



Effect of sleep duration on muscle mass in Korean non-elderly adults

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ABSTRACT

Objective: This study investigated the association of sleep duration and muscle mass in non-elderly adults.

Methods: The present study analyzed young (19–39 years) and middle-aged (40–59 years) men and women who participated in the Korea National Health and Nutrition Examination Survey. Muscle mass was measured using dual energy X-ray absorptiometry scan. A self-reported questionnaire was used for assessing sleep duration, which was categorized into ≤ 6 , 7, 8, and ≥ 9 h per day.

Results: Participants with low muscle mass were more prevalent in the longer sleep group, among men and women. Furthermore, in subgroup analysis, in which participants were classified into a young and middle-aged group, height-adjusted appendicular skeletal muscle mass was inversely related to sleep duration, regardless of sex. After adjusting for covariates, the probability of low muscle mass was increased in longer sleepers, and sleep duration and low muscle mass showed a positive dose-dependent correlation in men and women.

Conclusion: In young and middle-aged adults, longer sleep duration may be related to decreased muscle mass, in both sexes.

Keywords: body composition, skeletal muscle, sleep

INTRODUCTION

Sleep has been considered as a basic life-style factor that has an impact on various health issues. To date, several studies have implicated inadequate sleep duration in various diseases, such as diabetes and coronary artery disease (1), and consequently in increased mortality (2). Several studies have shown that sleep was associated with obesity and bone health, although the tendencies varied with age, sex, and sleep duration. According to a cohort study that analyzed young adults, i.e., 18–30-year-old men and women, reduced sleep duration was associated with obesity (3). Furthermore, in a study among the elderly, individuals sleeping less than 5 h per day tended to have a high body-fat percentage and central obesity (4). Prolonged sleeping, exceeding 8 h per day, was associated with lower total hip and femur neck bone mineral density in aged women, but not in men (5), and compared to those having 8–9 h of sleep, restricted or prolonged sleepers tended to have a higher risk of osteoporosis among postmenopausal women (6). Recent evidence has suggested that fat, bone, and muscle are closely linked, not only at the whole organism level, but also at the molecular and cellular level (7, 8). Hence, sleep may also affect muscle mass, similar to its effects on obesity and osteoporosis.

Sarcopenia, as assessed by age-related reduction of skeletal muscle mass and decreased muscle strength, and/or impaired physical performance, is closely related to various health problems (9). Sarcopenia is a growing health concern among the elderly, worldwide, and is a major area of interest within the field of geriatric research. However, according to Korean studies analyzing representative national data, appendicular skeletal muscle mass (ASM) increased continuously in women until their 60s, after which it slowly decreased; furthermore, there was a weak positive correlation between age and height-adjusted ASM (10). Interestingly, the non-aged women in that study had relatively insufficient skeletal muscle mass, inappropriate for their age, as compared to aged women. Similarly, these features in young and middle-aged women in Korea were also found among Chinese women (11). The risk factors for a decline in muscle mass in these individuals may be different from those among the elderly, because young adults have dissimilar life styles, comorbidities, and hormonal levels than aged individuals.

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Previous studies did not investigate the connection between sleep duration and diminished muscle mass; moreover, only a few studies have been performed in young individuals. The present study investigated the effects of sleep duration on muscle mass in men and women. We also analyzed whether similar associations were seen among young (19–39 years) and middle-aged (40–59 years) individuals.

METHODS

Study population

Data used in our study were retrieved from the Korea National Health and Nutrition Examination Survey (KNHANES) between 2008 and 2011. KNHANES is a nationwide study that has been conducted by the Korea Centers for Disease Control and Prevention in order to demonstrate the health and nutritional state of the entire Korean population. The survey is composed of a self-reported questionnaire related to a health interview, nutritional questionnaire, and health measurements. Written informed consent was obtained from all participants of KNHANES. The study was approved by the Institutional Review Board of XXX Hospital and conformed to the tenets of the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

We analyzed data from participants, aged between 19 and 59 years, who underwent a health interview and dual energy X-ray absorptiometry (DXA) scan. We excluded those with chronic liver disease or chronic kidney disease, and a history of stroke, myocardial infarction, or any malignancy; eventually, the study group comprised 5,417 men and 7,194 women.

