Prospective Study of Physical Activity and Sleep in Middle-Aged and Older Adults

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Introduction: Few prospective cohort studies have examined the association between physical activity (PA) and insomnia prevention, and the effective PA intensity remains unclear. This prospective study explores how PA intensity prevents incident short sleep duration and subjective insufficient sleep in middle-aged and older adults.

Methods: A self-reported questionnaire gathered data on sleep and PA variables, including moderate low-intensity PA (MLPA); moderate high-intensity PA (MHPA); and vigorous-intensity PA (VPA), during health checkups conducted in Meiji Yasuda Shinjuku Medical Center in Tokyo. This study followed two cohorts from a 2008 baseline survey: (1) participants free of short sleep duration (n=7,061) and (2) participants free of insufficient sleep (n=7,385). They were divided into middle-aged (<60 years; 45.7 [8.8] years for sleep duration and 45.5 [8.8] years for sleep sufficiency) and older adults (both groups aged 65.3 [4.7] years) and followed for a mean 3.4 years until 2013. Data were analyzed in 2014.

Results: Engaging in MHPA (hazard ratio [HR]=0.81, 95% CI=0.67, 0.98) and VPA (HR=0.83, 95% CI=0.71, 0.97) had a significant preventive effect on incident subjective insufficient sleep among middle-aged adults. For older adults, only MLPA (HR=0.58, 95% CI=0.42, 0.81) had a significant preventive effect on incident insufficient sleep, and PA did not significantly affect incident short sleep duration.

Conclusions: Middle-aged adults engaging in MHPA and VPA and older adults engaging in MLPA can effectively maintain sleep sufficiency. When providing an effective PA program to prevent insomnia, the intensity of PA should correspond to the participant's age.
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Introduction

Some cohort studies have reported that approximately 20%–30% of Japanese people suffer from insomnia.[1,2] Insomnia is a known risk factor for obesity-related diseases,[3–5] depression,[6,7] and mortality[8,9]; it can also cause socioeconomic damage by decreasing daytime productivity.[10,11] A recent study estimated the economic damage caused by sleep problems to reach 3.5 trillion yen per year in Japan.[11] Preventing sleep problems is an important issue for the health of both individuals and the socioeconomy.

Intervention studies[12–16] have shown that physical activity (PA) can lead to better sleep by decreasing mental stress, increasing physical fatigue, downregulating body temperature, and regulating circadian rhythm.[17,18] An intervention study is the best method for examining causal relationships and mechanisms, but it is often limited by small sample sizes and difficulty in confirming its long-term effects. Epidemiologic findings based on large prospective cohort studies are also important for building sound evidence. However, most of the available information on PA and sleep patterns is based on cross-sectional studies, and the evidence that can be gathered in longitudinal studies remains wanting.[17,19]

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Evidence is lacking on the intensity levels of PA that effectively improve sleep. Intervention studies have reported significant improvement in sleep by using both lower[12,13] and higher intensities of PA,[14,16] but the most effective PA intensity is uncertain. Physical fitness typically decreases with age,[20,21] and the effective PA intensity for prevention of insomnia may differ by age. Additionally, the reason why adults suffer from sleep problems can change with age. Work may affect younger adults' sleep,[22,23] whereas the circadian phase shift is a major cause of insomnia in older adults.[24] Therefore, the association between PA intensity and sleep can change with age, and revealing these age differences would be helpful for developing strategies to prevent insomnia. The purpose of this study is to reveal effective levels of PA intensity that prevent short sleep duration and subjective insufficient sleep in both middle-aged and older adults.

Methods

Study Population

Data were gathered at health checkups conducted in Meiji Yasuda Shinjuku Medical Center in Shinjuku Ward, Tokyo, Japan. The majority of patients were employees and their spouses, with employers providing financial support for the annual health checkups. Figure 1 shows the flow of participants through the study. This study used health checkup data from 16,267 examinees in 2008 as baseline data. Of these examinees, 3,148 were excluded owing to incomplete data. Because mental disease is a strong risk factor for insomnia,[25] 263 individuals with a diagnosed history of mental disease including depression were excluded.

