Long sleep duration is associated with incident sarcopenia after two years in community-dwelling older men

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Research Article

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Abstract

**Background:** Sarcopenia, a progressive and generalized skeletal muscle disorder involving accelerated loss of muscle mass and muscle function, is a common condition in older individuals. This study aims to determine whether sleep latency and duration are independently associated with incident sarcopenia and to explore sex differences in these associations.

**Methods:** A two-year longitudinal analysis of cohort study data was conducted. The sample was 70-84 years old community-dwelling participants in the Korea Frailty and Aging Cohort Study at baseline survey in 2016-2017 who completed the follow-up survey after 2 years. Logistic regression was used to calculate odds ratios (OR) for sarcopenia and sarcopenia components. Sarcopenia was defined using the 2019 Asian Working Group for Sarcopenia guidelines.

**Results:** Among 1,353 non-sarcopenic participants in the baseline survey, 1,160 participants were classified as non-sarcopenic (85.8%) and 193 (14.2%) as sarcopenic after 2 years. Long sleep duration (> 8 hours per night) was associated with incident sarcopenia in men (OR = 2.410 (95% confidence interval [CI] 1.125-5.166) after adjusting for confounding factors). Long sleep duration was specifically associated with development of low skeletal muscle mass and low muscle strength in men; adjusted ORs were 2.163 (95% CI 1.016-4.605) and 2.695 (95% CI 1.130-6.431), respectively. There was no significant association between sleep latency and sarcopenia in men (OR 1.014; 95% CI 0.505-2.036). For women, long sleep duration (OR 2.093; 95% CI 0.753-5.812) and sleep latency (OR 0.674; 95% CI 0.351-1.296) were not associated with sarcopenia.

**Conclusion:** In men, long sleep duration was associated with incident sarcopenia, specifically the development of low muscle mass and low muscle strength, but not with low gait speed. In contrast, there was no such association for women.

Introduction

Aging is frequently accompanied by change in sleep patterns. Previous research has found an increase in sleep disturbances with aging, affecting up to 50% of the population. (1) Sleep disturbances are known to be associated with a higher risk of coronary disease, hypertension, diabetes, and mortality. (2–5)

Sarcopenia, a progressive and generalized skeletal muscle disorder involving accelerated loss of muscle mass and muscle function, is a common condition in older individuals. (6) Prevalence of sarcopenia varies from 9.9 to 40.4% depending on the definition used. (7) Sarcopenia contributes significantly to morbidity, decreased quality of life, and increased health care costs in the elderly. (8) Especially, sarcopenia is significantly correlated with cardiometabolic risk factors, notably diabetes, hypertension, and dyslipidemia. (9)

Several studies have indicated a relationship between sleep disturbances and sarcopenia. (10–12) Kwon et al. showed that long sleep duration (9 hours or longer) is independently associated with sarcopenia in
Korean adults, (11) while, Hu et al. showed a U-shaped relationship between self-reported sleep duration and sarcopenia in Chinese community-dwelling older women. (12) These previous studies were cross-sectional, a study design which does not allow inference of causality between sleep disturbance and sarcopenia. (10–12). Recently, Nakakubo et al. showed an association between long sleep duration and the risk of progression to sarcopenia among older Japanese adults, in a 4-year longitudinal study. (13) However, this study did not explore the effect of sleep latency or sex differences on associations. Therefore, this study aimed to determine whether sleep latency and duration were independently associated with incident sarcopenia in community-dwelling older adults, and to explore sex differences in these associations.

**Methods**

**Participants**

This study involved participants of the Korean Frailty and Aging Cohort Study (KFACS). (14) The KFACS is a national, multi-center, longitudinal cohort study. The baseline survey was conducted from 2016 to 2017, with a target number of 3,000 adults aged 70–84 years. The participants were recruited from 10 medical centers (8 hospitals and 2 public health centers) across the country. For the 3,014 baseline survey participants, the first follow-up surveys (n=2,864) were conducted from 2018 to 2019. Participants with missing data were excluded. Participants who did not have sarcopenia at baseline and participated in a follow-up survey 2 years later were included in this analysis (n=1,353).

