Association of Long Sleep and Physical Inactivity with Incident Disability in Community-Dwelling Older Adults: A 5-Year Longitudinal Study

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Abstract

Background

Good sleep durations and physical activity are essential factor for maintaining good health. This study examined whether sleep duration and physical inactivity were associated with incident disability among community-dwelling older adults.

Methods

A total of 4,372 adults aged ≥ 70 years participated in a baseline assessment. We also assessed self-reported sleep duration and physical activity using the International Physical Activity Questionnaire – Short Form at baseline assessment. We measured monthly incident disability, defined as the onset of being certified for personal support or care as required by Japanese public long-term care insurance over 5 years. The Cox proportional hazard regression analysis estimated hazard ratios (HRs) and 95% confidence intervals (CIs) for incident disability according to long sleep duration (≥ 9 h) and physical inactivity.

Results

Long sleep duration (HR 1.32, CI 95% 1.05–1.67) and physical inactivity (HR 1.33, CI 95% 1.13–1.57) were associated with incident disability in multivariate analyses. These results were also sustained in the model where both long sleep duration and physical inactivity were simultaneously submitted as independent variables. Furthermore, coexistence of long sleep duration and physical inactivity had higher risk of incident disability than each factor individually (HR 1.69, CI 95% 1.11–2.58), even though the synergistic interaction was mildly effective.

Conclusions

This study revealed that long sleep duration and physical inactivity were independently associated with the risk of incident disability among older adults. More attention should be paid to both sleep duration and physical activity in order to prevent incident disability.

Introduction

Disability in older adults, which is a growing public health concern, is associated with poor physical and mental health, increasing use of medical care, and high rate of institutionalization.[1, 2] Identifying risk factors for incident disability is required to develop preventive strategies. Physical activity plays an important role in improving health outcomes, including risk of disability. A previous systematic review suggested that higher levels of physical activity were beneficial in preventing incident disability.[3]

Good sleep condition in late life is an essential factor for maintaining good health. Poor sleep condition is associated with various adverse health outcomes, including disability in older adults.[4] Previous studies have identified insulin resistance,[5] autonomic nervous system dysregulation,[5, 6] metabolic derangement[7] and inflammation[8] as potential mediators between sleep disturbances and incident disability. Among sleep conditions (e.g., short/long sleep duration, excessive daytime sleepiness and insomnia), there has been growing evidence that the association of long sleep duration with health problems, mortality[9–13] and poor self-reported health.[14] Moreover, our previous study, covering a period of two years, showed that long sleep duration was associated with incident disability.[15]

However, when considering the association between sleep duration and health problems, it was inevitable to consider the association between sleep duration and physical activity, since it has been suggested that these two factors are related to each other. Long sleep duration was associated with a sedentary lifestyle and low levels of daytime physical activity,[16–18] while moderate physical activity was shown to have a positive impact on sleep quality among older adults in a systematic review.[19] Our previous study that revealed a longitudinal association of long sleep duration with incident disability was completed with only physical activity as a covariate.[15] Thus, in order to elucidate the association between long sleep duration and incident disability, an analysis that takes into account sleep duration and physical activity patterns should be conducted.

The primary aim of this study is thus to examine whether long sleep duration and physical inactivity were associated with incident disability among community-dwelling older adults. Second, we hypothesized that those who have both long sleep durations and physical inactivity show more risk of incident disability than those with either long sleep duration or physical inactivity only. In this study, an additive interaction between long sleep duration and low physical activity on incident disability was also examined.

Methods

Setting and participants

We assessed 5,257 individuals who were enrolled in part of the National Center for Geriatrics and Gerontology – Study of Geriatric Syndromes (NCGG-SGS) [20]. Inclusion criteria required that the participants were aged 70 years or older, lived in Nagoya City (from July 2013 to December 2013) at the time of examination. Four hundred participants were excluded from this study, based on the following criteria: 1) history of stroke, Parkinson's disease or Alzheimer's disease (n=360); 2) already certified by long-term care insurance (LTCI) at any level during the assessment (n=17); 3) inability to perform basic daily living tasks such as eating, grooming, bathing and using stairs (n=6); 4) severe cognitive impairment [Mini-Mental State Examination (MMSE)[21] < 20 (n=146)]; 5) a missing value in our assessment (n=168). Moreover, those who moved elsewhere (n=35) or died (n=123) during the follow-up period were also excluded. The final sample consisted of 4,372 people (mean age 75.9±4.2 years, 2,343

women). Informed consent was obtained from all participants before their inclusion in the study, and the Ethics Committee of the National Center for Gerontology and Geriatrics approved the study protocol.