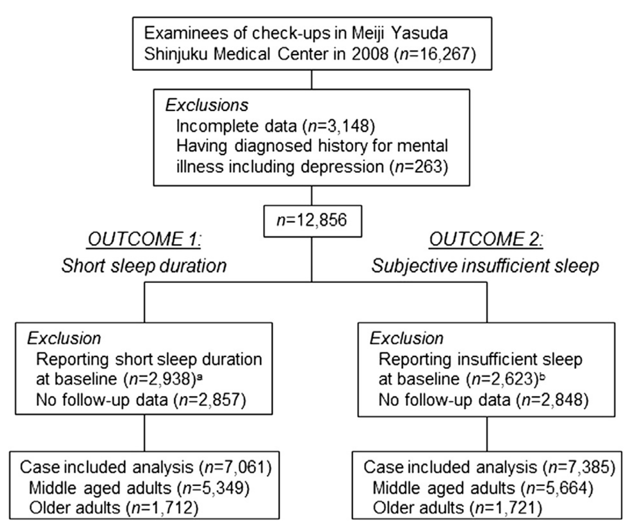

Figure 1. Flow of participants through the study.
[a]When looking at age stage, 2,691 of 10,397 middle-aged adults (25.9%) and 247 of 2,459 older adults (10.0%) reported short sleep duration at baseline.
[b]For sleep sufficiency, 2,376 of 10,397 middle-aged adults (22.9%) and 247 of 2,459 older adults (10.0%) reported insufficient sleep at baseline.

Because this study targeted two outcomes (short sleep duration and subjective insufficient sleep), we prepared two cohort models with participants that were free of the targeted outcome at baseline. In the cohort focused on short sleep duration, 2,938 individuals were excluded because of the prevalence of short sleep duration at baseline. Similarly, 2,623 individuals in the cohort looking at insufficient sleep were excluded owing to its prevalence at baseline. Furthermore, 2,857 individuals in the cohort for short sleep duration and 2,848 individuals in the cohort for insufficient sleep were excluded because they could not be followed for at least 1 year. Finally, there were 7,061 and 7,385 participants available for the short sleep duration and insufficient sleep cohorts, respectively. These participants were followed through their annual health checkups until they reported short sleep duration or insufficient sleep or until the end of 2013. When a participant did not attend an annual checkup, all available follow-up data were used. All participants provided informed consent. The Ethical Committee of Meiji Yasuda Life Foundation of Health and Welfare approved this study.

Measures

Quantitative and subjective assessments of sleep, sleep duration, and subjective sleep sufficiency were assessed via a self-administered questionnaire. For sleep duration, people reported their major patterns of sleep duration (hours per day) accurate to one decimal place. Sleep duration was considered short if it was less than 6.0 hours, and this sleep duration is a known risk factor of obesity-related diseases[5] and mortality.[8,9] Although long sleep duration, such as more than 9.0 hours, is also a known risk factor of heart disease[26] and mortality,[8,9] there were very few long-duration sleepers in the study at baseline (0.3% of middle-aged adults and 2.1% of older adults slept 9.0 hours or more). Therefore, this study focused only on short sleep duration.

To identify sleep sufficiency, a national standard question for Japanese health checkups was used.[27] Participants responded *yes* or *no* to the statement: *Do you sleep well and get a sufficient amount of rest?* For this study, a *no* response indicated insufficient sleep. Sleep sufficiency was validated through the 2013 survey data (Appendix Table 1). Four validation items (sleep latency, total time in bed, sleep duration, and sleep efficiency) were extracted from the Pittsburgh sleep quality index.[28] People who reported insufficient sleep were significantly more likely to have longer sleep latency (Cohen's d[29] in middle-aged adults, 0.34; d in older adults, 0.42); shorter total time in bed (d in middle-aged adults, 0.59; d in older adults, 0.67); shorter sleep duration (d in middle-aged adults, 0.81; d in older adults, 1.04); and lower sleep efficiency (d in middle-aged adults, 0.42; d in older adults, 0.61) than those reporting sufficient sleep.

