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ORIGINAL ARTICLE

# The association between hand grip strenght and global PSQI score in the middleaged and elderly population

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## Abstract

The existing studies on the association between the decline in handgrip strength (HGS) and poor sleep are uncertain. This study aimed to evaluate the independent association between HGS and sleep quality assessed by global Pittsburgh Sleep Quality Index (PSQI) score in the middleaged and elderly population. Data were obtained from the Midlife in the United States (MIDUS) study, a longitudinal study including 1255 middleaged and elderly individuals. Linear regression and logistic regression analyses were performed to examine the association of HGS with global PSQI score. A total of 1142 (aged 42–84) individuals were included in this study. Their median age was 54.0 years old, and 496 of them were male. After fully controlling for confounding factors, including socio-demographic, hematologic and other relevant factors, linear regression analysis showed that HGS (− 0.024 [− 0.040–0.007], $P = 0.004$) was negatively associated with global PSQI score. Logistic regression analysis showed that lower HGS (0.574 [0.342–0.964], $P = 0.002$) was associated with poorer sleep quality (global PSQI score > 5). Sensitivity analysis furthermore showed that the association between lower HGS and poor sleep quality was not affected by hypnotics use. The results of this study showed that lower HGS was independently associated with poor sleep quality among middle-aged and elderly people from the United States. Future longitudinal and interventional studies are warranted to assess whether elevated HGS may improve sleep quality.

**Keywords** Sleep quality · Hand grip strength · Sarcopenia · Middleaged and elderly people · Epidemiology

## Introduction

In the last few decades, sleep problems, including short sleep time, sleep disturbance, low sleep efficiency, excessive daytime sleepiness and others, have become increasingly serious due to social and economic factors [1–3]. Existing studies have shown close associations between poor sleep and adverse health status, such as obesity, diabetes mellitus and cardiovascular diseases (CVDs, including hypertension, coronary heart disease and stroke) and mental disorders [4–7]. Good sleep quality is regarded as an important condition for individuals' health status [8]. However, the mechanisms that may clarify the association between sleep problems and adverse health outcomes are still unknown. Importantly, some studies have shown that poor sleep was also related to self-perceived difficulties in moving speed in elderly adults [9, 10]. In elderly adults, poor sleep quality could predict a higher risk for mobility limitation and a decline in physical functioning [11]. A decline in mobility capacity or physical functioning is often a result of physical impairment, such as the impaired neuromuscular system [12, 13]. A constantly

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deteriorating muscular system may provide biological pathways linking poor sleep quality to adverse health outcomes [12, 13].

As a simple and well-established indicator of muscle power, handgrip strength (HGS) has been considered a reliable indicator of an individual's muscle power or overall physical function. For instance, HGS has been a powerful index for diagnosing sarcopenia and frailty in adults [14–18]. A reduction in HGS could predict age-related functional decline [15]. To date, studies have investigated associations between the muscular system and various sleep parameters, including sleep quality, diurnal variation, sleep fragmentation, primary sleep disorders, and the use of sedative agents in different populations [16–22]. Among middle-aged and elderly people, however, few studies have examined the relationship between HGS and sleep quality. Further exploration of the association should be helpful to enhance our understanding of the links between sleep problems and public health.

We assumed that changes in HGS were related to the level of sleep quality based on previous studies. This study aimed to estimate HGS and to examine the association between HGS and global Pittsburgh Sleep Quality Index (PSQI) scores, independent of confounding factors, including sociodemographic, hematologic and other relevant factors, in the middle-aged and elderly populations.

## Materials and methods

### Study population

The data on study were collected from the Midlife in the United States (MIDUS) study, a longitudinal study of a national (US) sample of adults. The physical and mental health problems were investigated in the MIDUS study. As a sub-group of the MIDUS study, 1255 participants completed the Biomarkers Project, in which participants provided socio-demographic, behavioral, psychologic, and biological assessments. Hence, it could produce enough data to be used for multivariate calibration analysis [23]. Sleep disorders such as obstructive sleep apnea (OSA) contributes to poor sleep quality and is quite prevalent in middle-aged and elderly people. For the purpose of our study, the participants with diagnosed OSA were excluded ($N=6$).

Full details of Biomarkers Project protocol from the MIDUS study are available elsewhere [23, 24]. Complete data and specific codebooks are also available at http://www.midus.wisc.edu/. In summary, participants in the MIDUS study were originally recruited in 1995–1996 by means of a national sample collected by random-digit-dialing procedures. All living participants in the first MIDUS survey who could safely go to the clinic were considered eligible for participation in the Biomarkers Project. They were recruited to participate using e-mail and follow-up phone calls. Data were collected between at one of three affiliated General Clinical Research Centers of the MIDUS study (Georgetown University; University of Wisconsin-Madison; University of California-Los Angeles). By using a standardized protocol that was consistent across the three sites, participants completed detailed self-administered questionnaires, medical history interviews, and the collection of blood specimens during a 2-day visit. Each participant was remunerated $200 for participating, and traveling expenses were covered. Blood samples from all participants were collected and tested during the 2-day visit. The blood inflammatory markers including C-reactive protein, interleukin-6 (IL-6), and tumor necrosis factor-α (TNF-α), dehydroepiandrosterone (DHEA), dehydroepiandrosterone sulfate (DHEA-S) and creatinine were measured. According to Declaration of Helsinki guidelines, the Ethics Committee of each General Clinical Research Center (Georgetown University; University of Wisconsin-Madison; University of California-Los Angeles) approved this prospective study and all patients gave written informed consent.