Measures

Certification of need for care in the LTCI system

The nationally uniform criteria for long-term care need certification were objectively established by the Japanese government, and certification of need with respect to levels of care for older adults is determined based on evaluation results by the Certification Committee for Long-Term Care Need in municipalities in accordance with these basic guidelines. Participants were followed monthly for incident certification of care needs according to the LTCI system during the 5 years after the baseline assessment. We defined incident disability as the point at which a participant was certified as needing care or support according to LTCI classification. The computer-aided standardized needs-assessment system used by the mandatory social LTCI system categorizes people into 7 levels of needs. [22]

Sleep duration and physical activity

Sleep duration and physical activity were assessed by self-reporting. We asked participants about their usual sleep and wake times, and the difference between them were calculated as their sleep duration. According to their self-reported sleep duration, the participants with sleep duration of ≥ 9 h were assigned to long sleep duration [15].

Physical activity was measured using the International Physical Activity Questionnaire – Short Form (IPAQ-SF).[23] The IPAQ-SF assesses usual 7 days' physical activity for each item (i.e., walking, moderate physical activity and vigorous physical activity) to estimate the time spent engaged in 10 or more minutes of physical activity per usual week. Participants were required to report the frequency and duration of their engagement in each item of physical activity. According to the official IPAQ guidelines, walking, moderate physical activity and vigorous physical activity were respectively assigned an intensity of 3.3, 4.0, and 8.0 METs, and total weekly physical activity (MET-min week⁻¹) was calculated by adding the products of reported time for each item by a MET value that was specific to each category of physical activity. Both the total volume and the number of day/sessions are included in the IPAQ analysis algorithms. Participants were identified by three levels of physical activity – low, moderate and high – referring to the official IPAQ guidelines[24] and were divided into two groups in this study: inactive (low) or active (moderate or high) groups.

Sociodemographic variables and covariates

Data on sociodemographic variables including sex, age and educational level (years) were collected, along with medical history, weight (kg) and height (m). Body mass index (BMI) was derived as weight in kilograms divided by the square of height in meters. Participants were asked about medical diagnoses (heart disease, diabetes, respiratory disease, hypertension and hyperlipidemia) and medications in face-to-face interviews. Depressive symptoms were measured using the Geriatric Depression Scale (range 0–

15),[25] with higher scores indicating more depressive symptoms. MMSE was used as a screening tool for global cognitive function (range 0–30, with higher scores indicating better functioning).[21] For smoking and alcohol drinking status, participants were categorized as current, past, or never smokers or alcohol drinkers, respectively.

Statistical analysis

All analyses were performed using SPSS 25.0 for Windows (SPSS Japan Inc., Tokyo, Japan) and statistical significance was set at $p < 0.05$. The characteristics are summarized as mean $\pm$ standard deviation (SD) for continuous variables and as count and percentage for categorical variables. Comparisons between independent and incident disability groups were performed using *t*-test and Pearson's chi-squared test for categorical data. Univariate and multivariate Cox proportional hazard regression analyses were conducted to assess hazard ratios (HR) with 95% confidence intervals (CI) of long sleep duration and low physical activity for the risk of incident disability. In multivariate analysis, potential confounders included age, sex, BMI, education level, number of medications, MMSE score, medical history, depressive symptoms, smoking habits and alcohol consumption. Sleep duration and physical activity were individually (Model 1 and Model 2) and simultaneously (Model 3) submitted as independent variables.

Furthermore, the participants were also classified according to the combination of sleep duration and physical activity, as follows: 1) not long sleep duration & active (Not long & Active); 2) not long sleep duration & inactive (Not long & Inactive); 3) long sleep duration & active (Long & Active); 4) long sleep duration & inactive (Long & Inactive). Kaplan–Meier survival analysis for the incident disability was performed to compare 4 groups. Univariate and multivariate Cox proportional hazard regression analyses were also conducted with the same covariates. In addition, to assess an additive interaction between long sleep duration and low physical activity, we estimated the relative excess risk due to interaction (RERI) using the method described by Rothman.[26, 27] RERI between two factors (A and B) is defined as 'departure from additive effects' and is calculated as follows using adjusted HRs:[28]

$$\text{RERI} = \text{HR}(\text{A\&B}) - \text{HR}(\text{A}) - \text{HR}(\text{B}) + 1$$

$\text{RERI} < 0$, $\text{RERI} = 0$ and $\text{RERI} > 0$ indicate antagonistic interaction, absence of interaction and synergistic interaction, respectively.

Results

Of the 4,372 participants initially included, 878 participants (20.1%) developed a disability during the 5-year follow-up period. The differences in characteristics between independent and incident disability groups in the first wave are summarized in Table 1. The number of participants with long sleep duration was 267 (6.1%) and that of participants with low physical activity was 713 (16.3%).