A questionnaire assessed PA in daily life including leisure-time, household, and occupational PA by weekly frequency (never, less than once a week, once a week, twice a week, and three or more times a week); duration ($<$10 minutes/session, 10–19 minutes/session, 20–29 minutes/session, and $\geq$30 minutes/session); and intensity (moderate low-intensity PA [MLPA], moderate high-intensity PA [MHPA], and vigorous-intensity PA [VPA]). MLPA includes activities such as walking, gymnastics, golf, table tennis, house cleaning, and carrying light loads. MHPA includes baseball,

Table 1. Baseline Characteristics by Physical Activity Level in Analysis for Short Sleep Duration

	Middle-aged adults (n=5,349, mean age=45.7±8.8 years, male=51.2%)									Older adults (n=1,712, mean age=65.3±4.7 years, male=63.8%)								
	MLPA			MHPA			VPA			MLPA			MHPA			VPA		
Baseline variables	**<1-x/w**	**≥1-x/w**	***p*-value**	**<1-x/w**	**≥1-x/w**	***p*-value**	**<1-x/w**	**≥1-x/w**	***p*-value**	**<1-x/w**	**≥1-x/w**	***p*-value**	**<1-x/w**	**≥1-x/w**	***p*-value**	**<1-x/w**	**≥1-x/w**	***p*-value**
Number	2,972	2,377		4,800	549		4,541	808		645	1,067		1,477	235		1,424	288	
Mean (SD) age (years)	44.7 (8.9)	46.8 (8.5)	<**0.001**	45.6 (8.8)	46.4 (8.7)	**0.041**	45.7 (8.8)	45.6 (8.8)	0.934	64.7 (4.5)	65.7 (4.7)	<**0.001**	65.3 (4.7)	65.8 (4.8)	0.079	65.4 (4.7)	65.2 (4.4)	0.693
Male gender	56.2	45.1	<**0.001**	51.9	45.2	**0.003**	49.8	59.3	<**0.001**	60.6	65.8	**0.031**	64.0	62.6	0.658	63.2	67.0	0.219
Mean (SD) BMI (kg/m^2)	22.3 (3.2)	22.3 (3.3)	0.609	22.3 (3.2)	22.1 (2.9)	0.192	22.3 (3.3)	22.1 (2.7)	0.059	22.9 (2.9)	22.5 (2.6)	**0.013**	22.6 (2.7)	22.7 (2.6)	0.788	22.7 (2.8)	22.5 (2.3)	0.415
Smoking status			<**0.001**			**0.040**			<**0.001**			<**0.001**			0.143			0.220
Never	50.3	58.3		53.4	57.7		54.1	52.7		52.7	49.4		50.1	54.0		50.3	52.4	
Former	23.0	22.9		22.9	23.3		21.6	30.6		30.5	40.1		36.4	37.0		36.2	37.8	
Current	26.6	18.8		23.6	18.9		24.3	16.7		16.7	10.5		13.5	8.9		13.5	9.7	
Alcohol consump-tion (g/day)			<**0.001**			0.743			<**0.001**			0.271			**0.011**			0.198
Never	11.8	15.1		13.4	12.2		13.9	9.5		19.7	19.7		20.2	16.6		20.4	16.3	
<20	60.7	61.0		60.7	61.4		60.9	60.3		52.1	55.5		55.0	49.4		54.1	54.5	
≥20	27.6	23.9		25.9	26.4		25.2	30.2		28.2	24.8		24.8	34.0		25.5	29.2	
Milk products intake			<**0.001**			<**0.001**			<**0.001**			0.300			0.190			**0.003**
Never or seldom	38.8	28.9		35.2	27.3		35.6	27.7		28.2	24.8		26.7	22.6		27.7	18.4	
Once every 2 days	13.5	13.6		13.7	12.2		13.2	15.2		10.5	10.8		11.0	8.9		10.8	10.1	

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Table 1. Baseline Characteristics by Physical Activity Level in Analysis for Short Sleep Duration *(continued)*