### Global PSQI score

The PSQI was a reliable measure of overall sleep status and was widely used in various populations [25]. The 19 items were divided into seven component scores that reflected the severity of sleep problems in the following aspects: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, use of sleep medication, and daytime dysfunction. A global PSQI score ranging from 0 to 21 can be obtained by summing the seven components after weighting them on a scale ranging from 0 to 3 [$\alpha=0.74$]. For each component as well as the global PSQI score, higher sleep score showed worse sleep status [25]. The global PSQI score > 5 indicated poor sleep quality [26].

### HGS

HGS was used to evaluate muscle strength in this study. Both knee extension strength and HGS are widely used for measuring muscle strength, and these two measures are highly consistent [27]. Compared with knee extension strength, however, the measurement of HGS is more convenient and is not influenced by disabled lower limbs [28]. Therefore, the measurement of HGS is more feasible in the middle-aged and elderly population for a large-scale community survey. HGS was assessed by a dynamometer (Sammons Preston, Bolingbrook, IL, USA). Following the American Society of Hand Therapists' recommendation for measuring HGS, the measurements were recorded in kilograms (kg) [29]. The participants completed three trials for each hand. The

average value of the three measurements for each hand was regarded as the final estimate value of HGS. For the purpose of this study, HGS for the dominant hand in all the participants was used for analysis.

### Covariates

The results need to be adjusted because of variables that are known for their associations with HGS or sleep quality. Sociodemographic characteristics and lifestyle factors, including age, sex, race, education, marital status, smoking status, number of drinking years, exercise and hypnotic use, were obtained from self-evaluation questionnaires. The questionnaires also collected data on self-reported comorbidities, including CVDs (heart disease, hypertension, transient ischemic attack (TIA) or stroke), diabetes mellitus, cholesterol problems, respiratory diseases (asthma, emphysema/chronic obstructive pulmonary disease [COPD]), cancer and arthritis. Marital status was defined as "currently married" or "not currently married". Education was defined "with bachelor's degree or higher" or high school education and lower. The participants were categorized as normal weight (BMI < 25), overweight (25 ≤ BMI < 30) and obese (BMI ≥ 30). Smoking status was classified as "current smoker" or "not current smoker". Exercise was defined as "Whether or not have frequency of exercises ≥ 3/week". CVDs, diabetes mellitus, cholesterol problems, respiratory diseases, cancer, arthritis and hypnotic use were dichotomized as "yes" or "no".

### Statistical analysis

The normality of the data was analyzed by the Kolmogorov–Smirnov test combined with Q-Q plots. The data that were not normally distributed are expressed as the median (interquartile range [IQR]). Age, number of drinking years, anxiety score, depression score, perceived stress score, HGS, and IL-6, TNF-α, C-reactive protein, DHEA, DHEA-S and creatinine levels presented nonnormal distributions and, therefore, are described by the median with IQR. Chi-square tests were used to compare categorical variables between participants with low (< 5) global PSQI scores and participants with high (> 5) global PSQI scores. The Mann–Whitney *U* test was used to compare continuous variables. Linear regression was performed to examine the relationship between HGS and global PSQI scores. Furthermore, HGS was categorized by quartiles (quartile 4: ≥ 75th percentile, quartile 3: 50th–75th percentile, quartile 2: 25th–50th percentile, quartile 1: ≤ 25th percentile). Logistic regression was performed to examine the association between HGS and poor sleep quality (global PSQI score > 5), with quartile 1 as the reference category. The crude model was adjusted for age and gender. Model 1 was adjusted for age, gender, race, education, BMI, currently married, current smoker, number of drinking years, exercise, anxiety score, depression score, perceived stress score, CVDs (heart disease, hypertension and TIA or stroke), diabetes mellitus, cholesterol problems, respiratory diseases (asthma and emphysema/COPD), cancer and arthritis. Model 2 was adjusted for Model 1 + blood parameters (IL6, TNF-α, C-reactive protein, DHEA, DHEA-S and creatinine levels). Sensitivity analysis was performed by adding "hypnotic use" as a covariate to examine whether hypnotic use impacted the association between HGS and poor sleep quality (global PSQI score > 5). *P* values < 0.05 were considered statistically significant. All analyses were performed using SPSS 24.0 and R 3.5.

## Results

### Characteristics of the study participants

Due to missing data for 107 participants, the remaining 1142 participants (age 42–84) were included and further analyzed in this study (Fig. 1).