**Sleep parameters**

Sleep parameters were reported by participants using a questionnaire about usual sleep patterns for the past 4 weeks. Two questions about subjective sleep quality were extracted from the Pittsburgh Sleep Quality Index (PSQI) questionnaire: 1) How long (in minutes) has it taken you to fall asleep each night? 2) How many hours of actual sleep did you get at night? (15) Sleep latency and sleep duration measures were based on the answers provided. Sleep duration was categorized as short (<6 hours), average (6–8 hours), or long (>8 hours). Prolongation of sleep latency was defined as taking more than 60 min to fall asleep. (16)

**Definition of sarcopenia**

Sarcopenia was defined according to the Asian Working Group for Sarcopenia (AWGS) guidelines of 2019. AWGS 2019 defines “sarcopenia” as low muscle mass plus low muscle strength or low physical performance.

The AWGS 2019 cutoffs for low muscle mass in sarcopenia diagnosis are height-adjusted appendicular skeletal muscle (ASM) <7.0 kg/m^2 in men and <5.4 kg/m2 in women. Height-adjusted ASM was defined as ASM (kg)/height (m2), and ASM was measured using dual-energy X-ray absorptiometry (DXA) (Lunar, GE Healthcare, Madison, WI; Hologic DXA, Hologic Inc., Bedford, MA). ASM was calculated as the sum of
the lean mass of the right and left arms and legs under the assumption that all non-fat and non-bone tissues were skeletal muscles. Handgrip strength, measured using a digital handgrip dynamometer (T.K.K.5401; Takei Scientific Instruments Co. Ltd., Tokyo, Japan), was used to indicate low muscle strength. The diagnostic cutoffs for handgrip strength were <28.0 kg for men and <18.0 kg for women. The participants were instructed to squeeze the handle with maximum effort for 3 seconds using each hand. Each hand was tested twice, and maximum handgrip strength was defined as the highest measurement for each hand, expressed in kilograms. Physical performance was evaluated using usual gait speed, 5-times-sit-to-stand test, and the Short Physical Performance Battery (SPPB). The cutoff for low physical performance was usual gait speed <1 m/s, 5-time chair stand time ≥ 12 seconds, or SPPB score ≤ 9. The usual gait speed over a distance of 4 m was measured using an automatic gait speed meter (Dynamicphysiology, Daejeon, Korea) with acceleration and deceleration phases of 1.5 m each. Participants were asked to perform the test by walking at a normal pace. The 5-times-sit-to stand test measures the time taken to stand 5 times from a sitting position without using the arms from a straight-backed armchair. Participants were asked to stand up and sit down 5 times, as quickly as possible. The SPPB consists of 3 standing-balance measures, 5 chair-stand time measures, and an assessment of usual gait speed. Each test was assigned a score of 0 to 4, based on normative scores obtained from the Established Population for Epidemiologic Studies of the Elderly, with a total score of 0 to 12. (17, 18)

**Other variables**

The medical histories of participants were noted from a predefined list of chronic health conditions. Low physical activity level was defined as <494.65 kcal/week for men and <283.50 kcal/week for women, corresponding to the lowest 20% of the total energy consumed in a population-based Korean survey of older adults from among the general population. (14) Energy expenditure estimates (kcal/week) were calculated using the International Physical Activity Questionnaire (IPAQ), and metabolic equivalent scores were derived from vigorous, moderate, and mild activities in the questionnaire. Nutritional status was rated using the Korean version of the short form of the Mini-Nutritional Assessment (MNA) and those who scored 11 or less were classified as at risk of malnutrition or presence of malnutrition. (19) A 15-item Korean version of the Short Form Geriatric Depression Scale (GDS-K) was used to evaluate depression, with a score of 6 or higher defined as suggestive of depression. (20) Polypharmacy was defined as the use of five or more prescribed medicines for more than 3 months.