	Middle-aged adults (n=5,349, mean age=45.7±8.8 years, male=51.2%)									**Older adults (n=1,712, mean age=65.3±4.7 years, male=63.8%)**								
	MLPA			**MHPA**			**VPA**			**MLPA**			**MHPA**			**VPA**		
Baseline variables	**<1-x/w**	**≥1-x/w**	***p*-value**	**<1-x/w**	**≥1-x/w**	***p*-value**	**<1-x/w**	**≥1-x/w**	***p*-value**	**<1-x/w**	**≥1-x/w**	***p*-value**	**<1-x/w**	**≥1-x/w**	***p*-value**	**<1-x/w**	**≥1-x/w**	***p*-value**
One or more times per day	47.7	57.4		51.1	60.5		51.2	57.1		61.2	64.4		62.4	68.5		61.5	71.5	
Coffee intake			0.917			0.555			0.133			0.171			0.538			0.464
Never or seldom	19.8	20.1		20.1	18.2		20.4	17.3		26.4	28.8		27.5	30.2		28.2	26.0	
Moderate	23.8	24.0		23.8	24.8		23.8	24.6		26.8	29.1		28.6	25.5		28.5	26.7	
Often or very often	56.4	55.9		56.1	57.0		55.8	58.0		46.8	42.2		43.9	44.3		43.3	47.2	
Days off a week			**<0.001**			**<0.001**			0.977			**<0.001**			**0.017**			0.080
≤1	7.9	7.2		7.8	6.0		7.5	7.8		7.9	4.0		5.1	8.1		5.7	4.5	
2	82.8	75.9		79.9	77.6		79.8	79.3		48.7	35.9		42.0	32.3		40.7	40.6	
3–6	3.4	6.9		4.6	8.6		4.9	5.3		14.0	19.4		16.7	21.7		16.6	20.8	
7	0.7	2.2		1.3	1.8		1.4	1.2		11.8	17.9		15.2	17.9		15.1	18.1	
Not reported	5.2	7.9		6.4	6.0		6.4	6.3		17.7	22.8		21.0	20.0		21.8	16.0	
Mean (SD) sleep duration (h/d)[a]	6.5 (0.6)	6.5 (0.6)	0.055	6.5 (0.6)	6.5 (0.6)	0.721	6.5 (0.6)	6.5 (0.6)	0.308	6.8 (0.8)	6.9 (0.7)	**<0.001**	6.9 (0.7)	7.0 (0.8)	**0.032**	6.9 (0.7)	6.9 (0.7)	0.637
Subjective insufficient sleep	16.6	14.0	**0.009**	15.9	11.1	**0.003**	16.3	10.5	**<0.001**	8.7	5.9	**0.029**	6.8	8.1	0.462	7.3	5.2	0.202

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Table 1. Baseline Characteristics by Physical Activity Level in Analysis for Short Sleep Duration (*continued*)

Baseline variables	Middle-aged adults (n=5,349, mean age=45.7±8.8 years, male=51.2%)									Older adults (n=1,712, mean age=65.3±4.7 years, male=63.8%)								
	MLPA			MHPA			VPA			MLPA			MHPA			VPA		
	<1-x/w	≥1-x/w	*p*-value	<1-x/w	≥1-x/w	*p*-value	<1-x/w	≥1-x/w	*p*-value	<1-x/w	≥1-x/w	*p*-value	<1-x/w	≥1-x/w	*p*-value	<1-x/w	≥1-x/w	*p*-value
MLPA (≥1x/w)	–	–	–	45.4	35.9	**<0.001**	46.8	31.4	**<0.001**	–	–	–	65.8	40.4	**<0.001**	66.0	44.1	**<0.001**
MHPA (≥1x/w)	11.8	8.3	**<0.001**	–	–	–	9.5	14.5	**<0.001**	21.7	8.9	**<0.001**	–	–	–	12.7	18.8	**0.007**
VPA (≥1x/w)	18.6	10.7	**<0.001**	14.4	21.3	**<0.001**	–	–	–	25.0	11.9	**<0.001**	15.8	23.0	**0.007**	–	–	–

Note: Boldface indicates statistical significance ($p<0.05$). Values are percentages unless stated otherwise.
[a]People who reported short sleep duration (≤5.9 hours/day) were excluded.
MLPA, moderate low-intensity physical activity; MHPA, moderate high-intensity physical activity; VPA, vigorous-intensity physical activity.

basketball, hiking, light carpentry work, light farming, and carrying moderate loads. VPA includes jogging, bicycling, tennis, swimming, mountaineering, carpentry work, farming, and carrying heavy loads. MLPA corresponds to approximately 3–5 METs, MHPA corresponds to 5–7 METs, and VPA corresponds to ≥7 METs.[30]

Because 10 minutes is considered the minimum duration for a single-event activity,[31] a single session of PA was determined to be ≥10 minutes. To obtain adequate statistical power, MLPA, MHPA, and VPA were, respectively, categorized into dichotomous variables of "less than once a week" and "once a week or more."

