Brief Report

Gender-Specific Association Between Self-reported Sleep Duration and Falls in High-Functioning Older Adults

Hsu-Ko Kuo,1,2,3 Cheryl C. H. Yang,4 Yau-Hua Yu,5 Kang-Ting Tsai,6 and Ching-Yu Chen3

1Department of Geriatrics and Gerontology and 2Department of Internal Medicine, National Taiwan University Hospital, Taipei. 3Division of Gerontology Research, Institute of Population Health Sciences, National Health Research Institutes, Taipei, Taiwan. 4Sleep Research Center, National Yang-Ming University, Taipei, Taiwan. 5Department of Medical Research, Veteran General Hospital and National Yang-Ming University, Taipei, Taiwan. 6Department of Family Medicine, Chi Mei Medical Center, Tainan, Taiwan.

Background. Prior studies have shown that sleep disturbances are related to falling and its risk factors, such as poorer cognition, depression, and physical function. However, little is known about the gender-specific associations between falling and sleep duration.

Methods. Study participants were from the annual Health Examination for the Elderly Program in the National Taiwan University Hospital (135 women and 121 men, mean age 72.2 years). Self-reported sleep duration was grouped into three categories: less than 5, 5–7.9, and 8 or more hours. Short sleep duration was defined as sleep duration less than 5 hours. Falling during the previous 12 months was ascertained by self-report questionnaire. The association of sleep duration with falling was examined by using multiple logistic regression. We approximated risk ratio (RR) of falls from the adjusted odds ratio (OR) after correction of falls incidence in the previous year.

Results. Sleep duration was inversely associated with falling among women. After adjusting for multiple confounding factors including use of antihypertensives and psychotropic medications, the OR of falls for each hour decrease in sleep duration was 1.95 (95% confidence interval [CI] 1.24–3.06). Moreover, women with sleep deprivation had a greater odds of falls within the last year than those with longer sleep durations. The estimated RR of falls comparing women with short sleep duration (sleep <5 hours) with those without was 2.98 (95% CI 1.32–4.62). We did not find an association among men.

Conclusion. Sleep deprivation is independently associated with falls in women but not in men. Short sleep duration may be an indicator to identify women at risk for falling.

Key Words: Sleep duration—Falls—Cross-sectional study.

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hort sleep duration is a common concern in modern society. Over the past few years, the prevalence of sleep deprivation has grown to epidemic proportions. According to the 2009 Sleep in America Poll by the National Sleep Foundation, the number of Americans who reported that they got 6 hours or less has increased significantly since 2001 (13%–20%) (1). Inadequate sleep is associated with unhealthy lifestyles and negatively affects health and safety. Growing evidence indicates that sleep deprivation is also associated with a number of health outcomes, including all-cause mortality (2,3), hypertension (4), coronary heart disease (5), diabetes (6–8), and obesity (9).

Falling is a major geriatric syndrome where disturbed sleep may play a role as a significant source of morbidity. Several geriatric studies have found that sleep disturbances are related to falling (10–13) and its risk factors, such as poorer cognition (14,15), depression (16), and impairment in physical function (17). Falls generally result from the interaction of multiple risk factors and unsafe situations. Sleep deprivation causes slowness in response and decrease in vigilance and likely results in greater risk of falls and injurious accidents. Moreover, use of psychotropic medications, such as benzodiazepines or antidepressants, commonly prescribed to alleviate sleeping problems, is a well-known risk factor for falling. It is therefore very challenging to distinguish whether it is poor sleep or use of medications for sleep problems that explain the increased risk of falls among older adults.

Although some studies have been performed to examine the relation of sleep disorders to falls, little is known about the gender-specific association between falling and sleep duration. We aimed to test the hypothesis that short sleep duration is associated with falling in both men and women. We sought to achieve the study goals by analyzing data in a group of high-functioning older adults who participated in the Health Examination for the Elderly Program (HEEP) in the National Taiwan University Hospital (NTUH), a tertiary medical center in Taipei, Taiwan. We conducted gender-specific analyses with the inclusion of a number of potential confounding variables. In order to avoid possible confounding effect of psychotropic medications, the associations
between falling and sleep duration were also examined after excluding users of psychotropic medications.