**Ethical approval**

The present study was submitted and exempt from the requirement for Institutional Review Board (IRB) approval by the Clinical Research Ethics Committee of Kyung Hee University Medical Center (IRB number: 2021-03-057) and complied with the ethical rules for human experimentation stated in the Declaration of Helsinki. Informed consent was obtained from all participants or their proxy.

**Statistical analysis**
Characteristics were compared according to sarcopenia category using independent sample t-tests for continuous data and chi-square tests for categorical data. The associations between sleep latency or duration and sarcopenia were explored using logistic regression analyses. Statistical analysis was performed using IBM SPSS Statistics Version 23.0 (Armonk, NY, IBM Corp.), and significance was defined as a p-value < 0.05.

**Results**

**General characteristics of the study population**

Among 1,353 non-sarcopenic participants at baseline, 1,160(85.7%) were classified as non-sarcopenic and 193(14.3 %) as sarcopenic after 2 years, according to the AWGS guidelines of 2019. (Table 1) The median ages of non-sarcopenic and sarcopenic participants were 75.3, 76.4 years in men, and 74.9, 76.4 in women, respectively. The prevalence of cerebrovascular disease (CVD), angina, and depression was higher in men in the sarcopenic group than in those in the non-sarcopenic group. The prevalence of CVD was higher in women with sarcopenia. Rates of low physical activity in non-sarcopenic and sarcopenic participants were 4.5%, 12.6% in men and 7.0%, 16.7% in women, respectively. The median duration of sleep was 6.4 hours in both groups in men, and 5.9, 6.0 hours in non-sarcopenic and sarcopenic women, respectively. The rates of long sleep duration (total sleep time > 8 hours per night) in non-sarcopenic and sarcopenic participants were 5.7%, 11.7% in men and 3.5%, 6.7 % in women, respectively. (Table 1)

**Table 1. Characteristics of study participants, according to sarcopenia status at 2 years**
<table>
<thead>
<tr>
<th></th>
<th>Male (n=631)</th>
<th>Female (n=722)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-Sarcopenic (n=528)</td>
<td>Sarcopenic (n=103)</td>
</tr>
<tr>
<td>Age, year</td>
<td>75.3±3.6</td>
<td>76.4±4.0</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>24.6±2.9</td>
<td>24.1±2.4</td>
</tr>
<tr>
<td>Polypharmacy&lt;sup&gt;a&lt;/sup&gt;</td>
<td>166(31.4%)</td>
<td>42(40.8%)</td>
</tr>
<tr>
<td>Smoking&lt;sup&gt;b&lt;/sup&gt;</td>
<td>405(76.7%)</td>
<td>71(68.9%)</td>
</tr>
<tr>
<td>Alcohol drinking&lt;sup&gt;c&lt;/sup&gt;</td>
<td>181(34.3%)</td>
<td>32(31.1%)</td>
</tr>
<tr>
<td>Married</td>
<td>346(65.5%)</td>
<td>62(60.2%)</td>
</tr>
<tr>
<td>Live alone</td>
<td>30(5.7%)</td>
<td>8(7.8%)</td>
</tr>
<tr>
<td>Education&lt;sup&gt;d&lt;/sup&gt;</td>
<td>423(80.1%)</td>
<td>74(71.8%)</td>
</tr>
<tr>
<td>Working</td>
<td>149(28.2%)</td>
<td>27(26.2%)</td>
</tr>
<tr>
<td>Low physical activity&lt;sup&gt;e&lt;/sup&gt;</td>
<td>24(4.5%)</td>
<td>13(12.6%)</td>
</tr>
<tr>
<td>MNA score</td>
<td>12.8±1.6</td>
<td>12.9±1.2</td>
</tr>
<tr>
<td>Risk of malnutrition&lt;sup&gt;f&lt;/sup&gt;</td>
<td>94(17.3%)</td>
<td>13(14.9%)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>271(51.3%)</td>
<td>60(58.3%)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>120(22.7%)</td>
<td>31(30.1%)</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>142(26.9%)</td>
<td>27(26.2%)</td>
</tr>
<tr>
<td>Angina</td>
<td>31(5.9%)</td>
<td>13(12.6%)</td>
</tr>
<tr>
<td>CHF</td>
<td>4(0.8%)</td>
<td>0(0.0%)</td>
</tr>
<tr>
<td>CVD</td>
<td>24(4.5%)</td>
<td>14(13.6%)</td>
</tr>
<tr>
<td>Arthritis</td>
<td>56(10.6%)</td>
<td>14(13.6%)</td>
</tr>
<tr>
<td>Osteoporosis</td>
<td>81(15.3%)</td>
<td>15(14.6%)</td>
</tr>
<tr>
<td>Depression&lt;sup&gt;g&lt;/sup&gt;</td>
<td>43(8.1%)</td>
<td>16(15.5%)</td>
</tr>
<tr>
<td>HRT&lt;sup&gt;h&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep duration</td>
<td>6.4±1.3</td>
<td>6.4±1.5</td>
</tr>
</tbody>
</table>
Sleep pattern and incident sarcopenia in men

