Multidimensional sleep health is associated with physical frailty in a national sample of Taiwanese community-dwelling older adults: Sex matters

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ABSTRACT

Objectives: Although individual sleep characteristics are related to frailty, these characteristics do not occur separately. A multidimensional measure of sleep might provide a better estimation of frailty compared to isolated sleep characteristics. This study investigated the association of a multidimensional measure of sleep health with frailty both across and within sex groups.

Design: Data were from the Taiwan Longitudinal Study on Aging (2011), a survey with a nationally representative sample of Taiwanese older adults (N = 2,015). Frailty was defined using the Fried criteria. Self-reported sleep during the past month was used to conceptualize the five sleep health dimensions in the SATED model.

Their relationship was estimated using logistic regression analysis adjusting for sociodemographic characteristics (age, sex, education), health status (comorbidity, cognitive function, pain, depressive symptoms [excluding items overlapping with frailty and sleep]), and health risk behaviors (drinking, smoking, lack of exercise).

Matters show that having better sleep health across multiple dimensions is related to a lower risk of being frail, with differential risks for women and men.

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Introduction

Frailty is a geriatric syndrome marked by a loss of reserve physiological capacity to maintain homeostasis that affects about 12% of older adults worldwide. Although frailty makes individuals vulnerable to adverse outcomes, such as falls, fracture, disability, hospitalization, and death, the syndrome is preventable and reversible. Hence, identifying factors that are associated with frailty is imperative for the development of health promotion strategies to delay frailty.

Problems with sleep may increase the odds of frailty. For instance, previous studies find that longer and/or shorter sleep duration, poorer sleep quality, and insomnia are related to higher risks of frailty among older adults. Studies using objective measures also report that lower sleep efficiency and longer sleep latency are related to a higher likelihood of frailty.

One limitation in previous studies is that they examine the association of single sleep measures (e.g., poor sleep quality) with frailty, though multiple sleep characteristics are likely to co-occur. Operationally, sleep as a multidimensional construct can give a broader understanding of sleep health and may provide a better estimation of frailty compared to isolated sleep characteristic. Second, evidence suggests that the relationship between sleep and frailty may depend on sex although the effects remain unclear. For example, insomnia is related to frailty in both sexes among older...
Mexicans, but in another study, sleep complaints were associated with frailty in older Mexican women, but not men. In a separate study, longer sleep latency in men and longer sleep duration in women were related to frailty. These studies do not provide a comprehensive picture because men and women may sleep differently and may experience different sleep problems, which likely contributes to different results across studies using different sleep variables. Hence, whether the relationship between multidimensional (and comprehensive) sleep health and frailty differs within sex groups warrants further investigation. Sex-stratified analyses identify sex-specific risks of frailty associated with sleep health and yield more interpretable and generalizable findings specific to each sex group.

Third, previous studies have investigated the association of sleep with frailty by focusing on individuals with worse sleep (e.g., using the clinical cut-off of >5 in the Pittsburgh Sleep Quality Index). Recently, scholars have called for research on sleep health to promote healthy sleep and improve public health.

This study investigated the association of a multidimensional sleep health measure with frailty among community-dwelling older adults. The multidimensional sleep health measure was constructed based on the 5 positive attributes of sleep health in the SATED model—satisfaction in sleep, alertness during daytime, timing, efficiency, and duration. We hypothesized that better sleep health would be related to a lower likelihood of being frail among community-dwelling older adults. Additionally, we tested whether the relationship between sleep health and frailty in each sex stratum. Due to inconsistent findings in prior literature, we did not establish a specific hypothesis, but explored how older men and older women would exhibit different relationships between sleep health and frailty.

Methods

Data

Secondary data were obtained from the Taiwan Longitudinal Study on Aging (TLSA), a nationally representative sample aged 60 years and above. The TLSA was conducted by the Health Promotion Administration aiming to understand the impacts of population aging on the society in Taiwan. The Institutional Review Board of the Bureau of Health Promotion Department of Health, R.O.C approved the protocol. All participants provided signed informed consent before participation. More information about the TLSA can be found in previous reports. The present study used data from wave 2011 because items to operationalize the multidimensional sleep health measure were first available in this wave.

Sample

The sample size in wave 2011 was 3727. Based on the inclusion criteria of the current study, respondents who were younger than 65 years old (n = 1301) and living in long-term care facilities (n = 106) at the time of interview were excluded. Individuals with missing information on the multidimensional sleep health measure (n = 75) and other covariates were also excluded (n = 230). The final sample size was 2015. Compared to those who were excluded from the current analysis, the current sample was significantly older ($\chi^2$ (5, N = 3727) = 2472.77, $p < .001$) with a lower level of education ($\chi^2$ (1, N = 3727) = 74.94, $p < .001$). Significant difference in sex was not found ($\chi^2$ (1, N = 3727) = 2.49, $p = .114$).