METHODS

Source of Study Participants
The HEEP, a health service funded by Taipei City Government, is opened to senior citizens of Taipei City who are aged 65 years or older. The HEEP is provided in 6 tertiary medical centers and 23 community hospitals across Taipei City. The Kong-Kwan campus and Bei-Hu campus of the NTUH, located in the Ta-An and Wan-Hua District, respectively, are among two of the field sites for the HEEP. Most participants who signed up for the HEEP in the NTUH are independent community-dwelling elders of Taipei City. The following assessments are provided in a typical HEEP: questionnaires for chronic diseases profile; physical examinations and anthropometric measures; chest x-ray; electrocardiogram; urine/stool examination; and laboratory analyses including complete blood count, liver function, renal function, triglyceride, and cholesterol.

Participants of the current study were selected from those who signed up for the HEEP in the NTUH. Participants of HEEP was excluded from the study if they had any of the following conditions: known diagnosis of dementia; functional impairment requiring assistance in dressing, personal hygiene, or bathing; terminal illness; impairment in vision, hearing, or communicative ability, hence making participating in the study impossible; or histories of myocardial infarction or stroke.

From October 2006 through December 2008, 256 eligible individuals agreed to participate and had complete information in interview data, physical examination and measurements, as well as laboratory examinations. The NTUH Institutional Review Board reviewed and approved the study. Informed consents were obtained from all participants.

Assessment of Falls and Sleep Duration
A fall was defined as unintentionally coming to rest on the ground, floor, or other lower level for reasons other than sudden onset of acute illness or overwhelming external force. Ascertainment of falls was made by asking participants “Did you fall during the previous year?” Sleep duration was assessed through asking participants “How many hours of sleep do you usually get a night?” and was grouped into three categories: less than 5, 5–7.9, and 8 or more hours. Short sleep duration was defined as sleep duration less than 5 hours.

Sociodemographic and Interview Data
Age, gender, educational level, and status of smoking and alcohol drinking were obtained by self-report. Whether the participants lived alone or with families was recorded. Educational level was categorized to less than high school (HS), HS, or greater than HS. Smoking status of a participant was categorized to never-smoker, current smoker, or past smoker.

Participants were asked how often, on average, they consumed beer (12 oz), wine (4 oz), or liquor (one standard drink) during the previous year, with the use of six frequency categories ranging from never to one or more times per day. During the interview, we asked participants to bring all medications that they were actively taking. Use of antihypertensives, antidiabetic medications (including oral hypoglycemic agents or insulin injection), and any psychotropic medications (including antidepressants, sedatives, or antipsychotics) were recorded. Self-reported comorbidities including hypertension, heart disease (defined as a history of coronary heart disease, congestive heart failure, or angina), arthritis, and chronic lung disease (defined as chronic bronchitis or emphysema) were ascertained by questionnaires. Diabetes was defined by self-report of a physician’s diagnosis or the use of diabetic medications (including insulin injection or oral hypoglycemic agents). We used the Center for Epidemiological Studies-Depression scale (CES-D), a 20-item self-reported questionnaire, to evaluate depression. The full range of the scale is from 0 to 60, with a higher score indicating more severe symptoms. Depressive symptom was defined as CES-D score more than 16. Cognitive function was assessed by Mini-Mental State Examination (MMSE) scale from 0 to 30, with a higher score indicating better cognitive function.