Long sleep duration (> 8 hours) in men was associated with greater odds of incident sarcopenia after 2 years compared to the reference (6-8 hours). After adjusting for multiple factors including age, body mass index (BMI), smoking, polypharmacy, education, angina, CVD, depression, and physical activity, the association between long sleep duration and incident sarcopenia remained significant (odds ratio [OR] 2.410, 95% confidence interval [CI] 1.125-5.166, p-value [P] = .024). In comparison, short sleep duration (< 6 hours) was not associated with sarcopenia development in men (OR 1.192, CI 0.725-1.960, P = .488). Prolonged sleep latency (≥60 min) was not associated with sarcopenia in men (OR 1.014, CI 0.505-2.036, P = .969). (Table 2,3)

Table 2. Odds ratio of sleep duration relationship to incident sarcopenia, by sex

<table>
<thead>
<tr>
<th>Sleep Duration</th>
<th>Male</th>
<th>Female</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-8 hours</td>
<td>352 (66.7%)</td>
<td>60 (58.3%)</td>
<td>0.057</td>
</tr>
<tr>
<td>&lt;6 hours</td>
<td>146 (27.7%)</td>
<td>31 (30.1%)</td>
<td>0.234</td>
</tr>
<tr>
<td>&gt;8 hours</td>
<td>30 (5.7%)</td>
<td>12 (11.7%)</td>
<td>0.234</td>
</tr>
<tr>
<td>Sleep latency</td>
<td>20.6±24.8</td>
<td>21.3±22.4</td>
<td>0.771</td>
</tr>
<tr>
<td>&gt;60min</td>
<td>49 (9.3%)</td>
<td>13 (12.6%)</td>
<td>0.297</td>
</tr>
</tbody>
</table>

Continuous variables are presented as mean ± standard deviation or numbers with (percentages). BMI, body mass index; CHF, chronic heart failure; CVD, cerebrovascular Diseases; a. polypharmacy: use of 5 or more drugs more than 3 months; b. Smoking: ≥ 5pack-yr/lifetime; c. Alcohol drinking: ≥ 2-3 times/ week; d. Education: ≥ 7years; e. Low physical activity: <494.65 kcal for men and <283.50 kcal for women; f. Risk of malnutrition: MNA score ≤ 11; g. Depression: GDS score ≥ 6; h. HRT, hormone replacement therapy ≥ 1 month
### Table 3. Odds ratio of sleep latency relationship to incident sarcopenia, by sex