Measures

Frailty

Following previous studies, we used modified definitions to operationalize frailty under the Fried criteria (ie, weight loss, exhaustion, low physical activity, slowness, weakness). These modified definitions were commonly used to conceptualize frailty.

Weight loss was assessed using poor appetite (In the past week, were you not interested in eating or having a poor appetite?) from the Center for Epidemiologic Studies Depression Scale (CESD). Exhaustion was assessed by everything is an effort or cannot get going from the CESD. Low physical activity was defined based on the frequency of engaging in the following activities: gardening, walking, riding bicycle, jogging, hiking, playing ball, and other outdoor physical exercise. Slowness was conceptualized by the difficulty with walking 200 to 300 meters, and weakness was conceptualized as the difficulty with carrying items >11-12 kg. Individuals were categorized as having “normal” or “frail” traits based on values used in published studies (Table 1). A total number of frail traits (from 0 to 5) was calculated for each respondent. Individuals with 3 or more traits were considered as having frailty phenotype (coded as 1).

Sleep health

Self-reported sleep measures were used to conceptualize the 5 sleep health dimensions in the SATED model (ie, sleep satisfaction, daytime alertness, sleep timing, sleep efficiency, sleep duration). Sleep satisfaction, daytime alertness, and sleep duration were assessed using relevant single item from the survey (Table 1). Sleep timing was assessed by mid-sleep time by calculating the middle time between the time when individuals went to bed and got up. Sleep efficiency was assessed by time staying awake in bed through calculating the difference between total time in bed (ie, the time when individuals went to bed and got up) and time asleep. Individuals were categorized as having “good” or “poor” sleep health in each dimension based on the values used in the previous studies (Table 1). Sleep health composite score was calculated by summing up “good” sleep health dimensions (from 0 to 5; higher scores representing better sleep health) and used in the analysis.

Covariates

Sociodemographic characteristics (comorbidity, cognitive function, pain), health status (comorbidity, cognitive function, pain), health status (comorbidity, cognitive function, pain), health behaviors (drinking, smoking, lack of exercise) were included as covariates due to their known effects on sleep or frailty. Sociodemographic information included age (65-69 [reference], 70-74, 75+, sex [female [reference], male], education [primary or below [reference], secondary or above]). For comorbidity, individuals were asked whether a doctor had ever told them that they had the following health conditions: hypertension, diabetes, heart disease, stroke, cancer, lung disease, asthma, arthritis, liver disease, and renal disease. Individuals’ total number of conditions were categorized into 0, 1, or 2 or more conditions. Global cognitive function was assessed by the Short Portable Mental Status Questionnaire, which has been validated against the Mini-Mental State Examination. The participants were asked about today’s date, day of the week, the current home address, age in years, and to subtract 3 from 20 for 4 consecutive times. The total incorrect answer (0-5) was used in the analysis, a higher score indicating poorer cognitive function. Any pain was assessed by asking if individuals experienced pain in their body in the past month. Depressive symptoms were assessed by the 10-items CESD. Individuals rated each item on a 0 (no) to 3 (often or most of the time) scale. We excluded reports of “poor appetite”, “everything is an effort”, “cannot get going”, and...
“restless sleep” from the total score calculation to avoid circularity shared variance with frailty and sleep health. Hence, the possible total score ranged from 0 to 18. Drinking frequency was assessed by asking whether individuals drank alcohol in the past 12 months on a 0 (never) to 4 (no exercise) scale. Smoking history was assessed by asking individuals if they had ever smoked. Their responses were categorized into never smoke (reference), ever smoked, and smoke now. Exercise frequency was recorded on a 0 (9 times or above per week) to 4 (no exercise) scale.

**Results**

Participant characteristics (Table 2) revealed 9% of the respondents were frail. The average sleep health composite score was 2.51. The most prevalent good sleep health dimension was daytime alertness (91%) and the least prevalent was sleep efficiency (11%). Compared to individuals who were not frail, those who were frail scored significantly lower on the multidimensional sleep health composite, and significantly fewer of them indicated satisfaction with sleep, being alert during daytime, and having adequate sleep duration. Significant differences in all covariates were also found when comparing frailty status.