Demographic variables included age; gender; BMI; alcohol consumption (never, <20.0 grams/day, and ≥20.0 grams/day of alcohol); smoking status (never, former, and current); milk product consumption (never or seldom, once every two days, and one or more times per day); coffee intake (never or seldom, moderate, and often or very often); and days off from work per week (≤1 day/week, 2 days/week, 3–6 days/week, 7 days/week, and not reported). All demographic variables except BMI were assessed through a self-administered questionnaire. The question of days off was frequently left blank, especially in women and older adults, even when they answered every other question; these participants may not have been employed. To maintain a sample balance, when participants answered all the other questions except the one about days off, their days off were coded as "not reported."

Statistical Analysis

Participants were grouped into middle-aged adults (<60 years) and older adults (≥60 years), and all analyses were conducted with these groups. To compare baseline characteristics with engagement in PA, chi-square tests for categorical variables and Student's *t* test for continuous variables were used. Cox proportional-hazards analysis was performed to examine the preventive effect of PA on the development of short sleep duration and insufficient sleep. Two multivariable-adjusted models were set in this study: covariates of Model 1 included age, gender, BMI, alcohol consumption, smoking status, milk product consumption, coffee intake, and number of days off from work. Additionally, sleep duration in the outcome for insufficient sleep and sleep sufficiency in the outcome for short sleep duration, respectively, were adjusted. In Model 2, all three PA intensity variables were entered simultaneously into Model 1 to adjust for their effects on each other as covariates. The level of significance for all analyses was set at $p<0.05$. Statistical analyses were performed in 2014 using SPSS, version 21.0.

Results

Tables 1 and 2 show characteristics of participants in the two cohorts. In both middle-aged and older adults, participants who engaged in MLPA were less likely to engage in MHPA and VPA, whereas participants who engaged in MHPA were more likely to also engage in VPA.

During a mean follow-up period of 3.4 years, 1,245 of 5,349 (23.3%) middle-aged adults (17,968 person-years, 3.0 follow-up visits per person) newly reported short

Table 2. Baseline Characteristics by Physical Activity Level in Analysis for Subjective Insufficient Sleep

Baseline variables	Middle-aged adults (n=5,664, mean age=45.5±8.8 years, male=52.7%)									Older adults (n=1,721, mean age=65.3±4.7 years, male=63.5%)								
	MLPA			MHPA			VPA			MLPA			MHPA			VPA		
	<1-x/w	**≥1-x/w**	***p*-value**	**<1-x/w**	**≥1-x/w**	***p*-value**	**<1-x/w**	**≥1-x/w**	***p*-value**	**<1-x/w**	**≥1-x/w**	***p*-value**	**<1-x/w**	**≥1-x/w**	***p*-value**	**<1-x/w**	**≥1-x/w**	***p*-value**
Number	3,137	2,527		5,075	589		4,756	908		646	1,075		1,494	227		1,437	284	
Mean (SD) age (years)	44.6 (8.8)	46.6 (8.5)	<**0.001**	45.4 (8.8)	46.2 (8.6)	**0.032**	45.5 (8.8)	45.5 (8.7)	0.907	64.7 (4.6)	65.7 (4.7)	<**0.001**	65.3 (4.7)	65.9 (4.8)	**0.045**	65.4 (4.8)	65.3 (4.5)	0.848
Male Gender	57.3	47.0	<**0.001**	53.8	43.0	<**0.001**	51.4	59.4	<**0.001**	60.5	65.3	**0.046**	63.7	62.6	0.748	62.9	66.5	0.244
Mean (SD) BMI (kg/m^2)	22.5 (3.3)	22.4 (3.3)	0.166	22.5 (3.4)	22.0 (2.8)	**0.002**	22.5 (3.4)	22.3 (2.8)	0.168	22.9 (2.9)	22.6 (2.7)	**0.033**	22.7 (2.8)	22.8 (2.6)	0.459	22.7 (2.8)	22.6 (2.4)	0.338
Smoking status			<**0.001**			**0.007**			<**0.001**			<**0.001**			0.111			0.278
Never	50.8	57.3		53.1	58.7		53.7	53.6		51.7	50.1		50.2	54.2		50.5	52.1	
Former	22.6	23.1		22.9	22.8		21.6	29.6		30.0	39.8		36.0	37.0		35.8	37.7	
Current	26.6	19.6		24.0	18.5		24.7	16.7		18.3	10.0		13.8	8.8		13.7	10.2	
Alcohol consumption (g/day)			**0.001**			0.962			**0.002**			0.303			**0.030**			0.097
Never	11.8	14.3		13.0	12.6		13.5	9.8		19.2	20.0		20.1	17.2		20.4	16.2	
<20	60.9	61.8		61.3	61.6		61.3	61.2		52.8	55.3		55.1	49.8		54.6	53.5	
≥20	27.3	23.9		25.8	25.8		25.1	29.0		28.0	24.7		24.8	33.0		25.1	30.3	
Milk products intake			<**0.001**			<**0.001**			<**0.001**			0.225			0.169			**0.001**
Never or seldom	38.4	29.1		35.1	27.3		35.6	27.1		28.0	24.8		26.6	22.0		27.6	18.3	
Once every two days	13.2	14.1		13.9	11.5		13.3	15.4		11.9	11.0		11.6	9.7		11.6	9.9	