In the crude model, Cox proportional hazard regression showed that the long sleep duration (HR: 1.72, CI 95%: 1.37–2.16) and low physical activity (HR: 1.60, CI 95%: 1.37–1.88) had a higher rate of incident

disability. These results were also sustained in multivariate analyses adjusted for covariates (Table 2, Model 1 and Model 2). Furthermore, both long sleep duration and physical inactivity were included in the multivariate Cox proportional hazard regression analysis as explanatory variables using the forced entry method adjusted for the other covariates. The results showed that long sleep duration and physical inactivity independently had an impact on incident disability (Table 2, Model 3).

Kaplan–Meier survival curves showed the highest rate of incident disability in the long sleep duration & low physical activity group (Fig. 1, $p < 0.001$). Compared with the Not long & Active group, other groups showed a significantly higher rate of incident disability ($p < 0.01$ for all). Long & Inactive showed a significantly higher rate of incident disability than Not long & Inactive ($p = 0.007$) and Long & Active ($p = 0.029$). There was no significant difference in the rate of incident disability between Not long & Inactive and Long & Active ($p = 0.690$).

In the Cox proportional hazard regression analysis, a crude model indicated that Not long & Inactive (HR: 1.58, CI 95%: 1.33–1.86), Long & Active (HR: 1.66, CI 95%: 1.27–2.17) and Long & Inactive (HR: 2.82, CI 95%: 1.86–4.28) had significant association with incident disability, compared with the Not long & Active group. Multivariate analysis adjusted for covariates showed similar association (Fig. 2). The RERI was 0.04 between long sleep duration and low physical activity with respect to incident disability, indicating a slight synergistic interaction.

Discussion

Our study revealed that long sleep duration and physical inactivity were independently associated with the risk of incident disability among older adults. These results were sustained after adjusted for age, sex, BMI, education, medication, medical history, current drinking habit, current smoking habit, GDS score and MMSE score. Coexistence of long sleep duration and physical inactivity had a higher risk of incident disability than each factor individually, even though the synergistic interaction was mildly effective.

In this study, long sleep duration was shown to be associated with incident disability during a 5-year follow-up period. This result is consistent with our previous study conducted among other participants during a 2-year follow-up period.[15] Other previous cross-sectional studies showed that long sleep duration was also associated with other health adverse outcomes, such as physical frailty[29] and social frailty.[30] Additionally, long sleep duration was a risk factor for cognitive decline after 4 years among older adults.[31] These functional declines are included in geriatric syndromes and are serious risk factors for incident disability.[32–34] Although our study could not examine the cause of incident disability in detail, these functional declines would be mediated by the association between long sleep duration and incident disability. Furthermore, long sleepers were also found to have an increased wake after sleep onset (WASO) frequency and lower sleep efficiency.[35] Longitudinal study revealed that sleep complaints and lower sleep efficiency were associated with incident ADL disability among older adults.[4] [36] Therefore, the poor sleep quality would also be an underlying factor behind the association between long sleep duration and incident disability.

Physical inactivity was also independently associated with incident disability in this study. In older adults, physical activity contributes to the prevention of disability caused by chronic diseases or functional decline.[37–39] Physical inactivity was associated with incident disability over a 9-year period among older adults.[40] Our result was in line with these previous studies. IPAQ-SF, which was used to assess physical activity in our study and allows us to assess physical activity and classify it according to three levels, can be easily used in clinical or research settings with lower respondent burden. Previous studies reported that physical activity assessed by IPAQ-SF has a cross-sectional association with health-related outcomes including quality of life, metabolic syndrome, sarcopenia and mental health.[41–44] These studies would support the association between IPAQ-assessed physical inactivity and incident disability.

Coexistence of long sleep duration and physical inactivity showed a higher hazard ratio of incident disability than each factor individually. However, RERI between long sleep duration and low physical activity with respect to incident disability was small, indicating that the synergistic interaction was mildly effective. The effects of long sleep duration and physical inactivity on incident disability would be not synergistic but independent, although several studies have observed that long sleep duration is associated with a sedentary lifestyle and low levels of daytime physical activity.[16–18] Further studies would be needed to examine the association of all-day activity, including daytime sleep or other activities, with incident disability.

A major strength of this study was its use of a prospective cohort design, which can address the causality between sleep duration and incident disability among older adults using large cohort data. However, this study had several limitations. First, self-reported measures of sleep duration were utilized, rendering the study incapable of performing a truly objective assessment of sleep characteristics, such as an assessment performed using actigraphy. Previous research suggested that self-reported long sleepers, [45] as well as average sleepers,[46] tend to overestimate their total sleep time, instead considering their entire time in bed. Similarly, self-reports of physical activity are likely to overestimate time spent in all intensities of physical activity.[47] Further studies that assess sleep duration and physical activity objectively using devices might show different results from ours, as we used self-report questionnaires to assess sleep duration and physical activity. Second, there were other potential confounders that we could not assess, such as drug therapy. Third, medical diagnoses were obtained by self-report, not by consulting medical records. Furthermore, given the absence of random sampling methods, our participants were exclusively those who had the ability to receive health checkups from their homes. Therefore, our results may not be directly applicable to all older adults in Japan, which is one of the limitations of this study.