Descriptive analysis was used to examine the characteristics of all respondents and by sex. Correlational analysis was used to assess the relationship among the multidimensional sleep health measure and each sleep health dimension. To examine the effects of the multidimensional sleep health measure on frailty, multiple logistic regression analysis was first performed adjusting for sociodemographic information, and then adjusting for health and lifestyle characteristics. The same analysis stratified by sex was carried out to investigate whether the relationship between sleep health and frailty differed within sex groups. Sensitivity analysis was done to investigate which sleep health dimension was significantly related to frailty. We reported odds ratio (OR) with 95% confidence intervals (CI). The focal results were reported with the main text and the fully adjusted models can be found in Supplementary Tables 1-7. We applied sampling weights in all analyses and carried out all analyses with SPSS version 24 (IBM SPSS Statistics for Windows, Armonk, NY). The ethics board at the Taipei Medical University approved the secondary data analysis.

**Table 1** Operationalization of frailty and sleep health

<table>
<thead>
<tr>
<th>Frailty traits</th>
<th>Survey question</th>
<th>Responses</th>
<th>Definition of normal traits</th>
<th>Definition of frail traits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight loss</td>
<td>In the past week, did you have poor appetite?</td>
<td>0-no</td>
<td>0-no</td>
<td>3-often or chronically</td>
</tr>
<tr>
<td>Exhaustion</td>
<td>In the past week, did you feel that everything was an effort?</td>
<td>0-no</td>
<td>0-no</td>
<td>3-often or chronically</td>
</tr>
<tr>
<td>Low physical activity</td>
<td>How often do you do gardening?</td>
<td>3-often or chronically</td>
<td>3-1 to 2 times a week</td>
<td>2- to 3 times a month</td>
</tr>
<tr>
<td>Slowness</td>
<td>Do you have any difficulty walking for 200 to 300 meters?</td>
<td>0-no difficulty</td>
<td>0-no difficulty</td>
<td>1-some difficulty</td>
</tr>
<tr>
<td>Weakness</td>
<td>Do you have any difficulty lifting or carrying something weighing 11-12 kg?</td>
<td>0-no difficulty</td>
<td>0-no difficulty</td>
<td>1-some difficulty</td>
</tr>
<tr>
<td>Sleep health dimension</td>
<td>Survey question</td>
<td>Reponses</td>
<td>Definition of “good” sleep health</td>
<td>Definition of “poor” sleep health</td>
</tr>
<tr>
<td>SATED 1: Sleep satisfaction</td>
<td>How was your overall sleeping quality in the past month?</td>
<td>1-very good</td>
<td>1-very good</td>
<td>3-not so good</td>
</tr>
<tr>
<td>SATED 2: Daytime alertness</td>
<td>How often did you have difficulty staying awake when you drove, ate or engaged in the other social activities in the past month?</td>
<td>0-never</td>
<td>0-never</td>
<td>2-once or twice per week</td>
</tr>
<tr>
<td>SATED 3: Sleep timing (sleep midpoint)</td>
<td>In the past month, when did you usually go to bed?</td>
<td>0-never</td>
<td>0-never</td>
<td>2-once or twice per week</td>
</tr>
<tr>
<td>SATED 4: Sleep efficiency</td>
<td>In the past month, when did you usually get up?</td>
<td>0-never</td>
<td>0-never</td>
<td>2-once or twice per week</td>
</tr>
<tr>
<td>SATED 5: Sleep duration</td>
<td>In the past month, approximately how many hours were you asleep every night?</td>
<td>0-never</td>
<td>0-never</td>
<td>2-once or twice per week</td>
</tr>
</tbody>
</table>

SATED, satisfaction, alertness, timing, efficiency, and duration scale.

Statistical analysis

Descriptive analysis was used to examine the characteristics of all respondents and by sex. Correlational analysis was used to assess the relationship among the multidimensional sleep health measure and each sleep health dimension. To examine the effects of the multidimensional sleep health measure on frailty, multiple logistic regression analysis was first performed adjusting for sociodemographic information, and then adjusting for health and lifestyle characteristics. The same analysis stratified by sex was carried out to investigate whether the relationship between sleep health and frailty differed within sex groups. Sensitivity analysis was done to investigate which
relationships among the 5 dimensions were relatively low, indicating that each sleep dimension provided relatively unique information about overall sleep health.