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Table 2. Baseline Characteristics by Physical Activity Level in Analysis for Subjective Insufficient Sleep *(continued)*

Baseline variables	Middle-aged adults (n=5,664, mean age=45.5±8.8 years, male=52.7%)									Older adults (n=1,721, mean age=65.3±4.7 years, male=63.5%)								
	MLPA			MHPA			VPA			MLPA			MHPA			VPA		
	<1-x/w	≥1-x/w	*p*-value	<1-x/w	≥1-x/w	*p*-value	<1-x/w	≥1-x/w	*p*-value	<1-x/w	≥1-x/w	*p*-value	<1-x/w	≥1-x/w	*p*-value	<1-x/w	≥1-x/w	*p*-value
One or more times per day	48.4	56.7		51.1	61.1		51.1	57.5		60.1	64.2		61.8	68.3		60.8	71.8	
Coffee intake			0.452			0.497			0.054			0.093			0.392			0.532
Never or seldom	18.9	19.7		19.4	18.3		19.8	16.4		25.5	28.0		26.7	29.5		27.3	25.7	
Moderate	23.6	24.3		23.7	25.8		23.8	24.2		26.9	29.9		29.3	25.1		29.1	27.1	
Often or very often	57.6	55.9		56.9	55.9		56.3	59.4		47.5	42.1		44.0	45.4		43.6	47.2	
Days off a week			<**0.001**			<**0.001**			0.670			<**0.001**			**0.027**			0.179
≤1	8.0	6.9		7.7	5.8		7.4	8.0		9.0	4.2		5.8	7.0		6.1	5.6	
2	83.1	76.6		80.5	77.6		80.4	79.1		46.9	36.1		41.5	31.3		40.4	39.1	
3–6	3.3	6.8		4.5	8.1		4.7	5.7		15.2	19.1		16.9	22.0		16.9	21.1	
7	0.8	2.2		1.4	1.9		1.4	1.3		11.8	17.9		15.0	19.4		15.2	17.6	
Not reported	4.7	7.6		6.0	6.6		6.1	5.8		17.2	22.8		20.7	20.3		21.5	16.5	
Mean (SD) sleep duration (h/d)	6.2 (0.8)	6.3 (0.8)	**0.015**	6.2 (0.8)	6.3 (0.8)	0.236	6.3 (0.8)	6.3 (0.8)	0.537	6.7 (0.9)	6.8 (0.9)	**0.001**	6.8 (0.9)	6.9 (0.9)	**0.004**	6.8 (0.9)	6.9 (0.8)	0.070
Subjective insufficient sleep[a]	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0	–

(continued on next page)

Table 2. Baseline Characteristics by Physical Activity Level in Analysis for Subjective Insufficient Sleep (*continued*)