<table>
<thead>
<tr>
<th>Sleep Duration</th>
<th>OR</th>
<th>95% CI</th>
<th>P</th>
<th>OR</th>
<th>95% CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-8h</td>
<td>1</td>
<td>Ref</td>
<td></td>
<td>1</td>
<td>Ref</td>
<td></td>
</tr>
<tr>
<td>&lt;6h</td>
<td>1.24</td>
<td>0.77</td>
<td>2.00</td>
<td>0.364</td>
<td>0.812</td>
<td>1.291</td>
</tr>
<tr>
<td>&gt;8h</td>
<td>2.35</td>
<td>1.14</td>
<td>4.84</td>
<td>0.021</td>
<td>1.81</td>
<td>4.68</td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-8h</td>
<td>1</td>
<td>Ref</td>
<td></td>
<td>1</td>
<td>Ref</td>
<td></td>
</tr>
<tr>
<td>&lt;6h</td>
<td>1.26</td>
<td>0.78</td>
<td>2.10</td>
<td>0.347</td>
<td>0.81</td>
<td>1.31</td>
</tr>
<tr>
<td>&gt;8h</td>
<td>2.41</td>
<td>1.16</td>
<td>5.06</td>
<td>0.019</td>
<td>2.08</td>
<td>5.58</td>
</tr>
</tbody>
</table>

Model 1: unadjusted

Model 2: adjusted for age and BMI

Model 3: adjusted for age, BMI, smoking, polypharmacy, education, angina, CVD, and depression

Model 4: adjusted for age, BMI, smoking, polypharmacy, education, angina, CVD, depression, and low physical activity

* P-value was obtained by logistic regression analysis; OR, odds ratio; CI, confidence interval; BMI, body mass index; CVD, cerebrovascular disease
Model 1: unadjusted

Model 2: adjusted for age and BMI

Model 3: adjusted for age, BMI, smoking, polypharmacy, education, angina, CVD, and depression

Model 4: adjusted for age, BMI, smoking, polypharmacy, education, angina, CVD, depression, and low physical activity

* P-value was obtained by logistic regression analysis; OR, odds ratio; CI, confidence interval; BMI, body mass index; CVD, cerebrovascular disease

### Sleep pattern and incident sarcopenia in women

Compared to normal sleep duration, the adjusted ORs of long sleep duration and short sleep duration for sarcopenic women were 2.093 (CI 0.753–5.812, P=.157) and 0.852 (CI 0.520–1.393, P=.522), respectively, which were not significant. Prolonged sleep latency (≥ 60 min) was not associated with sarcopenia in women (OR 0.674, CI 0.351-1.296, P=.237). (Table 2) (Table 3)

### The effect of sleep duration on sarcopenia components in men

In men, after adjusting for multiple factors (such as age, BMI, polypharmacy, alcohol, education, working, hypertension, osteoporosis, and depression), the association between long sleep duration and low muscle mass was significant (OR 2.163, 95% CI 1.016-4.605, P=.045) (Table 4). Also, the association between long sleep duration and low muscle strength remained significant after adjusting for multiple correlates (OR 2.695, 95% CI 1.130-6.431, P=.025). (Table 5) In comparison, long sleep duration was not associated with low gait speed (OR 1.075, 95% CI 0.546-2.117, P=.833) in men. (table 6) Short sleep duration (<6 hours) was not associated with any sarcopenia component (low muscle mass, low muscle strength, or low physical performance) in unadjusted or adjusted analyses. (Table 4,5,6)

### Table 4. Odds ratio of sleep duration relationship to low height-adjusted ASM index, 2-year follow-up, by sex
<table>
<thead>
<tr>
<th>Model</th>
<th>Sleep Duration</th>
<th>OR</th>
<th>95% CI</th>
<th>P</th>
<th>OR</th>
<th>95% CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model1</td>
<td>6-8h</td>
<td>1</td>
<td>Ref</td>
<td>Ref</td>
<td>1</td>
<td>Ref</td>
<td>Ref</td>
</tr>
<tr>
<td></td>
<td>&lt;6h</td>
<td>0.814</td>
<td>0.571</td>
<td>1.159</td>
<td>0.254</td>
<td>0.932</td>
<td>1.298</td>
</tr>
<tr>
<td></td>
<td>&gt;8h</td>
<td>1.818</td>
<td>0.939</td>
<td>3.517</td>
<td>0.076</td>
<td>0.657</td>
<td>0.26</td>
</tr>
<tr>
<td>Model2</td>
<td>6-8h</td>
<td>1</td>
<td>Ref</td>
<td>Ref</td>
<td>1</td>
<td>Ref</td>
<td>Ref</td>
</tr>
<tr>
<td></td>
<td>&lt;6h</td>
<td>0.808</td>
<td>0.542</td>
<td>1.205</td>
<td>0.296</td>
<td>0.928</td>
<td>1.326</td>
</tr>
<tr>
<td></td>
<td>&gt;8h</td>
<td>1.891</td>
<td>0.908</td>
<td>3.937</td>
<td>0.089</td>
<td>0.711</td>
<td>0.26</td>
</tr>
<tr>
<td>Model3</td>
<td>6-8h</td>
<td>1</td>
<td>Ref</td>
<td>Ref</td>
<td>1</td>
<td>Ref</td>
<td>Ref</td>
</tr>
<tr>
<td></td>
<td>&lt;6h</td>
<td>0.828</td>
<td>0.552</td>
<td>1.24</td>
<td>0.359</td>
<td>0.975</td>
<td>1.408</td>
</tr>
<tr>
<td></td>
<td>&gt;8h</td>
<td>2.163</td>
<td>1.016</td>
<td>4.605</td>
<td>0.045</td>
<td>0.766</td>
<td>0.278</td>
</tr>
</tbody>
</table>