Table 1 presents sociodemographic characteristics for 1142 participants who were divided into two groups according to PSQI score > 5. The participants were mainly composed of 1085 (95.01%) whites. The median age of the patients was 54.0 years. The participants with a global PSQI score > 5 tended to be females and current smokers. The prevalence of hypertension, TIA or stroke, diabetes mellitus, asthma, arthritis and hypnotic use was also higher in participants with a global PSQI score > 5. The participants with a global PSQI score ≤ 5 tended to be currently married, were more likely to have an exercise frequency ≥ 3/week and acquired a higher level of education.

### Lower HGS was associated with higher global PSQI scores by the linear regression analysis

Table 2 presents the association between HGS and global PSQI scores using multivariate linear regression. Model 1 showed that HGS (− 0.031 [− 0.046, − 0.015], $P < 0.001$) was negatively associated with global PSQI scores after adjustments for age, gender, race, education, BMI, currently married, current smoker, number of drinking years, exercise, anxiety score, depression score, perceived stress score, CVDs (heart disease, hypertension and TIA or stroke), diabetes mellitus, cholesterol problems, respiratory diseases (asthma and emphysema/COPD), cancer and arthritis. Lower HGS (− 0.024 [− 0.040, − 0.007], $P < 0.001$; Model 2) remained significantly related to higher global PSQI scores after incorporating blood parameters (IL6, TNF-α, C-reactive protein, DHEA, DHEA-S and creatinine levels) into Model 1. We also

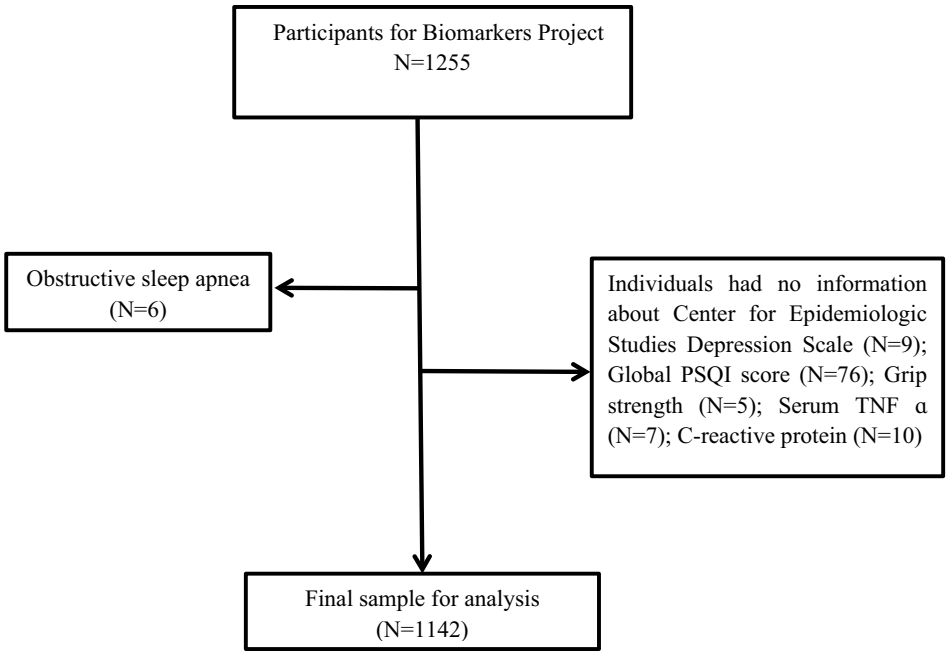


**Fig. 1** The flow chart of participants included in this study

found that HGS was significantly associated with sleep latency (− 0.008 [− 0.013, − 0.003], $p = 0.001$), habitual sleep efficiency (− 0.007 [− 0.012, − 0.001], $P < 0.012$) and sleeping medication (− 0.006 [− 0.011, 0.000], $P = 0.034$) after fully adjusting for these confounding factors.

### Lower HGS was associated with poor sleep quality (global PSQI score > 5) using logistic regression analysis

Table 3 presents the associations between HGS and sleep quality using multivariate logistic regression. The crude model indicated that lower HGS (0.395 [0.268, 0.583], $P < 0.001$) was associated with poor sleep quality (global PSQI score > 5) after adjusting for age and gender. After adjustments for age, gender, race, education, BMI, currently married, current smoker, number of drinking years, exercise, anxiety score, depression score, perceived stress score, CVDs (heart disease, hypertension and TIA or stroke), diabetes mellitus, cholesterol problems, respiratory diseases (asthma and emphysema/COPD), cancer and arthritis in Model 1, the results were similar to those of the crude model (0.504 [0.323, 0.786], $P < 0001$). This association remained statistically significant and changed little when incorporating the confounding factors (serum IL6, serum TNF-α, serum C-reactive protein, blood DHEA, blood DHEA-S and blood creatinine levels) into Model 1 (0.574 [0.342, 0.964], $P = 0.002$; Model 2). All of the above results were from the comparison between quartile 4 (the highest category) and quartile 1 (the lowest, reference category).