Anthropometric Data, Physical Measures, and Laboratory Examination
Body mass index calculated as weight in kilograms divided by the square of height in meters. Two supine blood pressure (BP) determinations were taken by a trained research assistant with a mercury sphygmomanometer. BPs were measured in the right arm unless otherwise specified. Averaged systolic BP and diastolic BP were obtained. Waist circumference was measured at the iliac crest to the nearest 0.1 cm. Central obesity was defined by a waist circumference more than 90 cm in men, whereas a waist circumference more than 80 cm in women. We used the Short Physical Performance Battery (SPPB) to assess the lower extremity function among study population (18). The test consists of three components: balance, timed 8-foot walking speed, and chair stands. The sum of the three components comprised the final SPPB score with a possible range from 0 to 12 (12 indicating the highest degree of lower extremity functioning). Full criteria for test administration are available at www.grc.nia.nih.gov/branches/l edb/sppb/index.htm. Blood specimens were processed in the NTUH central laboratories for analysis. Levels of serum total cholesterol and triglycerides were measured enzymatically, and levels of high-density lipoprotein cholesterol were measured using precipitation. Serum fasting glucose levels were processed by using the hexokinase enzymatical method.

Analysis
Differences in baseline characteristics between men and women were compared by Student’s t test (continuous
variables) or chi-squared test (categorical variables). The associations of short sleep duration with falls were examined in both men and women. The odds ratios (ORs) of falls comparing participants with short sleep duration (night sleep <5 hours) with those with night sleep more than 5 hours were calculated by using multiple logistic regression. We used an extended-model approach for covariates adjustment: Model 1 = age, educational level (<HS and >HS), and living status (live alone or not); Model 2 = Model 1 + health behaviors (smoking status and alcohol consumption); Model 3 = Model 2 + comorbid conditions and diseases (hypertension, diabetes, heart disease, arthritis, chronic lung disease, depressive symptom, and presence of central obesity); Model 4 = Model 3 + low-extremity function summary score (SPPB score) and cognitive function (MMSE score).

Because of the high incidence of falls among participants (22.3%), we used the following formula to approximate the risk ratios (RRs) from the adjusted ORs (19):

\[ RR = \frac{OR}{(1-P) + (P \times OR)}, \]

\( P \) indicates the incidence of falls among “nonexposed” group, namely men or women without short sleep duration; whereas OR indicates adjusted odds ratio.

Sleep duration was further grouped into three categories, namely less than 5, 5 – 7.9, and 8 or more hours. Compared with participants with sleep duration 5 – 7.9 hours, ORs of falls with other sleep categories were calculated while controlling for covariates in Model 4. We further restricted the analyses to participants who were not users of any psychoactive medications in order to avoid any confounding effect of psychotropic medication on the association between falling and sleep duration. Data management and analysis were performed using STATA 10.0 software (STATA Corporation, College Station, TX).

**RESULTS**

**Characteristics of Study Population**

Selected baseline characteristics of the study population as a whole (N = 256, mean age 72.2 years) and by gender were summarized in Table 1. One hundred and thirty-five