Definition of low muscle mass

For muscle mass measurement, subjects were asked to check their DXA using a Discovery W fan-beam densitometer (Hologic, Inc., Bedford, MA). ASM was assessed using the sum of non-fat and non-bone tissue masses of limbs and we calculated ASM divided by the height squared (kg/m^2). To date, various methods have been developed and introduced to determine low muscle mass (LMM). In this study, LMM was defined by height-adjusted ASM below $7.0 \text{ kg}/\text{m}^2$ in men and below $5.4 \text{ kg}/\text{m}^2$ in women, based on the Asian Working Group for Sarcopenia recommendation in an Asia consensus report (9).

Sleep duration

A self-reporting questionnaire contained the following short-answer question: "On average, how many hours do you sleep a day?" Sleep duration was determined on the basis of the answer to this question. Furthermore, the participants were divided into four groups based on their performance on sleep: less than 6 h ($\leq 6\text{h}$), 7 h (7 h), 8 h (8 h), over 9 h ($\geq 9\text{h}$).

Statistical analysis

All analyses were carried out using integrated weighted values, designated by the Korea Centers for Disease Control and Prevention, which were based on the sampling design, number of subjects, and research measurement items of each survey year. Integrated weight values were used to adjust non-responders to reflect the health status of the entire Korean population.

To compare the baseline characteristics of the study population, using a complex sample general linear model for continuous variables and complex samples logistic regression analysis for categorical variables. The results were shown as mean \pm standard error (SE) or estimated proportion (SE). Complex samples logistic regression analysis was performed to calculate the odds ratio and 95% confidence intervals of sleep duration and LMM after controlling for potential confounders in three steps. To estimate P for trends, the sleep duration group was regarded as a continuous variable in the trend analysis. Data management and analysis were performed using SPSS version 20.0 (IBM, New York, NY). P values and trends of < 0.05 were considered statistically significant.

RESULTS

General characteristics of study participants

The baseline characteristics of the men are summarized according to sleep hour in **Table 1**. In all groups, classified by sleep duration, the mean age of participants was in their 30s. The participants with less than 6 h sleep were older than the other group participants. Body mass index and waist circumference were greatest in ≤ 6 h sleepers and lowest in \geq