The associations of a multidimensional sleep health measure with frailty and stratified by sex

The results from the adjusted logistic regression analysis showed that the multidimensional sleep health composite was significantly associated with frailty adjusting for age, sex, and education (OR = 0.57, 95% CI = 0.49-0.68; Model 1A in Table 4). This effect remained significant after adding comorbidity, cognitive function, any pain, depressive symptoms, drinking, smoking, and exercise to the model (OR = 0.78, 95% CI = 0.64-0.94; Model 2A in Table 4). Specifically, individuals scored one point higher on the multidimensional sleep health measure were approximately 22% less likely to be frail.

The effect of the multidimensional sleep health composite on frailty was significant among female (OR = 0.59, 95% CI = 0.48-0.72; Model 3A in Table 4) and male (OR = 0.54, 95% CI = 0.39-0.75; Model 5A in Table 4) respondents adjusting for age and education. Significant effect was observed only among women (OR = 0.79, 95% CI = 0.63-0.98; Model 4A in Table 4) after further adjusting for comorbidity, cognitive function, any pain, depressive symptoms, drinking, smoking, and exercise, but not among men. The effects on women showed that those who scored one point higher on the multidimensional sleep health measure had lower odds of being frail by 21%.

Figure 1 depicts the adjusted probability of being frail based on the score of the multidimensional sleep health composite in the entire sample stratified by sex. The sleep health composite score exhibited a dose-response relationship with the adjusted probability of being frail in the entire sample of older Taiwanese, such that each additional increase in the sleep health was associated with a decreased probability of being frail. Similar trends were observed among female and men although only the effects among women reached significant level.

The associations of individual sleep health dimensions with frailty and stratified by sex

The results from the adjusted logistic regression analyses (Table 4) revealed that sleep satisfaction (OR = 0.57, 95% CI = 0.49-0.68; Model 1B), daytime alertness (OR = 0.21, 95% CI = 0.14-0.31; Model 1c), and sleep duration (OR = 0.50, 95% CI = 0.34-0.74; Model 1F) were
significantly associated with frailty in the entire sample adjusting for age, sex, and education. After considering individuals’ health and risk behaviors, only daytime alertness remained significant (OR = .46, 95% CI = 0.29-0.75; Model 2C).

For women, sleep satisfaction (OR = 0.29, 95% CI = 0.19-0.44; Model 3B), daytime alertness (OR = 0.29, 95% CI = 0.18-0.47; Model 3C), and sleep duration (OR = 0.48, 95% CI = 0.30-0.78; Model 3F) were significantly related to frailty adjusting for age and education. However, these effects were no longer significant after adding health and risk behaviors to the model. For men, sleep satisfaction (OR = 0.47, 95% CI = 0.24-0.94; Model 5B) and daytime alertness (OR = 0.10, 95% CI = 0.05-0.21; Model 5C) were significantly associated with frailty adjusting for age and education. Only daytime alertness (OR = 0.33, 95% CI = 0.13-0.82; Model 6C) remained significant after adding health and risk behaviors to the model. Figure 2 shows the adjusted probability of being frail according to the 5 sleep dimensions in the entire sample stratified by sex.

**Discussion**

The current study investigated the relationship between a multi-dimensional sleep health composite and frailty among community-dwelling older adults. Our findings revealed that better sleep health was significantly associated with lower odds of frailty above and beyond sociodemographic characteristics, health status, and health risk behaviors. We also found that the association of the multidimensional sleep health composite with frailty in each sex stratum, such that the relationship was only significant among older women, but not older men, in fully adjusted models. For individual sleep health dimensions, only daytime alertness was significantly related to frailty in the entire sample and among men adjusting for sociodemographic characteristics, health status, and health risk behaviors. Although sleep satisfaction, daytime alertness, and sleep duration were significantly related to frailty adjusting for sociodemographic information among women, none of these sleep health dimensions remained significant after taking health and risk behaviors into account.

To the authors’ knowledge, this is the first study to examine the relationship between the multidimensional sleep health measure and frailty among community-dwelling older adults. Previous studies have shown that individual sleep characteristics are significantly related to frailty.4,26,7 Our findings show that the probability of being frail is reduced with the increment in the sleep health composite score and that only daytime alertness among the 5 sleep health dimensions was significantly associated with frailty. This means that,
if we only consider single sleep measures (eg, sleep duration or quality as in most previous studies) when estimating the risk of frailty, we may underestimate the effect of sleep and miss opportunities to intervene early. Together, these findings reiterate the importance of understanding sleep in a multidimensional manner and suggest the potential additive effects of individual sleep characteristics.