### Lower HGS was associated with poor sleep quality by sensitivity analysis

Table 4 presents the sensitivity analysis performed by adding hypnotic use as a covariate. The results indicated that lower HGS remained associated with poor sleep quality (global PSQI score > 5). This association remained statistically significant in Model 1 and Model 2, which suggested that the association between HGS and poor sleep quality was not significantly affected by hypnotic use. The fully adjusted odds ratio (OR) for poor sleep quality in model 2 was 0.617 (0.364, 0.903) in quartile 4 (the highest) versus quartile 1 (the lowest) HGS categories.

## Discussion

This study aimed to investigate the association between sleep quality assessed by global PSQI scores and HGS, which is a powerful predictor of morbidity and mortality for many diseases, such as CVDs and other chronic health problems, among middle-aged and elderly people. In addition to subjective sleep quality, sleep duration and daytime dysfunction, HGS was strongly associated with the other 4 indicators from the PSQI by multivariate linear regression analysis. Furthermore, lower HGS was significantly associated with poor sleep quality (global PSQI score > 5) after adjustments were made for enough confounding factors in the multivariate logical regression analysis. Compared with the strength of lower limbs, HGS is affected less by loss in muscle mass due to aging or sedentary behavior and is key to meeting the demands of daily living [30–33]. Thus, we adopted HGS to

**Table 1** Characteristics of participants stratified by global PSQI score

| Variables | Total ($N=1142$) | Score ≤ 5 ($N=786$) | Score > 5 ($N=356$) | $P$ value |
|---|---|---|---|---|
| Age (years) | 54 (45–63) | 54 (45–63) | 53 (44–61) | 0.081 |
| Gender (male), *n* (%) | 496 (43.43) | 370 (47.07) | 126 (35.39) | < 0.001 |
| Race (white), *n* (%) | 1085 (95.01) | 743 (94.52) | 342 (96.08) | 0.197 |
| Education (with bachelor's degree or higher), *s* (%) | 445 (38.97) | 265 (33.72) | 180 (50.56) | < 0.001 |
| BMI | | | | 0.094 |
| < 25, *n* (%) | 274 (23.99) | 190 (24.17) | 84 (23.60) | |
| 25–30, *n* (%) | 398 (34.85) | 288 (36.64) | 110 (30.90) | |
| ≥ 30, *n* (%) | 470 (41.16) | 308 (39.19) | 162 (45.51) | |
| Currently married, *n* (%) | 249 (21.80) | 185 (23.54) | 64 (17.98) | 0.035 |
| Current smoker, *n* (%) | 164 (14.36) | 89 (11.32) | 75 (21.07) | < 0.001 |
| Number of drinking years | 6.00 (2.00–25.00) | 6.00 (2.38–25.00) | 5.00 (2.00–22.00) | 0.093 |
| Frequency of exercises ≥ 3/week, *n* (%) | 880 (77.06) | 624 (79.39) | 256 (71.91) | 0.005 |
| Anxiety score | 1.80 (1.40–2.20) | 1.80 (1.40–2.10) | 1.90 (1.40–2.30) | 0.001 |
| Depression score | 6.00 (3.00–12.00) | 5.00 (2.00–9.63) | 10.00 (6.00–18.00) | < 0.001 |
| Perceived stress score | 22.00 (17.00–26.00) | 21.00 (17.00–25.00) | 25.00 (20.00–28.00) | < 0.001 |
| HGS (kg/force) | 32.67 (25.67–42.67) | 34.67 (26.67–44.42) | 30.67 (23.67–39.25) | < 0.001 |
| Hypnotics use, *n* (%) | 148 (12.96) | 61 (7.76) | 87 (24.43) | < 0.001 |
| Diseases currently diagnosed | | | | |
| Physician diagnosed heart disease, *n* (%) | 133 (11.65) | 84 (10.69) | 49 (13.76) | 0.133 |
| Physician diagnosed hypertension, *n* (%) | 411 (35.99) | 255 (32.44) | 156 (43.82) | < 0.001 |
| Physician diagnosed TIA or stroke, *n* (%) | 47 (4.12) | 24 (3.05) | 23 (6.46) | 0.007 |
| Physician diagnosed mellitus diabetes, *n* (%) | 134 (11.73) | 77 (9.80) | 57 (16.01) | 0.003 |
| Physician diagnosed cholesterol problems, *n* (%) | 478 (41.86) | 317 (40.33) | 161 (45.22) | 0.120 |
| Physician diagnosed asthma, *n* (%) | 136 (11.91) | 80 (10.18) | 56 (15.73) | 0.007 |
| Physician diagnosed emphysema/COPD, *n* (%) | 30 (2.63) | 17 (2.16) | 13 (3.56) | 0.145 |
| Physician diagnosed cancer, *n* (%) | 160 (14.01) | 106 (13.49) | 54 (15.17) | 0.260 |
| Physician diagnosed arthritis, *n* (%) | 380 (33.27) | 226 (28.75) | 154 (43.26) | < 0.001 |
| Blood samples | | | | |
| Serum IL-6 (pg/mL) | 2.10 (1.36–3.45) | 1.99 (1.31–3.20) | 2.50 (1.58–3.95) | < 0.001 |
| Serum TNF-α (pg/mL) | 2.05 (1.69–2.51) | 2.04 (1.66–2.47) | 2.09 (1.73–2.55) | 0.101 |
| Serum C-reactive protein (ug/mL) | 1.44 (0.70–3.63) | 1.28 (0.63–3.01) | 2.19 (0.87–4.38) | < 0.001 |
| Blood DHEA (ng/mL) | 4.90 (3.00–7.70) | 5.18 (3.30–7.83) | 4.20 (2.53–7.20) | < 0.001 |
| Blood DHEA-S (ug/dL) | 87.00 (52.00–143.25) | 95.5 (58.00–147.00) | 71.00 (40.25–134.00) | < 0.001 |
| Blood creatinine (mg/dL) | 0.80 (0.70–1.00) | 0.80 (0.70–1.00) | 0.80 (0.70–1.00) | 0.084 |