Table 1: Demographic characteristics by sleep duration in men

	Sleep duration (h)				P for trend
	≤ 6 (n = 2175 ^a)	7 (n = 1720 ^a)	8 (n = 1191 ^a)	≥ 9 (n = 331 ^a)	
Age (y)	39.1 ± 0.3	38.8 ± 0.3	37.9 ± 0.4	36.1 ± 0.8	< 0.001
Height (cm)	171.6 ± 0.2	172.1 ± 0.2	172.0 ± 0.2	171.3 ± 0.39	0.507
Weight (kg)	71.9 ± 0.3	71.6 ± 0.3	70.8 ± 0.4	68.3 ± 0.7	< 0.001
Body mass index (kg/m ²)	24.4 ± 0.1	24.1 ± 0.1	23.9 ± 0.1	23.3 ± 0.2	< 0.001
Waist circumference (cm)	84.1 ± 0.3	83.7 ± 0.3	83.2 ± 0.3	81.6 ± 0.6	< 0.001
Body fat percentage (%)	21.5 ± 0.1	21.7 ± 0.2	21.5 ± 0.2	21.4 ± 0.2	0.031
ASM (kg)	23.36 ± 0.08	23.33 ± 0.10	23.01 ± 0.11	23.34 ± 0.21	< 0.001
ASM/Ht ² (kg/m ²)	7.92 ± 0.03	7.86 ± 0.03	7.76 ± 0.03	7.59 ± 0.06	< 0.001
Protein intake (g/day)	92.2 ± 1.4	92.1 ± 1.6	90.3 ± 1.8	83.8 ± 3.6	0.070
Hypertension	9.2 (0.7)	8.4 (0.7)	8.8 (0.9)	7.0 (1.4)	0.394
Diabetes	3.6 (0.4)	3.2 (0.5)	3.8 (0.6)	3.8 (1.0)	0.923
Depression	1.3 (0.3)	0.6 (0.2)	1.7 (0.5)	1.8 (0.9)	0.155
Occupation (blue-collar workers)	35.7 (1.3)	32.0 (1.4)	36.3 (1.7)	33.2 (3.0)	0.076
Marital status (married)	71.9 (1.3)	72.6 (1.5)	65.0 (1.8)	52.8 (3.4)	< 0.001
Smoking status					0.124
Never	21.5 (1.0)	21.7 (1.2)	19.0 (1.3)	22.2 (2.5)	
Former	30.2 (1.1)	31.3 (1.2)	29.3 (1.5)	24.3 (2.6)	
Current	48.4 (1.2)	46.9 (1.4)	51.7 (1.6)	53.5 (3.1)	
Alcohol consumption					0.149
None	9.8 (0.7)	8.7 (0.8)	9.7 (1.0)	11.2 (1.9)	
Once a week or less frequently	51.1 (1.3)	52.5 (1.3)	55.1 (1.9)	56.5 (3.0)	
Twice a week or more	39.1 (1.3)	38.8 (1.3)	35.1 (1.7)	32.3 (2.9)	
Exercise frequency					0.030
None	45.4 (1.2)	47.5 (1.5)	49.2 (1.7)	56.7 (3.2)	
Less than twice a week	27.0 (1.1)	26.0 (1.2)	23.5 (1.4)	21.0 (2.5)	
Thrice a week or more	27.6 (1.1)	26.5 (1.2)	27.3 (1.5)	22.4 (2.7)	

^a Unweighted value.

Data are weighted to the residential population of Korea and calculated by complex samples general linear model and complex samples logistic regression analysis.

Values are expressed as mean ± standard error or estimated percentage (standard error).

ASM, appendicular skeletal muscle mass; Ht, height.

9 h sleepers. Shorter sleepers had a greater intake of protein than longer sleepers; however, this difference was not significant. As **Table 1** shows, there was a significant difference between sleep duration and height-adjusted ASM. A trend toward a decrease in ASM/Ht² was observed with increased sleep duration (P for trend < 0.001). In terms of comorbidities, the prevalence of hypertension, diabetes, and depression was revealed not to differ in accordance with sleep duration. Smoking and drinking status showed no effect, while the ≥ 9 h sleep group participants were less likely to be physically active than participants in the other three groups (P for trend = 0.030).

In **Table 2**, the features of the female participants are summarized. It was apparent that shorter sleepers were older and had a higher body mass index and waist circumference than longer sleepers (all P for trend < 0.001). Those with < 6 h sleep had a significantly higher muscle mass than > 9 h sleepers; the negative pattern of ASM/Ht² in women was similar to that in men (P for trend < 0.001). Participants with depression were more common in the prolonged sleep group (> 9 h) and the proportions of blue-collar workers were higher in the restricted sleep (< 6 h) group. The > 9 h group had a higher proportion of current smokers, heavy drinkers (drinking twice a week or more), and physically non-active individuals.

Sleep duration and prevalence of LMM

As sleep duration lengthened, LMM was more prevalent among men. The estimated LMM prevalence was 15.3% among < 6 h sleepers, 15.8% in the 7 h, 17.5% in the 8 h, and 24.7% in the > 9 h sleep groups in men (P for trend = 0.005). Similar to men, in women, there was a clear trend for increased prevalence of LMM according to sleep duration.

