seongnam, who were invited to participate in the study by letter and telephone. In total, 439 men and 561 women were ultimately included in the study. Whole body and regional body composition by DEXA (Lunar Corp., Madison, WI, USA) were included as a part of this study, and several measures in this cohort are related to sarcopenia.

We previously reported the prevalence of sarcopenia and the associations with risk of metabolic syndrome using data from this cohort17). The cutoff values for sarcopenia were set as less than 1 SD below the sex-specific mean for a young reference group, and both muscle mass parameters, ASM/wt and ASM/ht², were used. Interestingly, the prevalence of sarcopenic obesity was 16.7% in men and 5.7% in women older than 65 years. Moreover, sarcopenia was associated with a greater risk of high blood pressure in both obese and nonobese subjects, and ASM/wt values less than 1 SD below the mean of healthy young adults were used to categorize sarcopenia20).

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difference in the prevalence of sarcopenia using EWGSOP
ASM/ht^2 and EWGSOP-ASM/wt was much greater in women: 8.8% (24/272) and 41.2% (112/272), respectively. Moreover, the adjusted hazard ratios of sarcopenia for mortality were 4.00 for ASM/ht^2 and 6.89 for ASM/wt in men. Interestingly, sarcopenia defined by these criteria was not associated with a greater risk of death in women. There are additional reports about the clinical consequences of sarcopenia regarding functional limitation or physical performance, and both ASM/wt and ASM/ht^2 were used and compared in those studies^{27,28).

3. Data from Korean Genome Epidemiologic Study

Two communities in Korea were selected for the Korean Genome Epidemiologic Study (KoGES) in 2001; the Ansung cohort represented a rural community, and the Ansan cohort an urban community. KoGES is an ongoing prospective study involving a biennial examination. Details of the KoGES and the method used have been described previously^{29). In brief, a total of 10,038 subjects aged from 40 to 69 years were recruited (5,020 from a farming community, Ansung and 5,018 from an industrial community, Ansan). From the third visit of the participants in this study, whole body and regional body composition by DEXA (Lunar Corp.) were also included as a part of this study. Although there are as yet no published data, we could assess the DEXA data of this cohort and included the muscle parameters analyzed in this cohort in Table 1.

4. Results from Korean Sarcopenic Obesity Study

The Korean Sarcopenic Obesity Study (KSOS) is an ongoing prospective, observational cohort study initiated in September 2007. The KSOS was intended to examine the prevalence of sarcopenia and sarcopenic obesity in Korean adults and to evaluate the effects of sarcopenia and Sarcopenic Obesity on metabolic disorders and health outcomes. Using 2 SDs of ASM/ht^2 below reference values from young, healthy adults, the prevalence of sarcopenia and sarcopenic obesity were 4.1% and 0.8% respectively in older women (≥60 years), and 6.3% and 1.3% respectively in older men^{30). By contrast, the prevalence of sarcopenia and sarcopenic obesity were 14.2% and 12.5% respectively in older women and 5.1% and 5.1% respectively in older men, using 2 SDs below the SMI^{30). Interestingly, SMI values were significantly lower in patients with diabetes than in those without diabetes^{31). Moreover, patients with diabetes had a three times greater risk of sarcopenia (odds ratio, 3.06; 95% confidence interval, 1.42 to 6.62) than subjects without diabetes in a multiple logistic regression analysis^{31). As a single indicator of sarcopenic obesity, authors introduced the ratio of visceral fat to thigh muscle area (VMR) measured using computed tomography. VMR is significantly increased in subjects with metabolic syndrome and independently associated with metabolic syndrome^{32). Multiple binary logistic regression analysis showed that a homeostasis model assessment of insulin resistance (HOMA-IR) and high sensitive C-reactive