*PSQI* pittsburgh sleep quality index; *HGS* hand grip strength; *BMI* body mass index; *TIA* transient ischemic attack; *COPD* chronic obstructive pulmonary disease; *IL-6* interleukin-6; *TNF-a* tumor necrosis factor-α; *DHEA* dehydroepiandrosterone; *DHEAS* dehydroepiandrosterone sulfate

consistently and easily represent muscle strength. Although HGS has been known to be affected by physical, psychological, and other factors in previous literature, few studies have analyzed those factors comprehensively in a large-sample population. In this study, we further explored the relationship between HGS and global sleep quality in the general US population.

Sleep-related studies have been ongoing for more than forty years. Sleep problems are an important risk factor for chronic health problems such as CVDs, including hypertension, coronary heart disease and stroke [4–7]. However, the mechanisms underlying the association between sleep problems and adverse health outcomes remain unclear. The relationship between sleep quality and physical function or muscle power has been reported in patients diagnosed with COPD, athletes and the elderly population [34]. As a well-established indicator of muscle power, HGS was considered a reliable indicator of individuals' muscle power or overall physical function [35]. Consistent with the literature, our results showed a negative correlation between HGS and global PSQI scores in Model 1 and Model 2 (Table 2), but subjective sleep quality, sleep duration and daytime dysfunction were not associated with HGS. These inconsistent findings may be at least partly explained by the different study

**Table 2** Multiple linear regression analysis for relationship between HGS and global PSQI score

| Variables | *B* | Sβ | 95% CI | *P* value |
|---|---|---|---|---|
| Crude | | | | |
| Global PSQI score | − 0.055 | − 0.189 | − 0.080–0.031 | < 0.001 |
| 1. Subjective sleep quality | − 0.006 | − 0.108 | − 0.011–0.001 | 0.012 |
| 2. Sleep latency | − 0.009 | − 0.114 | − 0.015–0.002 | 0.008 |
| 3. Sleep duration | − 0.006 | − 0.093 | − 0.011–0.001 | 0.032 |
| 4. Habitual sleep efficiency | − 0.014 | − 0.165 | − 0.021–0.007 | < 0.001 |
| 5. Sleep disturbances range | − 0.003 | − 0.067 | − 0.007–0.001 | 0.121 |
| 6. Sleeping medication | − 0.012 | − 0.136 | − 0.019–0.004 | 0.002 |
| 7. Daytime dysfunction | − 0.006 | − 0.113 | − 0.011–0.002 | 0.009 |
| Model 1 | | | | |
| Global PSQI score | − 0.031 | − 0.104 | − 0.046–0.015 | < 0.001 |
| 1. Subjective sleep quality | − 0.002 | − 0.041 | − 0.005–0.001 | 0.162 |
| 2. Sleep latency | − 0.009 | − 0.120 | − 0.014–0.005 | < 0.001 |
| 3. Sleep duration | − 0.002 | − 0.026 | − 0.005–0.002 | 0.398 |
| 4. Habitual sleep efficiency | − 0.007 | − 0.086 | − 0.012–0.002 | 0.004 |
| 5. Sleep disturbances range | − 0.004 | − 0.081 | − 0.006–0.001 | 0.006 |
| 6. Sleeping medication | − 0.008 | − 0.091 | − 0.013–0.003 | 0.003 |
| 7. Daytime dysfunction | 0.001 | 0.027 | − 0.001–0.004 | 0.329 |
| Model 2 | | | | |
| Global PSQI score | − 0.024 | − 0.081 | − 0.040–0.007 | 0.004 |
| 1. Subjective sleep quality | − 0.001 | − 0.015 | − 0.004–0.002 | 0.620 |
| 2. Sleep latency | − 0.008 | − 0.104 | − 0.013–0.003 | 0.001 |
| 3. Sleep duration | − 0.001 | − 0.015 | − 0.005–0.003 | 0.634 |
| 4. Habitual sleep efficiency | − 0.007 | − 0.080 | − 0.012–0.001 | 0.012 |
| 5. Sleep disturbances range | − 0.003 | − 0.058 | − 0.006–0.000 | 0.060 |
| 6. Sleeping medication | − 0.006 | − 0.068 | − 0.011–0.000 | 0.034 |
| 7. Daytime dysfunction | 0.001 | 0.023 | − 0.002–0.004 | 0.429 |