Table 2: Demographic characteristics by sleep duration in women

	Sleep duration (h)				P for trend
	≤ 6 (n = 2557 ^a)	7 (n = 2259 ^a)	8 (n = 1791 ^a)	≥ 9 (n = 587 ^a)	
Age (y)	41.1 ± 0.3	39.0 ± 0.3	37.4 ± 0.3	34.1 ± 0.6	< 0.001
Height (cm)	158.4 ± 0.2	158.7 ± 0.1	159.3 ± 0.2	159.3 ± 0.3	< 0.001
Weight (kg)	58.3 ± 0.2	57.6 ± 0.2	57.1 ± 0.3	56.7 ± 0.5	< 0.001
Body mass index (kg/m ²)	23.3 ± 0.1	22.9 ± 0.1	22.5 ± 0.1	22.4 ± 0.2	< 0.001
Waist circumference (cm)	77.2 ± 0.2	76.0 ± 0.3	75.5 ± 0.3	75.1 ± 0.5	< 0.001
Body fat percentage (%)	32.3 ± 0.2	32.3 ± 0.2	31.9 ± 0.2	32.0 ± 0.3	0.060
ASM (kg)	14.90 ± 0.06	14.71 ± 0.06	14.65 ± 0.07	14.54 ± 0.11	0.001
ASM/Ht ² (kg/m ²)	5.93 ± 0.02	5.84 ± 0.02	5.77 ± 0.03	5.73 ± 0.04	< 0.001
Protein intake (g/day)	60.5 ± 0.8	61.3 ± 0.8	64.6 ± 1.0	62.3 ± 1.6	0.007
Hypertension	7.7 (0.6)	7.0 (0.6)	5.3 (0.6)	5.0 (1.1)	0.016
Diabetes	2.5 (0.3)	2.0 (0.4)	2.0 (0.4)	2.0 (0.7)	0.265
Depression	5.1 (0.5)	2.7 (0.4)	3.2 (0.4)	7.7 (1.3)	< 0.001
Occupation (blue-collar workers)	17.8 (1.0)	15.0 (1.0)	13.5 (1.0)	9.9 (1.5)	< 0.001
Marital status (married)	80.5 (1.1)	78.2 (1.2)	75.5 (1.4)	66.5 (2.5)	< 0.001
Smoking status					< 0.001
Never	85.7 (0.9)	87.8 (0.9)	85.7 (0.9)	77.2 (2.1)	
Former	6.5 (0.6)	7.0 (0.7)	7.7 (0.8)	11.7 (1.6)	
Current	7.8 (0.7)	5.3 (0.6)	6.5 (0.7)	11.1 (1.5)	
Alcohol consumption					< 0.001
None	25.8 (1.0)	23.9 (1.1)	23.6 (1.2)	25.5 (2.0)	
Once a week or less frequently	60.9 (1.1)	66.9 (1.2)	66.7 (1.4)	58.2 (2.5)	
Twice a week or more	13.4 (0.8)	9.3 (0.7)	9.7 (0.9)	16.3 (1.9)	
Exercise frequency					0.086
None	60.2 (1.2)	57.1 (1.2)	57.9 (1.5)	65.1 (2.4)	
Less than twice a week	15.7 (0.9)	16.9 (0.9)	16.5 (1.1)	14.5 (1.6)	
Thrice a week or more	24.1 (1.0)	26.0 (1.1)	25.6 (1.3)	20.4 (2.1)	

^a Unweighted value.

Data are weighted to the residential population of Korea and calculated by complex samples general linear model and complex samples logistic regression analysis.

Values are expressed as mean ± standard error or estimated percentage (standard error).

ASM, appendicular skeletal muscle mass; Ht, height.