We found that better sleep health was significantly associated with frailty only among women after controlling for sociodemographic characteristic, health status, and health risk behaviors. One possible explanation for our findings may be sex differences in shared pathways. For instance, previous evidence has shown that inflammatory biomarkers of frailty pathogenesis, such as C-reactive protein, are more likely to be elevated among women than men. Poor sleep has also been linked to increased C-reactive proteins level among women, but not among men. Having better sleep health might impact frailty through the reduction of inflammatory biomarkers among older women. Further investigations on the sex differences in the underlying mechanisms between sleep health and frailty are warranted.

Among the 5 sleep health dimensions, we found that daytime alertness was independently associated with frailty in the entire sample in the fully adjusted models (Model 2C in Table 4). Further analyses entering all 5 sleep health dimensions simultaneously in the model also showed similar results (Supplementary Table 7). Our results also showed sex differences in the relationship between daytime alertness and frailty, such that daytime alertness was significantly associated with frailty in men (Model 6C in Table 4), but not in women (Model 4C in Table 4). There were only a few studies investigating the impact of daytime alertness on frailty, more studies investigating the impact of daytime alertness on frailty simultaneously with other sleep dimensions are recommended.

Our study contributes to the literature on sleep and aging by demonstrating that better sleep health is associated with a lower likelihood of being frail among community-dwelling older adults. Recent studies have shown that behavioral changes are effective in improving sleep health among older adults with insomnia or even among individuals without sleep disorders. At the population level, public health education targeting sleep myths and increasing knowledge on sleep hygiene may have the potential to change sleep practices. Because the existing interventions on frailty are mainly focused on nutrition and exercise training, more studies are needed to investigate the impacts of sleep-focused interventions on frailty risk. Our study also reveals that the effects of sleep health on frailty may be stronger among older women than older men. This is not to negate the benefits of sleep health on preventing frailty among men, but to emphasize the sex differences in this relationship and effective strategies specific for each sex might be needed.

Using a representative national sample of older adults in a relatively understudied Asian context is a unique strength of this study. We include extensive covariates of sociodemographic characteristics, during the daytime significantly increased the risks of being frail by 3 times. In another study, daytime alertness was not significantly associated with frailty in the entire sample, and not in each sample of men and women. One other study that focused only on older men also did not find the relationship between daytime alertness and frailty. Although a recent meta-analysis showed that daytime drowsiness was significantly correlated with frailty, the pooled effects included social frailty (ie, reduced social interactions), which made it difficult to discern the effects of daytime alertness on physical frailty. Because these studies looked at the individual effects of daytime alertness on frailty, more studies investigating the impact of daytime alertness on frailty simultaneously with other sleep dimensions are recommended.
health, and risk behaviors in analyses, increasing the validity of our findings. There are, however, limitations in this study. First, the cross-sectional design is susceptible to reverse causality. Previous study suggested that there might be bi-directional relationship between sleep and frailty. Further longitudinal investigations on this relationship are warranted. Second, due to the constraints of archival data, we used self-report items to create an adopted frailty index and the multidimensional measure of sleep health according to the SATED model. Future studies may benefit from the utilization of a validated tool to assess frailty and sleep health. Third, although napping is associated with frailty and mortality and sleep medications can affect sleep, they are not available in the TLSA dataset, precluding investigation of their moderation effects on the relationship between sleep health and frailty. Last, sleep disorders can increase the risks of frailty which may help explain our findings. For instance, obstructive sleep apnea is associated with higher odds of frailty among older adults and the significant relationship between obstructive sleep apnea and frailty has been observed among older women. However, variables on sleep disorders are not available in the TLSA. We are, therefore, unable to further investigate whether the impacts of sleep health on frailty are independent of sleep disorders, whether sleep disorder modify the relationship between sleep health and frailty, and whether sleep disorders account for the differences in the relationship between sleep health and frailty within each sex. Our models may have captured some of the effects of sleep disorders on frailty because many symptoms of sleep disorders overlap with SATED dimensions. Nevertheless, concerns may remain regarding uncaptured, respiratory-specific characteristics (eg, sleep-disordered breathing) that may not overlap with the sleep health dimensions. We recommend future research to delve into these relationships among older adults.

This study shows the first empirical evidence that sleep health may be an early risk factor for frailty by investigating the association of a multidimensional measure of sleep health with frailty among community-dwelling older adults in Taiwan. Our findings show that better sleep health is related to lower odds of frailty independent of sociodemographic, health status, and health risk behaviors. We also report that the associations of individual sleep health facets with frailty within each sex, with a stronger relationship between overall sleep health and frailty among older women. Improving sleep health among older adults may help delay and prevent frailty.

Declaration of conflict of interest
The authors have declared no conflicts of interest.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.sleh.2022.05.003.

Reference


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