### Table 1. Characteristics of Study Participants (N = 256)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Women (n = 135)</th>
<th>Men (n = 121)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Falls (−)</td>
<td>Falls (+)</td>
</tr>
<tr>
<td>Continuous variables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (y)</td>
<td>70.7 (4.4)</td>
<td>72.0 (5.7)</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>23.8 (2.8)</td>
<td>23.9 (3.1)</td>
</tr>
<tr>
<td>Sleep duration at night (h)</td>
<td>5.9 (1.3)</td>
<td>5.2 (1.1)</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>134.5 (19.2)</td>
<td>135.8 (15.5)</td>
</tr>
<tr>
<td>Fasting plasma glucose (mg/dL)</td>
<td>100.4 (13.7)</td>
<td>101.2 (20.3)</td>
</tr>
<tr>
<td>Total cholesterol (mg/dL)</td>
<td>199.5 (25.8)</td>
<td>201.1 (37.3)</td>
</tr>
<tr>
<td>Triglyceride (mg/dL)</td>
<td>118.1 (48.8)</td>
<td>100.9 (38.5)</td>
</tr>
<tr>
<td>High-density lipoprotein cholesterol (mg/dL)</td>
<td>50.9 (10.4)</td>
<td>55.3 (12.2)</td>
</tr>
<tr>
<td>Short Physical Performance Battery score</td>
<td>11.0 (1.1)</td>
<td>10.5 (1.8)</td>
</tr>
<tr>
<td>Mini-Mental State Examination score</td>
<td>29.1 (1.2)</td>
<td>29.0 (1.9)</td>
</tr>
<tr>
<td>Categorical variables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current smoker</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Not drinking alcohol</td>
<td>48 (47.1)</td>
<td>21 (63.6)</td>
</tr>
<tr>
<td>Education &lt; high school</td>
<td>16 (15.7)</td>
<td>3 (9.1)</td>
</tr>
<tr>
<td>Live alone</td>
<td>12 (11.8)</td>
<td>3 (9.1)</td>
</tr>
<tr>
<td>Night sleep duration &lt;5 h</td>
<td>15 (14.7)</td>
<td>11 (33.3)</td>
</tr>
<tr>
<td>History of hypertension</td>
<td>60 (58.8)</td>
<td>16 (48.5)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>11 (10.8)</td>
<td>4 (12.1)</td>
</tr>
<tr>
<td>Heart disease</td>
<td>14 (13.7)</td>
<td>6 (18.2)</td>
</tr>
<tr>
<td>Arthritis</td>
<td>49 (48.0)</td>
<td>19 (57.6)</td>
</tr>
<tr>
<td>Chronic lung disease</td>
<td>9 (8.8)</td>
<td>7 (21.2)</td>
</tr>
<tr>
<td>Central obesity</td>
<td>96 (94.1)</td>
<td>32 (97.0)</td>
</tr>
<tr>
<td>Depressive symptom</td>
<td>7 (6.9)</td>
<td>2 (6.1)</td>
</tr>
<tr>
<td>Use of antihypertensives</td>
<td>50 (49.0)</td>
<td>16 (48.5)</td>
</tr>
<tr>
<td>Use of antidepressives, antidepressants or sedatives</td>
<td>32 (31.4)</td>
<td>11 (33.3)</td>
</tr>
</tbody>
</table>

Notes: Fall (+) = fallen in the past year; Fall (−) = not fallen in the past year.
* Values in the continuous variables were expressed as M (SD).
† Values in the categorical variables were expressed as N (%).
female participants represented 52.7% of the study population. More than half (53.9%) of the study participants had hypertension, 10.6% diabetes mellitus, 14.5% heart diseases, 11.7% chronic lung disease, and 5.9% depressive symptoms. About one fourth of the women and 20% of the men experienced falls during previous year. Men tended to be older, to be current smoker, and to have higher education and more hours of night sleep than women did. Women were more likely to live alone, to have arthritis and central obesity, and to use psychotropic medications than men did. There was no difference in physical function; cognitive function; and such comorbidities as hypertension, diabetes mellitus, heart disease, chronic lung disease, depressive symptom, and depressive symptom between men and women.

Female faller during the previous year had lower SPPB score compared with female nonfaller (10.5 vs 11.0, \( p = .026 \)). Women who fell during the previous year tended to sleep less than those who did not (5.2 vs 5.9 hours, \( p = .005 \)). Likewise, 33.3% of female faller during the previous year had short sleep duration, whereas 14.7% of women who did not fall had short sleep duration (\( p = .024 \)).

### Association Between Short Sleep Duration and Falls

Short sleep duration was significantly associated with falls among women (Table 2). After adjusting for age, education level, and living status, the OR of falls comparing women with short sleep duration (sleep <5 hours) with those without was 3.96 (95% confidence interval [CI] 1.40–11.22, \( p = .01 \)). After correction of falls incidence among female participants without short sleep duration (20.2%), the estimated RR of falls comparing women with short sleep duration with those without was 2.48 (95% CI 1.30–3.66). Additional covariates adjustment did not change the association. The association remained significant after additional adjustment of covariates in Model 2 through Model 4, meaning that the association between short sleep duration and falls among women was independent of health behaviors (smoking and alcohol consumption), comorbid conditions and diseases (diabetes mellitus, hypertension, heart disease, arthritis, chronic lung disease, depressive symptom, and presence of central obesity); and use of medications including antihypertensives, antidepressants, sedatives, or antipsychotics. Model 4 = Model 3 + low-extremity function summary score (Short Physical Performance Battery score) + Mini-Mental State Examination score.