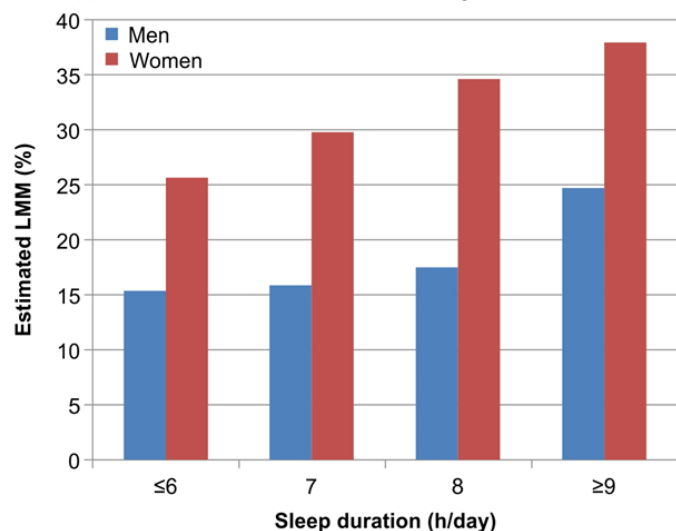


Figure 1: The prevalence of low muscle mass according to sleep hours in men and women. Data are weighted to the residential population of Korea and calculated by complex samples logistic regression analysis. LMM, low muscle mass.

The estimated prevalence of LMM in accordance with sleep duration was 25.6%, 29.7%, 34.6%, and 37.9%, respectively (P for trend < 0.001). **Figure 1** demonstrates the sex-specific prevalence of LMM according to sleep period.

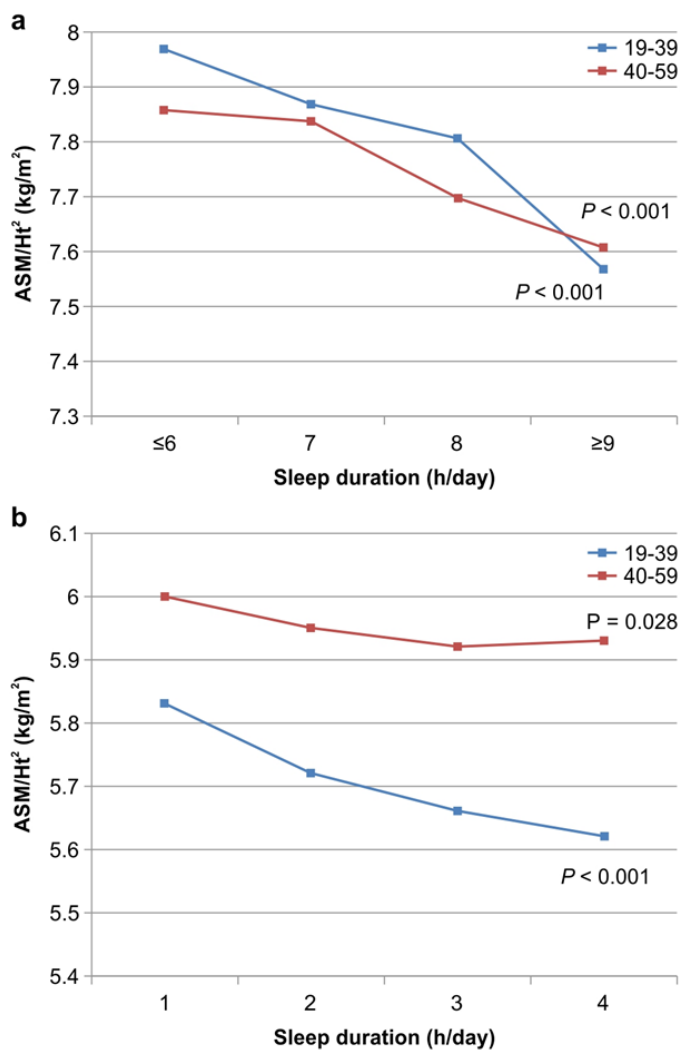


Figure 2: Association between muscle mass and sleep duration in age groups in men (a) and women (b). Data are weighted to the residential population of Korea and calculated by complex samples general linear model. ASM, appendicular skeletal muscle mass; Ht, height

Sleep duration and muscle mass by age and sex

In subgroup analysis, we analyzed the implications of muscle mass and sleep duration stratified by age groups. Men and women participants were categorized into two groups based on age: 19–39, and 40–59 years. Among men and women aged 19–39 years, there was a significant negative association between sleep duration and height-adjusted ASM (all P for trend < 0.001). Furthermore, there was an inverse correlation between sleep duration and muscle mass in the middle-aged group. Among men aged 40–59 years, ASM/Ht² was 7.86 for the ≤ 6 h, 7.84 for the 7 h, 7.7 for the 8 h, and 7.61 for the ≥ 9 h groups (P for trend < 0.001), and among middle-aged women, it was 6.0, 5.95, 5.92, and 5.93 in the ≤ 6 h, 7 h, 8 h, and ≥ 9 h groups, respectively (P for trend = 0.028). The results obtained from the subgroup analysis are presented in **Figure 2**.