Conclusion

We revealed that long sleep duration and physical inactivity were independently associated with the risk of incident disability among older adults from longitudinal cohort data during a 5-year follow-up period. These results suggest that more attention should be paid to both sleep duration and physical activity in order to prevent incident disability among older adults. Further research is needed to examine the

association of long sleep duration and physical inactivity with incident disability using objective assessment methods.

Declarations

Ethics approval and consent to participate

Informed consent was obtained from all participants before their inclusion in the study. The Ethics Committee of the National Center for Gerontology and Geriatrics approved the study protocol and all methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable.

Availability of data and materials

All data generated or analysed during this study are included in this published article.

Competing interests

The authors declare no competing conflicts of interest.

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Authors' contributions

SN designed and supervised all aspects of the study implementation and drafted the manuscript. TD and HS contributed to the conception and design of the study and provided feedback on the study implementation. KT contributed to the design of the study, and subject recruitment and screening. SK, IH, YK contributed to subject recruitment and screening. All authors participated in drafting the manuscript and revising it critically for important intellectual content. All authors have read and approved the manuscript.

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Tables

Table 1. Characteristics of participants.

	Overall			Independent			Incident Disability			<i>p</i>
	(n=4,372)			(n=3,494)			(n=878)			
Age (year)	75.85	±	4.23	75.11	±	3.72	78.80	±	4.81	< 0.001
Women	2,343		(53.6)	1,826		(52.3)	517		(58.9)	< 0.001
Education level (year)	12.02	±	2.59	12.13	±	2.58	11.57	±	2.59	< 0.001
Medications (number)	3.35	±	2.83	3.09	±	2.65	4.38	±	3.27	< 0.001
Body mass index (kg/m ²)	22.92	±	3.00	22.95	±	2.93	22.81	±	3.24	0.200
Mini Mental State Examination (points)	26.15	±	2.32	26.28	±	2.28	25.61	±	2.39	< 0.001
Geriatric depression scale (points)	2.84	±	2.69	2.66	±	2.58	3.57	±	2.99	< 0.001
Current alcohol consumption										< 0.001
Never	2,153		(49.2)	1,680		(48.1)	473		(53.9)	
Past	383		(8.8)	286		(8.2)	97		(11.0)	
Current	1,836		(42.0)	1,528		(43.7)	308		(35.1)	
Current smoking habit										0.038
Never	2,765		(63.2)	2,181		(62.4)	584		(66.5)	
Past	1,349		(30.9)	1,095		(31.3)	254		(28.9)	
Current	258		(5.9)	218		(6.2)	40		(4.6)	
Disease (yes)										
Hypertension	2,091		(47.8)	1,611		(46.1)	480		(54.7)	< 0.001
Diabetes	553		(12.6)	420		(12.0)	133		(15.1)	0.015
Hyperlipidemia	1,791		(41.0)	1,459		(41.8)	332		(37.8)	0.035
Respiratory disease	770		(17.6)	585		(16.7)	185		(21.1)	0.003
Long sleep duration	267		(6.1)	185		(5.3)	82		(9.3)	< 0.001
Physical inactivity	713		(16.3)	515		(14.7)	198		(22.6)	< 0.001

Values are presented as n (%), mean ± SD. Continuous variables were analyzed by *t*-test, and categorical variables were analyzed by χ^2 tests.

Table 2. Hazard ratios for incident disability during 5 years according to long sleep duration and physical inactivity.

	Model 1			Model 2			Model 3		
	HR (95% CI)		<i>p</i>	HR (95% CI)		<i>p</i>	HR (95% CI)		<i>p</i>
Long sleep duration	1.32	(1.05–1.67)	0.019				1.31	(1.03–1.65)	0.026
Physical inactivity				1.33	(1.13–1.57)	< 0.001	1.32	(1.13–1.56)	< 0.001

HR: hazard ratio, CI: confidence interval. All models were adjusted for age, sex, BMI, education, medication, GDS score and MMSE score, medical history, current drinking habit, current smoking habit.

Model 1 and Model 2: Long sleep duration and physical inactivity were individually submitted as independent variables.

Model 3: Long sleep duration and physical inactivity were simultaneously submitted as independent variables.

Figures

Figure 1

Kaplan–Meier survival curves of older adults showing the relationship of sleep duration and physical activity with incident disability during a 5-year follow up period.

Sleep duration & physical activity

Figure 2

Multivariate Cox proportional hazard regression analysis adjusted for age, sex, BMI, education, medication, medical history, current drinking habit, current smoking habit, and GDS and MMSE scores.