Crude: Adjusted for age and gender

Model 1: Adjusted for age, gender, race, education, BMI, currently married, current smoker, number of drinking years, exercise, anxiety score, depression score, perceived stress score, CVDs (heart disease, hypertension, and TIA or stroke), mellitus diabetes and cholesterol problems and respiratory diseases (asthma and emphysema/COPD), cancer and arthritis

Model 2: Adjusted for age, gender, race, education, BMI, currently married, current smoker, number of drinking years, exercise, anxiety score, depression score, perceived stress score, CVDs (heart disease, hypertension, and TIA or stroke), mellitus diabetes and cholesterol problems and respiratory diseases (asthma and emphysema/COPD), cancer and arthritis, blood parameters (IL6, TNF-α, C-reactive protein, DHEA, DHEA-S and creatinine)

*PSQI* pittsburgh sleep quality index; *HGS* handgrip strength; *BMI* body mass index; *TIA* transient ischemic attack; *COPD* chronic obstructive pulmonary disease; *IL-6* interleukin-6; *TNF-a* tumor necrosis factor-α; *DHEA* dehydroepiandrosterone; *DHEAS* dehydroepiandrosterone sulfate; *Sβ* standardization coefficient

populations selected and study designs used, the hypotheses being investigated and the different methods of analyzing data. Previous studies have also suggested that muscle power or physical function is an important indicator for major geriatric syndromes, such as impaired mobility, falls, frailty and sarcopenia. Declines in physical function have been linked with poor recovery from illness.

The results of our study mainly contributed to the literature in four aspects. First, the data of this study were from the MIDUS study, a longitudinal study of a national (US) sample of middle-aged and elderly populations. The study proved that lower HGS was closely associated with global PSQI scores, which expands upon the sparse research to date on associations between muscle power and sleep status. Second, we first used the measurement method of calculating the global PSQI score to assess an individual's overall sleep quality. This global PSQI score represents stable sleep status over a long period, which can further support the reliability of the research results. Third, an inverse correlation between HGS and global PSQI scores was proven after adjustments were made for confounding factors, including sociodemographic characteristics, lifestyle factors, age-related comorbidities, inflammation and hormones. Hormone insufficiency and activation of inflammatory reactions have been reported to contribute to loss of muscle power. We collected biochemistry data that had not been adjusted for in previous studies. Moreover, the additional sensitivity analysis (Table 4) revealed a significant association between lower HGS and poorer sleep quality, which was affected by hypnotic use.

## Limitations

There are a few limitations to the present study. First, this is a cross-sectional study and thus it is not possible to make causal inferences. Secondly, the PSQI is used for assessing participants' self-reported sleep quality. A more objective tool such as polysomnography is better to assess sleep status for the study population.

## Conclusions

Lower HGS is associated with poor sleep quality among middle-aged and elderly people, which may be particularly important for the middle-aged and elderly population to prevent chronic health problems, such as sleep disorders.

**Table 3** Multivariate logistic regression analysis for association between HGS and poor sleep quality (global PSQI score > 5)

| Variables | *n* | Cut off | Crude | Model 1 | Model 2 |
|---|---|---|---|---|---|
| Hang grip strength | | | | | |
| Quartile 1 (low) | 289 | ≤ 25.67 | 1.000 (ref.) | 1.000 (ref.) | 1.000 (ref.) |
| Quartile 2 | 288 | 25.67–32.67 | 0.683 (0.482–0.969) | 0.801 (0541–1.186) | 0.798 (0.536–1.188) |
| Quartile 3 | 282 | 23.67–42.67 | 0.496 (0.345–0.712) | 0.533 (0.352–0.807) | 0.645 (0.415–0.942) |
| Quartile 4 (high) | 283 | ≥ 42.67 | 0.395 (0.268–0.583) | 0.504 (0.323–0.786) | 0.574 (0.342–0.964) |
| *P*-trend | | | < 0.001 | < 0.001 | 0.002 |

Crude: Adjusted for age and gender

Model 1: Adjusted for age, gender, race, education, BMI, currently married, current smoker, number of drinking years, exercise, anxiety score, depression score, perceived stress score, CVDs (heart disease, hypertension, and TIA or stroke), mellitus diabetes and cholesterol problems and respiratory diseases (asthma and emphysema/COPD), cancer and arthritis