*Not adjusting for use of psychotropic medications.

### Association Between Sleep Duration and Falls

There was an inverse relationship between sleep hours and falls among women. For each hour decrease in night sleep duration, the OR of falls was 1.95 (95% CI 1.24–3.06) after adjusting for covariates in the Model 4. Excluding users of psychotropic medications did not change the association. With each hour decrease in sleep duration, the OR of falls was 2.22 (95% CI 1.17–4.40) among women who did not use psychotropic medications. We did not find an association in men.

We subsequently grouped sleep duration into three categories, namely less than 5, 5–7.9, and 8 or more hours, and the results of multiple logistic regression were shown in Table 3.
Table 3. Multivariate-Adjusted Association Between Sleep Duration and Falls

<table>
<thead>
<tr>
<th>Sleep Duration</th>
<th>Women OR (95% CI) p Value</th>
<th>Men OR (95% CI) p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5 h</td>
<td>5.31 (1.51–18.62) .009</td>
<td>2.79 (0.21–37.02) .437</td>
</tr>
<tr>
<td>5–7.9 h</td>
<td>1.00 (reference)</td>
<td>1.00 (reference)</td>
</tr>
<tr>
<td>≥8 h</td>
<td>0.25 (0.02–3.78) .315</td>
<td>1.69 (0.35–8.28) .516</td>
</tr>
</tbody>
</table>

Notes: CI = confidence interval; OR = odds ratio. Adjusted covariates included age, educational level (<HS and >HS), and living alone or not; health behaviors (smoking and alcohol consumption); comorbid conditions and diseases (diabetes mellitus, hypertension, heart disease, arthritis, chronic lung disease, depressive symptom, and presence of central obesity); use of medications including antihypertensives, antidepressants, sedatives, or antipsychotics; low-extremity function summary score (Short Physical Performance Battery score) and Mini-Mental State Examination score.

*Not adjusting for use of psychotropic medications.

In the full-adjusted model (Model 4), we observe an inverse association between sleep duration and falls among women. Women with less sleep hours tended to have higher odds of falls. The OR for falls was 5.31 (95% CI 1.51–18.62, p = .009) comparing women with sleep duration less than 5 hours with those with sleep duration of 5–7.9 hours. Using sleep duration less than 5 hours or more than 8 hours as comparison group, the trend across categories of sleep duration was statistically significant among women (p = .004). We did not observe an association or any trend among men. After excluding participants who were current users of psychotropic medications, the inverse association between sleep duration and falls among women still remained. Women with sleep duration less than 5 hours had the highest odds of falls (OR 8.41, p = .023). The trend across categories of sleep duration was statistically significant among women (p = .01).

**DISCUSSION**

In this cohort of 256 high-functioning older adults, we found a sex-specific association between sleep duration and falls. Older women with short sleep durations had a greater odds of falling within the last year than women with longer sleep durations. The association was independent of age, educational level, living status, health behaviors (smoking and alcohol consumption), comorbid conditions and diseases, use of medications (antihypertensives and psychotropic medications), low-extremity function, and cognitive function. The inverse association between sleep duration and falls remained significant among women even after we excluded users of psychotropic medications. The association did not exist in men. Our study supported previous studies examining relation of sleep disorders to falls and physical function. Australian researchers, by collecting data from residential aged care facilities and Internet survey, suggested that sleep disturbances were associated with history of falls during the previous year (11). Brassington and colleagues (10) cross-sectionally examined 1526 community-dwelling older adults in northern California and demonstrated an independent association between falls and self-reported sleep problems, including early morning awakening, daytime napping, and difficulties in falls asleep at night as well as waking up and getting up in the morning. St George and colleagues (20), by following 169 older adults from self-care retirement villages and assisted-care hostels for 1 year, showed that residents who napped more than 30 minute during the day, or reported less than 6 hours of sleep at night, were three times more likely to suffer from multiple falls. Researchers from the Study of Osteoporotic Fractures suggested that actigraphy-measured short nighttime sleep duration and increased sleep fragmentation were associated with increased risk of falls in older Caucasian women, independent of psychotropic medications use and other risk factors for falls (12). Unlike these earlier investigations, our study firstly examined gender-specific associations between sleep duration and falls with inclusion of a number of potential confounding variables. Moreover, the role of psychotropics usage in the association between sleep deprivation and falls was carefully assessed. Not only did we adjust for the use of psychotropic medications as a covariate but we also restricted the analyses to participants who were not users of any psychotropic medications to avoid possible confounding effect.