Model 1: unadjusted

Model 2: adjusted for age and BMI

Model 3: adjusted for age, BMI, polypharmacy, alcohol consumption, education, working, HTN osteoporosis and depression

* P-value was obtained by logistic regression analysis; ASM, appendicular skeletal muscle; OR, odds ratio; CI, confidence interval; BMI, body mass index; HTN, hypertension

**Table 5. Odds ratio of sleep duration relationship to low muscle strength, 2-year follow-up, by sex**
<table>
<thead>
<tr>
<th></th>
<th>sleep duration in men</th>
<th>sleep duration in women</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR</td>
<td>95% CI</td>
</tr>
<tr>
<td>Model 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-8h Ref</td>
<td>1</td>
<td>Ref</td>
</tr>
<tr>
<td>&lt;6h</td>
<td>1.219</td>
<td>0.733</td>
</tr>
<tr>
<td>&gt;8h</td>
<td>2.212</td>
<td>1.026</td>
</tr>
<tr>
<td>Model 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-8h Ref</td>
<td>1</td>
<td>Ref</td>
</tr>
<tr>
<td>&lt;6h</td>
<td>1.199</td>
<td>0.716</td>
</tr>
<tr>
<td>&gt;8h</td>
<td>2.396</td>
<td>1.09</td>
</tr>
<tr>
<td>Model 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-8h Ref</td>
<td>1</td>
<td>Ref</td>
</tr>
<tr>
<td>&lt;6h</td>
<td>1.155</td>
<td>0.677</td>
</tr>
<tr>
<td>&gt;8h</td>
<td>2.637</td>
<td>1.105</td>
</tr>
<tr>
<td>Model 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-8h Ref</td>
<td>1</td>
<td>Ref</td>
</tr>
<tr>
<td>&lt;6h</td>
<td>1.137</td>
<td>0.664</td>
</tr>
<tr>
<td>&gt;8h</td>
<td>2.695</td>
<td>1.13</td>
</tr>
</tbody>
</table>

Model 1: unadjusted

Model 2: adjusted for age and BMI

Model 3: Age, BMI, polypharmacy, smoking, HTN, DM, angina, CVD, arthritis

Model 4: adjusted for age, BMI, polypharmacy, smoking, HTN, DM, angina, CVD, arthritis, and low physical activity

* P-value was obtained by logistic regression analysis; OR, odds ratio; CI, confidence interval; BMI, body mass index; HTN, hypertension; DM, diabetes; CVD, cerebrovascular disease