Model 2: Adjusted for age, gender, race, education, BMI, currently married, current smoker, number of drinking years, exercise, anxiety score, depression score, perceived stress score, CVDs (heart disease, hypertension, and TIA or stroke), mellitus diabetes and cholesterol problems and respiratory diseases (asthma and emphysema/COPD), cancer and arthritis, blood parameters (IL6, TNF-α, C-reactive protein, DHEA, DHEA-S and creatinine)

*PSQI* pittsburgh sleep quality index; *HGS* handgrip strength; *BMI* body mass index; *TIA* transient ischemic attack; *COPD* chronic obstructive pulmonary disease; *IL-6* interleukin-6; *TNF-a* tumor necrosis factor-α; *DHEA* dehydroepiandrosterone; *DHEAS*, dehydroepiandrosterone sulfate

**Table 4** Sensitivity analysis performed by adding hypnotics use as a covariate in the association between HGS and poor sleep quality (global PSQI score > 5)

| Variables | *N* | Cut off | Crude | Model 1 | Model 2 |
|---|---|---|---|---|---|
| HGS | | | | | |
| Quartile 1 (low) | 289 | ≤ 25.67 | 1.000 (ref.) | 1.000 (ref.) | 1.000 (ref.) |
| Quartile 2 | 288 | 25.67–32.67 | 0.707 (0.492–1.016) | 0.812 (05.43–1.214) | 0.791 (0.525–1.191) |
| Quartile 3 | 282 | 23.67–42.67 | 0.498 (0.343–0.721) | 0.540 (0.354–0.824) | 0.629 (0.403–0.984) |
| Quartile 4 (high) | 283 | ≥ 42.67 | 0.442 (0.297–0.659) | 0.546 (0.347–0.858) | 0.617 (0.364–0.903) |
| *P*-trend | | | < 0.001 | 0.002 | 0.015 |

Crude: Adjusted for age, gender and hypnotics use

Model 1: Adjusted for age, gender, race, education, BMI, currently married, current smoker, number of drinking years, exercise, anxiety score, depression score, perceived stress score, CVDs (heart disease, hypertension, and TIA or stroke), mellitus diabetes and cholesterol problems and respiratory diseases (asthma and emphysema/COPD), cancer, arthritis and hypnotics use

Model 2: Adjusted for age, gender, race, education, BMI, currently married, current smoker, number of drinking years, exercise, anxiety score, depression score, perceived stress score, CVDs (heart disease, hypertension, and TIA or stroke), mellitus diabetes and cholesterol problems and respiratory diseases (asthma and emphysema/COPD), cancer, arthritis, blood parameters (IL6, TNF-α, C-reactive protein, DHEA, DHEA-S and creatinine) and hypnotics use

*PSQI* pittsburgh sleep quality index; *HGS* handgrip strength; *BMI* body mass index; *TIA* transient ischemic attack; *COPD* chronic obstructive pulmonary disease; *IL-6* interleukin-6; *TNF-a* tumor necrosis factor-α; *DHEA* dehydroepiandrosterone; *DHEAS* dehydroepiandrosterone sulfate

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical approval** According to the Declaration of Helsinki guidelines, the Ethics Committee of each General Clinical Research Center (Georgetown University; University of Wisconsin-Madison; University of California-Los Angeles) approved this prospective study.

**Informed consent** All patients gave written informed consent.

## References

1. Sun W, Ling J, Zhu X, et al. Associations of weekday-to-weekend sleep differences with academic performance and health-related outcomes in school-age children and youths. Sleep Med Rev. 2019;46:27–53.
2. Drapeau CW, Nadorff MR, McCall WV, et al. Screening for suicide risk in adult sleep patients. Sleep Med Rev. 2019;46:17–26.
3. Patel SR. Social and demographic factors related to sleep duration. Sleep. 2007;30(9):1077–8.
4. Cappuccio FP, Cooper D, D'Elia L, et al. Sleep duration predicts cardiovascular outcomes: a systematic review and meta-analysis of prospective studies. Eur Heart J. 2011;32(12):1484–92.