The association between sleep deprivation and falls could be explained by a variety of mechanisms. First, early morning awakening, presumably representing sleep deprivation, was associated with cerebral white matter lesions (21), which have been recently shown as strong risk factors for falls in the general older population (22). Second, sleep deprivation in experimental animals triggered a proinflammatory state, involving increasing numbers of band neutrophils and monocytes as well as elevated levels of inflammatory cytokines (23). In human study, Patel and colleagues (24) demonstrated that a short sleep duration was associated with an elevated tumor necrosis factor alpha levels. Chronic inflammation is associated with poor muscle strength, slow gait speed, and poor functional status (25), all of which were risk factors of falls. Moreover, short sleep may be a marker of physical frailty, which is related to poor physical performance and elevated risk of falls. Although the observation that reduced duration of sleep may be associated with a higher risk of falls only among women is a novel finding, the mechanism underlying the gender-specific association is unknown. We cannot rule out the possibility of differential self-reporting of sleep habits between men and women, as suggested in a previous analysis from the Sleep Heart Health Study examining the relationship of gender to subjective measures of sleepiness (26). Further studies are
needed to investigate the role of gender as a possible effect modifier on the association between sleep and functional outcomes.

Our study has several clinical implications. First, in addition to being a predictor of such comorbidities as hypertension and diabetes, short sleep duration may be an important indicator for elevated risk of falls especially among women. Inquiring about sleep duration may be useful in identifying and targeting high-risk elderly women who may require intervention to prevent falls. Second, sleep hygiene recommendations, uniformly included as part of insomnia management, are believed to promote improved quantity and quality of sleep (27). However, the impact of sleep hygiene on such geriatric outcomes as falls is unknown. Clinical trials of sleep hygiene intervention with falls as outcome are warranted.

Our study has potential limitations deserving comment. Due to the small sample size and cross-sectional design, wide CIs were reported, and the causality between sleep duration and falls cannot be determined. Recruitment of more participants and a prospective follow-up will be needed. Second, we did not discriminate serious falls in our questionnaire. Thus, the effect of sleep deprivation on serious falls cannot be evaluated. Third, there is an association between daytime napping and risk of falls (13). However, there were no data of daytime napping, and it would be helpful to collect information about nap habits in our next phase of data collection. Fourth, the participants in our study were high-functioning health checkup volunteers, and the falls rate during the past 12 month in our study (22.5%) was well below the reported annual falls rates in community-dwelling older adults (35%–40%) (28). Therefore, the association in community-dwelling older adults may be different, and future studies are needed. Lastly, use of self-reported sleep duration may be inaccurate and could introduce bias. Although habitual sleep duration from subjective reports were moderately correlated with those are objectively measured (29), it would be useful to obtain sleep measures (e.g., polysomnography) as an important source of information about sleep problems.

In conclusion, sleep deprivation is independently associated with falls in women but not in men. Sleep deprivation may be an indicator to identify women at risk for falling. Further research should determine the prospective relationship between sleep problems and fallings and evaluate whether insomnia management may reduce risk of falling in older people.

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CORRESPONDENCE
Address correspondence to Ching-Yu Chen, MD, Division of Gerontology Research, Institute of Population Health Sciences, National Health Research Institutes, 10 F, Bldg F, 3 Yuanqu Street, Taipei (115), Taiwan. Email: cychen@ntumc.org

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