<table>
<thead>
<tr>
<th>Study population</th>
<th>No.</th>
<th>Age (yr)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>BMI (kg/m^2)</th>
<th>ASM (kg)</th>
<th>ASM/ht^2 (kg/m^2)</th>
<th>ASM/wt (%)</th>
<th>Cutoffs for lowest quintile ASM/ht^2 (kg/m^2)</th>
<th>ASM/wt (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KNHANES 2008-2010</td>
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<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Men</td>
<td>1,361</td>
<td>72.2±5.4</td>
<td>164.5±5.9</td>
<td>62.4±9.5</td>
<td>23.0±2.9</td>
<td>19.3±2.8</td>
<td>7.1±0.8</td>
<td>31.1±2.9</td>
<td>6.43</td>
<td>28.8</td>
</tr>
<tr>
<td>Women</td>
<td>1,923</td>
<td>72.9±5.9</td>
<td>150.3±6.0</td>
<td>54.6±9.2</td>
<td>24.1±3.4</td>
<td>13.4±1.9</td>
<td>5.9±0.7</td>
<td>24.8±2.9</td>
<td>5.34</td>
<td>22.5</td>
</tr>
<tr>
<td>KLoSHA†</td>
<td>318</td>
<td>75.9±8.6</td>
<td>164.4±6.2</td>
<td>64.0±9.9</td>
<td>23.6±3.2</td>
<td>18.6±2.6</td>
<td>6.9±0.8</td>
<td>28.9±2.9</td>
<td>6.19</td>
<td>26.4</td>
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<tr>
<td>Men</td>
<td>315</td>
<td>76.0±8.8</td>
<td>149.8±5.8</td>
<td>54.2±9.4</td>
<td>24.1±3.5</td>
<td>12.8±2.3</td>
<td>5.6±0.9</td>
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<tr>
<td>KoGES†</td>
<td>435</td>
<td>71.2±3.6</td>
<td>163.7±5.6</td>
<td>61.2±9.0</td>
<td>22.8±3.1</td>
<td>19.0±2.0</td>
<td>7.1±0.7</td>
<td>31.3±2.3</td>
<td>6.49</td>
<td>29.5</td>
</tr>
<tr>
<td>Men</td>
<td>284</td>
<td>71.0±3.5</td>
<td>149.4±6.0</td>
<td>54.1±8.6</td>
<td>24.2±3.4</td>
<td>13.2±1.6</td>
<td>5.9±0.6</td>
<td>24.5±1.8</td>
<td>5.39</td>
<td>23.0</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation. BMI, body mass index; ASM, appendicular skeletal muscle mass; ht^2, height squared (m); wt, weight (kg); KNHANES, Korean National Health and Nutrition Examination Survey; KLoSHA, Korean Longitudinal Study on Health and Aging; KoGES, Korean Genome Epidemiology Study. †Hologic and ‡Luna dual energy X-ray absorptiometry system was used for measurement of muscle mass.
protein were independently associated with sarcopenic obesity in women, while HOMA-IR and 25-hydroxyvitamin D levels were significant factors predicting sarcopenic obesity in men\textsuperscript{30}. Low muscle mass may be associated with different metabolic consequences according to body size phenotype, such as metabolically abnormal, but normal weight\textsuperscript{30}. Furthermore, individuals with lower muscle mass exhibited greater risk of nonalcoholic fatty liver disease\textsuperscript{30}. The longitudinal data of the KSOS demonstrated that visceral obesity at baseline was associated with future loss of skeletal muscle mass in Korean adults\textsuperscript{30}.

**PREVALENCE AND CUTOFFS FOR DEFINITION OF SARCOPENIA**

Both ASM/wt and ASM/ht\textsuperscript{2} indices have been used for assessing muscle mass, but the prevalence of sarcopenia varies according to which definition are used. The prevalence of sarcopenia was 9.3\% in Korean men and 0.2\% in women older than 65 years using the ASM/ht\textsuperscript{2} index with data from KNHANES. However, the prevalence was 10.4\% in men and 10.7\% in women in the same study population using the ASM/wt index\textsuperscript{37}. Variations in prevalence depending on the defining methods were similarly observed in other studies\textsuperscript{13,14,16}. Recently, several interventional modalities for preventing sarcopenia including nutritional support and promising drugs have been suggested\textsuperscript{38}. However, characterizing which subjects could benefit most from those treatments should be a priority before applying treatment. Therefore, further studies to determine appropriate criteria and operational method to define vulnerable sarcopenic elderly people are warranted.