5. Cappuccio FP, Taggart FM, Kandala NB, et al. Meta-analysis of short sleep duration and obesity in children and adults. Sleep. 2008;31(5):619–26.
6. Cappuccio FP, D'Elia L, Strazzullo P, et al. Quantity and quality of sleep and incidence of type 2 diabetes. Diabetes Care. 2009;33(2):414–20.
7. Cappuccio FP, Stranges S, Kandala NB, et al. Gender-specific associations of short sleep duration with prevalent and incident hypertension: the Whitehall II study. Hypertension. 2007;50(4):693–700.
8. Watson NF, Badr MS, Belenky G, et al. Joint consensus statement of the American academy of sleep medicine and sleep research society on the recommended amount of sleep for a healthy adult: methodology and discussion. Sleep. 2015;38(8):1161–83.
9. Goldman SE, Stone KL, Ancoliisrael S, et al. Poor sleep is associated with poorer physical performance and greater functional limitations in older women | sleep | Oxford academic [J]. Sleep. 2007;30(10):1317–24.
10. Sari S, Erkki K, Päivi S, et al. Sleep-related factors and mobility in older men and women. J Gerontol A Biol Sci Med Sci 2010;65(6):649–57. https://doi.org/10.1093/gerona/glq017
11. Huang Y, Zhu M. Increased global PSQI score is associated with depressive symptoms in an adult population from the United States. Nat Sci Sleep. 2020;12:487–95.
12. Rantanen T. Midlife HGS as a predictor of old age disability [J]. JAMA, 1999, 281.
13. Ferrucci L, Penninx BWJH, Volpato S, et al. Change in muscle strength explains accelerated decline of physical function in older women with high interleukinserum levels. J Am Geriatr Soc. 2002;50(12):1947–54.
14. Legrand D, Vaes B, Mathei C, et al. The prevalence of sarcopenia in very old individuals according to the European consensus definition: insights from the BELFRAIL study [J]. Age Ageing. 2013;42(6):727–34.
15. Bohannon RW. Hand-grip dynamometry predicts future outcomes in aging adults. J Geriatr Phys Ther. 2008;31(1):3–10.
16. Cruz-Jentoft AJ, Pierre BJ, Bauer Jürgen M, et al. Sarcopenia: European consensus on definition and diagnosis: report of the European working group on sarcopenia in older people. Age Aging. 2010;39(4):412–23.
17. Kim JS, Wilson JM, Lee SR. Dietary implications on mechanisms of sarcopenia: roles of protein, amino acids and antioxidants. J Nutr Biochem. 2010;21(1):1–13.
18. Todd G, Haberfield M, Faulkner PL, et al. Upper limb function is normal in patients with restless legs syndrome (Willis-Ekbom disease). Clin Neurophysiol. 2015;126(4):736–42.
19. Dam TTL, Ewing S, Ancoli-Israel S, et al. Association between sleep and physical function in older men: the osteoporotic fractures in men sleep study. J Am Geriatr Soc. 2008;56(9):1665–73.
20. Spira AP, Covinsky K, Rebok GW, et al. Poor sleep quality and functional decline in older women. J Am Geriatr Soc. 2012;60(6):1092–8.
21. Reyes S, Algarin C, Bunout D, et al. Sleep/wake patterns and physical performance in older adults. Aging Clin Exp Res. 2013;25(2):175–81.
22. Gauthier A, Davenne D, Martin A, et al. diurnal rhythm of the muscular performance of elbow flexors during isometric contractions. Chronobiol Int. 1996;13(2):135–46.
23. Dienberg Love G, Seeman TE, Weinstein M, et al. Bioindicators in the MIDUS National Study: protocol, measures, sample, and comparative context. J Aging Health. 2010;22(8):1059–80.
24. Gruenewald TL, Karlamangla AS, Hu P, et al. History of socioeconomic disadvantage and allostatic load in later life. Soc Sci Med. 2012;74(1):75–83.
25. Buysse DJ, Iii CFR, Monk TH, et al. The Pittsburgh sleep quality index: a new instrument for psychiatric practice and research. Psychiatry Res. 1989;28(2):193–213.
26. Shahid A, Wilkinson K, Marcu S, et al. Pittsburgh Sleep Quality Index (PSQI)[M]. In: STOP THAT and One Hundred Other Sleep Scales. New York: Springer; 2011.
27. Grip and Knee extension muscle strength reflect a common construct among adults. Muscle Nerve. 2012;46(4):127–131.
28. Bohannon RW. Muscle strength: clinical and prognostic value of hand-grip dynamometry. Curr Opin Clin Nutr Metab Care. 2015;18(5):465–70.
29. American Society of Hand Therapists. Clinical assessment recommendations. Indianapolis: American Society of Hand Therapists. 1981;3(2):21–7.
30. Cohen S. A global measure of perceived stress. J Health Soc Behav. 1983;24(1):29–32.
31. Radloff LS. The CES-D scale: a self-report depression scale for research in the general population. Appl Psychol Meas. 1977;1:385–401.
32. Huang Y, Jiang Y, Zhu M. The relationship between global sleep score and inflammatory markers in obese adults from the United States. Nat Sci Sleep. 2019;11:317–24.
33. Clare RH, Emma SH, Cyrus C, et al. Is grip strength associated with length of stay in hospitalised older patients admitted for rehabilitation? Findings from the Southampton grip strength study. Age Ageing. 2012;41(5):641–6. https://doi.org/10.1093/ageing/afs089
34. Bot AGJ, Mulders MAM, Fostvedt S, et al. Determinants of grip strength in healthy subjects compared to that in patients recovering from a distal radius fracture. J Hand Surg. 2012;37(9):1874–80.
35. Self-Reported Sleep Duration and Quality and Cardiovascular Disease and Mortality: A Dose-Response Meta-Analysis. J Am Heart Assoc. 2018;5(1):44–9.


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