**Table 6. Odds ratio of sleep duration relationship to low physical performance, 2-year follow-up, by sex**
<table>
<thead>
<tr>
<th>sleep duration in men</th>
<th>sleep duration in women</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OR</strong></td>
<td><strong>95% CI</strong></td>
</tr>
<tr>
<td>Model1</td>
<td></td>
</tr>
<tr>
<td>6-8h</td>
<td>1</td>
</tr>
<tr>
<td>&lt;6h</td>
<td>0.923</td>
</tr>
<tr>
<td>&gt;8h</td>
<td>1.094</td>
</tr>
<tr>
<td>Model3</td>
<td></td>
</tr>
<tr>
<td>6-8h</td>
<td>1</td>
</tr>
<tr>
<td>&lt;6h</td>
<td>0.842</td>
</tr>
<tr>
<td>&gt;8h</td>
<td>1.073</td>
</tr>
<tr>
<td>Model4</td>
<td></td>
</tr>
<tr>
<td>6-8h</td>
<td>1</td>
</tr>
<tr>
<td>&lt;6h</td>
<td>0.824</td>
</tr>
<tr>
<td>&gt;8h</td>
<td>1.075</td>
</tr>
</tbody>
</table>

Model 1: unadjusted

Model 2: adjusted for age and BMI

Model 3: Age, BMI, education, living alone, polypharmacy, HTN, DM, CVD, dyslipidemia, arthritis, depression

Model 4: Age, BMI, education, living alone, polypharmacy, HTN, DM, CVD, dyslipidemia, arthritis, depression, low physical activity

* P-value was obtained by logistic regression analysis; OR, odds ratio; CI, confidence interval; BMI, body mass index; HTN, hypertension; DM, diabetes; CVD, cerebrovascular disease

**The effect of sleep duration on sarcopenia components in women**

In women, after adjusting for multiple factors, the OR of long sleep duration in relation to low height-adjusted ASM was 0.766 (CI 0.278-2.105, P=.605) (Table 4); in relation to low muscle strength was 1.997 (CI 0.884-4.511, P=.096) (Table 5); and in relation to low physical performance was 1.885 (CI 0.879-4.042, P=.103) (Table 6). Also, short sleep duration (<6 hours) was not associated with any sarcopenia component (low muscle mass, low muscle strength, or low physical performance) in adjusted analyses.

**Discussion**
Our study shows that long sleep duration compared to normal sleep duration increases the risk of incident sarcopenia after 2 years in community-dwelling older adults, specifically in men. With regard to sarcopenia components, in men, long sleep duration was associated with low muscle mass and strength after 2 years.

The mechanism underlying the relationship between long sleep duration and sarcopenia is not fully understood. Chronic inflammation might intervene in the anabolic and catabolic metabolism of muscles, resulting in sarcopenia. (21) A population-based study suggested that circulating concentrations of interleukin-6 (IL-6) and tumor necrosis factor-α (TNF-α) are significantly elevated in sarcopenic elderly individuals, and higher IL-6 and C-reactive protein (CRP) levels increase the risk of muscle strength loss. (22) In a recent meta-analysis, higher IL-6 and CRP levels were significantly associated with long sleep duration, but not with short sleep duration. (23) In addition, one study reported that long sleep duration (≥ 9 hours) was closely related to increased insulin resistance (24), while other studies have proposed that insulin resistance contributes to a decline in skeletal muscle protein synthesis, resulting in sarcopenia in older people. (25) These findings might explain why long sleep duration can be associated with incident sarcopenia. In our study, CRP level did not show an association with incident sarcopenia, but insulin resistance showed an association in men (Table 7), which may explain some of the association between long sleep duration and incident sarcopenia in men.

Table 7. Insulin resistance and inflammation of study participants according to incident sarcopenia, 2 year follow-up, by sex.

<table>
<thead>
<tr>
<th></th>
<th>male(n=631)</th>
<th>female(n=722)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal (n=528)</td>
<td>Sarcopenia (n=103)</td>
</tr>
<tr>
<td>log(HOMA-IR)</td>
<td>0.15±0.31</td>
<td>0.22±0.37</td>
</tr>
<tr>
<td>log(hs-CRP)</td>
<td>-0.10±0.39</td>
<td>-0.03±0.43</td>
</tr>
</tbody>
</table>

* To evaluate insulin resistance, we used the homeostasis model assessment of insulin resistance (HOMA-IR), according to the following formula: HOMA-IR=fasting plasma glucose (mg/dL)×fasting insulin (μIU/mL)/405. (20)