Effect of sleep duration on LMM

As shown in **Table 3**, longer sleepers reported a significantly higher risk of LMM. After adjustment for age, smoking status, frequency of alcohol consumption, and exercise, compared to the reference group of < 6 h sleepers, the risk of LMM was significantly increased with ≥ 9 h sleep, regardless of sex. Furthermore, a positive dose-dependent correlation was found between sleep duration and the probability of LMM in men and women (P for trend = 0.005, < 0.01, respectively). Furthermore, further adjustment for marital status, working status, protein intake, and previous comorbidities, such as hypertension, diabetes, and depression, revealed that the 8 h sleep group also had a higher risk for LMM than the reference group, similar to the ≥ 9 h sleeper. After adjusting for such covariates, sleep duration was an independent risk factor for LMM among men and women (all P for trend = 0.042, < 0.001, respectively).

Table 3: Multivariate analysis of low muscle mass and sleep duration by sex

	Sleep duration (h)				P for trend
	≤ 6	7	8	≥ 9	
Men					
Model 1	1	1.03 (0.84–1.78)	1.17 (0.93–1.47)	1.83 (1.31–2.54)	0.005
Model 2	1	1.06 (0.86–1.30)	1.18 (0.94–1.49)	1.79 (1.28–2.51)	0.005
Model 3	1	0.96 (0.76–1.23)	1.30 (1.01–1.67)	1.59 (1.06–2.38)	0.042
Women					
Model 1	1	1.15 (0.99–1.33)	1.35 (1.14–1.61)	1.38 (1.08–1.75)	< 0.001
Model 2	1	1.15 (0.99–1.34)	1.36 (1.14–1.62)	1.34 (1.05–1.71)	0.001
Model 3	1	1.14 (0.97–1.34)	1.34 (1.12–1.61)	1.38 (1.11–1.78)	< 0.001

Model 1: adjusted for age.

Model 2: adjusted for age, smoking status, alcohol consumption, and exercise frequency.

Model 3: adjusted for age, smoking status, alcohol consumption, and exercise frequency, hypertension, diabetes mellitus, depression, marital status, occupation, protein intake.

Data are weighted to the residential population of Korea and calculated by complex samples logistic regression analysis.

Values are presented as prevalence odds ratio (95% confidential interval).

DISCUSSION

The purpose of the current study was to evaluate the effect of sleep duration on muscle mass status. The present study is one of the few that examined the association of sleep quantity and muscle mass indices in non-elderly men and women participants. The current study found that sleep duration and skeletal muscle mass were negatively associated, irrespective of sex and age group, and prolonged sleepers who slept 9 or more hours per day are more likely to suffer from LMM, among both men and women.

However, the findings of the current study differed from previous experimental studies. In a study of 10 overweight adults (mean age: 41.0 ± 5.0 years), who were calorie restricted for 14 days, and slept for 8.5 or 5.5 h at night, the restricted-sleep group showed decreased muscle mass as compared to the sufficient-sleep group (12). Furthermore, after 72 h of sleep deprivation, excretion of urinary urea as a marker of muscle catabolism increased (13). In a previous cross-sectional study of elderly individuals, men assessed as having poor quality sleep or poor sleep efficacy tend to have LMM, after adjusting for various co-variants; however, there was no correlation of sleep parameters with grip strength, as an index of muscle strength. Among elderly women, poor sleep quality and efficacy showed no association with body mass index-adjusted appendicular lean mass, but their grip strength was related to sleep (14). This inconsistency may be due to the difference in the age of participants in the studies.