**CHANGES IN BODY COMPOSITION IN KOREANS**

Muscle mass change with aging shows quite distinguished patterns in Korean men and women\textsuperscript{37}. The ASM of men increases rapidly until 20 years of age and then decreases constantly until 90 years of age, with a more rapid loss after 60 years of age. However, ASM in women shows a slow increase until 20 years of age and then tends to remain constant until 50 years of age, followed by a decrease. ASM/ht\textsuperscript{2} showed patterns similar to ASM in men, whereas the trend of ASM/ht\textsuperscript{2} values among women was discordant with that of ASM, and it increased constantly until 60 years of age and then decreased. Changes with aging in ASM/wt values in men and women were also quite different, indicating a sharp increase until 20 years of age and then a gradual decrease until 30 years of age, followed by a gentle decline to 90 years of age in men, but a continuous decreased until 60 years of age followed by a slight rise in women (Fig. 1). According to these patterns, the mean values for healthy adults (20–40 years) represent the peak levels in each index for men. However, in women, the mean values for healthy adults (20–40 years) do not present the highest levels in either ASM or decrease.

**Fig. 1.** Trends in ASM indices associated with aging in men and women using data from KNHANES 2008–2010. ASM, appendicular skeletal muscle mass; ht\textsuperscript{2}, height squared (m); wt, weight (kg); KNHANES, Korean National Health And Nutrition Examination Survey.
ASM/ht². Based on these findings, whether or not the values in this age group (20–40 years) could be used as reference values is controversial.

Besides using the mean values of young reference groups, IWGS and EWGSOP recommend values of the lowest quintile in study populations as an alternative threshold for defining sarcopenia²⁵,⁷. The values of each anthropometric and muscle mass parameter in the three cohorts mentioned are shown in Table 1. Although the numbers of elderly participants aged 65 years and older, included in each cohort study range from several hundred to several thousand, the values are quite similar in the same sexes. Therefore, it is conceivable that the method, using lowest quintile of a sex-specific study population, would better categorize elderly participants who have very low muscle mass in these study populations. Representatively, the cutoffs regarding lowest quintile of the elderly aged 65 years and older in KNHANES for ASM/ht² or ASM/wt, is 6.43 kg/m² and 28.8% respectively in men and 5.34 kg/m² and 22.5% respectively in women (Table 1).

In conclusion, emerging evidence now suggests that sarcopenia is becoming more important in consideration of the health of the elderly and is closely related to various clinical consequences: not only functional limitation and impaired physical performance, but also metabolic derangement and cardiovascular risk. However, the operational definition of sarcopenia is still contentious. The prevalence of sarcopenia and its effects on various health conditions are different according to the methods used to define sarcopenia, ASM/wt or ASM/ht² in muscle mass index, and less than 2 SDs below the mean of healthy adults or lowest quintile of a sex-specific study population in cutoffs for sarcopenia. Therefore, further studies are needed to reveal the most clinically relevant criteria.

Conflict of Interest Disclosures: The researchers claim no conflicts of interest.

REFERENCES


SUMMARY

Sarcopenia presents many negative health-related consequences including impaired energy homeostasis, risk of falls and cardiovascular disease, and subsequently higher mortality. It is becoming evident that sarcopenia has a negative impact on the healthy life of the elderly, and there have been also many investigations about sarcopenia in Korea. However, the prevalence of sarcopenia and its effects on various health conditions are different according to the methods used to define sarcopenia, ASM/ht² or ASM/wt in muscle mass index, and less than 2 SDs below the mean of healthy adults or lowest quintile of a sex-specific study population in cutoffs for sarcopenia. Therefore, further studies are needed to reveal the most clinically relevant criteria for sarcopenia.