To the authors’ knowledge, no longitudinal study has previously shown a sex-specific effect of sleep duration on incident sarcopenia in older adults. Nakakubo et al. found that long sleep duration was associated with an increased risk of progression to sarcopenia among older adults, but they did not show differences in the association according to sex. They did show that long sleep duration was associated with slow gait and lower grip strength but was not associated with lower muscle mass, which is different
from our study results. To evaluate ASM, Nakakubo et al. used multi-frequency bioelectrical impedance analysis, which can overestimate ASM compared with DXA (26), and could explain the divergent results.

In this study, sex differences were observed in the association between long sleep duration and incident sarcopenia. The explanation for the differential association according to sex may be that muscle mass declines more slowly in women than in men. According to a previous study, the decline in relative skeletal muscle mass (kg/m²) was steeper in men (15.2 – 0.07 × age; P < 0.001) than in women (8.9 – 0.02 × age; P<0.001). (27) Therefore, we speculate that a 2-year follow-up may not be long enough to determine the effect of sleep duration on incident sarcopenia in women.

This study had several limitations. First, the sleep variables were based on participant recall, which may differ from objective sleep measurements. One study reported that self-reported sleep latency was 10 minutes longer than objectively measured sleep latency and that estimated total sleep duration was a little shorter than the measured duration (median difference of ~18.5 min) in adults with a mean age of 50 years. (16, 28) Second, as the participants of this study were community-dwelling older adults, the results do not represent the entire Korean elderly population; this study did not include hospitalized, institutionalized, or bedridden elderly individuals.

The study also has several strengths. We enrolled a relatively large number of community-dwelling older adults aged 70–84 years, and the cohort was gathered from 10 regions nationwide, including urban and rural areas of Korea. Therefore, the cohort was representative of the community-living age group across Korea.

Conclusion

Long sleep duration (>8 hours per night) in men was associated with high odds for incident sarcopenia, and the main correlates of incident sarcopenia due to long sleep duration in men were muscle mass loss and declining muscle strength. In contrast, long sleep duration in women was not associated with incident sarcopenia after 2 years of follow-up.

Abbreviations

ASM, appendicular skeletal muscle; AWGS, Asian Working Group for Sarcopenia; BMI, body mass index; CI, confidence interval; CRP, C-reactive protein; CVD, cerebrovascular disease; DXA, dual-energy X-ray absorptiometry; GDS-K, Korean version of the Short Form Geriatric Depression Scale; IL-6, interleukin-6; IPAQ, International Physical Activity Questionnaire; IRB, Institutional Review Board; KFACS, Korean Frailty and Aging Cohort Study; MNA, Mini-Nutritional Assessment; OR, odds ratios; PSQI, Pittsburgh Sleep Quality Index; SPPB, Short Physical Performance Battery; TNF-α, tumor necrosis factor-α

Declarations

Ethics approval and consent to participate
The present study was submitted and exempt from the requirement for Institutional Review Board (IRB) approval by the Clinical Research Ethics Committee of Kyung Hee University Medical Center (IRB number: 2021-03-057). The KFACS protocol was approved by the IRB of the Clinical Research Ethics Committee of Kyung-Hee University Medical Center (IRB number: 2015–12-103). Written informed consent was obtained from all participants or their legal guardians. All methods were performed in accordance with the relevant guidelines and regulations.

**Consent for publication**

Not applicable.

**Availability of data and materials**

All cohort data that support the findings of this study are available from the KFACS and are open to all researchers on reasonable request. All published articles using the KFACS database, data provision manuals, and contact information are available on the KFACS website (http://www.kfacs.kr).

**Competing interests**

The authors declare no competing interests.

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**Authors’ contributions**

Conceptualization, CWW, SK; Data curation, HNL, SK; Funding acquisition, CWW; Investigation, CWW, SK; Methodology, CWW, SK, HNL; Writing-original draft, HNL, SK; Writing-review and editing, all. (HNL, SK, BSK, MJK, JSY, HHB, CWW)

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