The results obtained in studies of the elderly should be cautiously applied to young and middle-aged adults, as there are many differences in life style patterns and hormonal status between the elderly and non-elderly. Sleep quantity, quality, and architecture also change with age: a decrease in the total sleep duration and rapid eye movement sleep, increased sleep latency, and time spent awake at night time are common in older people (15).

A few possible mechanisms linking sleep duration and health problems have been proposed; however, there is a general lack of knowledge that could facilitate understanding of the underlying mechanisms. Stranges et al. suggested that prolonged sleep duration might reflect a poor health status, decreased physical strength, and a higher likelihood of unemployment; moreover, long sleepers have too little time to be physically active (16). Grandner and Drummond proposed that Prolonged sleeper tends to sleep fragmentation, photoperiodic abnormalities, lack of challenge, and depression so that they have higher chance to have health problem (17). Furthermore, short sleepers have more opportunity for food intake, and restricted sleep causes decreased secretion of leptin, an anorexigenic hormone, although it increases secretion of orexigenic hormones, such as ghrelin. Hence, insufficient sleepers easily feel starved and feel the need to consume food (18).

The findings of the current study may have some limitations. First, in this study, we assessed sleep duration only based on a self-reported questionnaire. Although many previous studies found that self-reported sleep duration was strongly correlated with sleep time as assessed using polysomnography, both in non-elderly and elderly subjects, it is possible that there could be bias in these responses (19, 20). Additionally, there is a lack of specific information about day-time naps, sleep quality, sleep architecture, and sleep-associated disease, such as sleep/wake disturbance, or sleep-disordered breathing. Laboratory-based sleep diagnostics, such as polysomnography, sleep latency test, and actigraphy could facilitate evaluation of the sleep condition. Moreover, some principal factors affecting muscle metabolism, such as

diet patterns, and status of related hormones, such as growth hormone, insulin-like growth factor-1, cortisol, testosterone, and insulin, were not considered.

Despite these limitations, the current study provides important new information about the association between sleep duration and reduced muscle quantity, especially among non-elderly participants. Sleep duration is potentially remediable, by means of appropriated interventions; thus, the progression of muscle mass reduction could be reversed or prevented. Future studies related to the quality of sleep need to be undertaken to elucidate the association between sleep and muscle metabolism more clearly.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

ETHICAL APPROVAL

The study was approved by the Institutional Review Board of Jeju National University Hospital, Jeju, Republic of Korea (IRB No. JEJUNUH 2016-06-019).

REFERENCES

1. Nagai M, Hoshida S, Kario K. Sleep duration as a risk factor for cardiovascular disease—a review of the recent literature. *Curr Cardiol Rev*. 2010;6(1):54-61. <https://doi.org/10.2174/157340310790231635>
2. Gallicchio L, Kalesan B. Sleep duration and mortality: a systematic review and meta-analysis. *J Sleep Res*. 2009;18(2):148-58. <https://doi.org/10.1111/j.1365-2869.2008.00732.x>
3. St-Onge MP, Perumean-Chaney S, Desmond R, et al. Gender differences in the association between sleep duration and body composition: The Cardia Study. *Int J Endocrinol*. 2010;2010:726071. <https://doi.org/10.1155/2010/726071>
4. Patel SR, Blackwell T, Redline S, et al. The association between sleep duration and obesity in older adults. *Int J Obes (Lond)*. 2008;32(12):1825-34. <https://doi.org/10.1038/ijo.2008.198>
5. Kim N, Choi HR, Kim SW, Kim BS, Won CW, Kim SY. Association between bone mineral density and sleep duration in the Korean elderly population. *Korean J Fam Med*. 2014;35(2):90-7. <https://doi.org/10.4082/kjfm.2014.35.2.90>
6. Chen G, Chen L, Wen J, et al. Associations between sleep duration, daytime nap duration, and osteoporosis vary by sex, menopause, and sleep quality. *J Clin Endocrinol Metab*. 2014;99(8):2869-77. <https://doi.org/10.1210/jc.2013-3629>
7. Hamrick MW, McNeil PL, Patterson SL. Role of muscle-derived growth factors in bone formation. *J Musculoskelet Neuronal Interact*. 2010;10(1):64-70
8. Trayhurn P, Drevon CA, Eckel J. Secreted proteins from adipose tissue and skeletal muscle—adipokines, myokines and adipose/muscle cross-talk. *Arch Physiol Biochem*. 2011;117(2):47-56. <https://doi.org/10.3109/13813455.2010.535835>
9. Chen LK, Liu LK, Woo J, et al. Sarcopenia in Asia: consensus report of the Asian Working Group for Sarcopenia. *J Am Med Dir Assoc*. 2014;15(2):95-101. <https://doi.org/10.1016/j.jamda.2013.11.025>
10. Kim YS, Lee Y, Chung YS, et al. Prevalence of sarcopenia and sarcopenic obesity in the Korean population based on the Fourth Korean National Health and Nutritional Examination Surveys. *J Gerontol A Biol Sci Med Sci*. 2012;67(10):1107-13. <https://doi.org/10.1093/gerona/gls071>
11. Wen X, Wang M, Jiang CM, Zhang YM. Are current definitions of sarcopenia applicable for older Chinese adults? *J Nutr Health Aging*. 2011;15:847-51. <https://doi.org/10.1007/s12603-011-0088-3>
12. Nedeltcheva AV, Kilkus JM, Imperial J, Schoeller DA, Penev PD. Insufficient sleep undermines dietary efforts to reduce adiposity. *Ann Intern Med*. 2010;153(7):435-41. <https://doi.org/10.7326/0003-4819-153-7-201010050-00006>

13. Kant GJ, Genser SG, Thorne DR, Pfalser JL, Mougey EH. Effects of 72 hour sleep deprivation on urinary cortisol and indices of metabolism. *Sleep*. 1984;7(2):142-6. <https://doi.org/10.1093/sleep/7.2.142>
14. Buchmann N, Spira D, Norman K, Demuth I, Eckardt R, Steinhagen-Thiessen E. Sleep, muscle mass and muscle function in older people. *Dtsch Arztebl Int*. 2016;113(15):253-60. <https://doi.org/10.3238/arztebl.2016.0253>
15. Ohayon MM, Carskadon MA, Guilleminault C, Vitiello MV. Meta-analysis of quantitative sleep parameters from childhood to old age in healthy individuals: developing normative sleep values across the human lifespan. *Sleep*. 2004;27(7):1255-73. <https://doi.org/10.1093/sleep/27.7.1255>
16. Stranges S, Dorn JM, Shipley MJ, et al. Correlates of short and long sleep duration: a cross-cultural comparison between the United Kingdom and the United States: the Whitehall II Study and the Western New York Health Study. *Am J Epidemiol*. 2008;168(12):1353-64. <https://doi.org/10.1093/aje/kwn337>
17. Grandner MA, Drummond SP. Who are the long sleepers? Towards an understanding of the mortality relationship. *Sleep Med Rev*. 2007;11(5):341-60. <https://doi.org/10.1016/j.smrv.2007.03.010>
18. Taheri S, Lin L, Austin D, Young T, Mignot E. Short sleep duration is associated with reduced leptin, elevated ghrelin, and increased body mass index. *PLoS Med*. 2004;1(3):e62. <https://doi.org/10.1371/journal.pmed.0010062>
19. Signal TL, Gale J, Gander PH. Sleep measurement in flight crew: comparing actigraphic and subjective estimates to polysomnography. *Aviat Space Environ Med*. 2005;76(11):1058-63.
20. O'Donnell D, Silva EJ, Münch M, Ronda JM, Wang W, Duffy JF. Comparison of subjective and objective assessments of sleep in healthy older subjects without sleep complaints. *J Sleep Res*. 2009;18(2):254-63. <https://doi.org/10.1111/j.1365-2869.2008.00719.x>



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