Baseline variables	Middle-aged adults (n=5,664, mean age=45.5±8.8 years, male=52.7%)									Older adults (n=1,721, mean age=65.3±4.7 years, male=63.5%)								
	MLPA			MHPA			VPA			MLPA			MHPA			VPA		
	<1-x/w	≥1-x/w	*p*-value	<1-x/w	≥1-x/w	*p*-value	<1-x/w	≥1-x/w	*p*-value	<1-x/w	≥1-x/w	*p*-value	<1-x/w	≥1-x/w	*p*-value	<1-x/w	≥1-x/w	*p*-value
MLPA (≥1x/w)	–	–	–	45.5	37.0	**<0.001**	47.2	31.1	**<0.001**	–	–	–	65.7	41.4	**<0.001**	66.1	44.0	**<0.001**
MHPA (≥1x/w)	11.8	8.6	**<0.001**	–	–	–	9.8	13.8	**<0.001**	20.6	8.7	**<0.001**	–	–	–	12.2	18.0	**0.009**
VPA (≥1x/w)	20.0	11.2	**<0.001**	15.4	21.2	**<0.001**	–	–	–	24.6	11.6	**<0.001**	15.6	22.5	**0.009**	–	–	–

Note: Boldface indicates statistical significance ($p<0.05$). Values are percentages unless stated otherwise.
[a]People who reported insufficient sleep were excluded.
MLPA, moderate low-intensity physical activity; MHPA, moderate high-intensity physical activity; VPA: vigorous-intensity physical activity

sleep duration and 165 of 1,712 (9.6%) older adults (5,791 person-years, 3.1 follow-up visits per person) newly reported short sleep duration. Furthermore, during the same period, 1,300 of 5,664 (23.0%) middle-aged adults (19,208 person-years, 3.0 follow-up visits per person) newly reported insufficient sleep and 164 of 1,721 (9.5%) older adults (5,836 person-years, 3.1 follow-up visits per person) newly reported insufficient sleep.

In the final hazard models for incident short sleep duration (Table 3), middle-aged adults performing VPA (hazard ratio [HR]=0.85, 95% CI=0.72, 1.01, p=0.067) and older adults performing MLPA (HR=0.74, 95% CI=0.53, 1.02, p=0.067) were more likely to link with lower HRs; however, no PA intensities were significantly associated with incident short sleep duration. Incident insufficient sleep among middle-aged adults was significantly prevented by engaging in MHPA (HR=0.81, 95% CI=0.67, 0.98, p=0.034) and VPA (HR=0.83, 95% CI=0.71, 0.97, p=0.022) (Table 4). In older adults, although there were also decreasing HRs for MHPA (HR=0.70, 95% CI=0.41, 1.19, p=0.186) and VPA (HR=0.83, 95% CI=0.53, 1.30, p=0.411), the significant preventive effect on incident insufficient sleep was only confirmed with MLPA (HR=0.58, 95% CI=0.42, 0.81, p=0.001). Appendix Figures 1 and 2 present Kaplan–Meier curves for the final models.

Discussion

This study investigated whether MLPA, MHPA, and VPA could prevent incident short sleep duration and subjective insufficient sleep in both middle-aged and older adults. Although there were no significant associations between any type of PA and incident short sleep duration in either middle-aged or older adults, there was a clear age difference in the association between PA intensity and incident insufficient sleep: in middle-aged adults, higher intensities of PA more effectively prevented incident insufficient sleep, but in older adults, MLPA was more effective for preventing incident insufficient sleep. This study supports the few studies that have confirmed the prospective association between PA and risk of sleep problems[32,33] and adds new information on the benefits of three types of PA for improving sleep based on age.

At baseline, the prevalence of both short sleep duration and subjective insufficient sleep were higher in middle-aged adults than in older adults. Increased sleep problems that occur with age is well known[34] and a previous Japanese study[2] reported on this phenomenon, but the data presented here dispute that conclusion. The study data were obtained from health checkups in Shinjuku,

Table 3. Hazard Ratios of Incident Short Sleep Duration by Physical Activity Levels

	Middle-aged adults		Older adults	
	<1x/w	≥1x/w	<1x/w	≥1x/w
Moderate low-intensity physical activity				
No. of person-years	9,847	8,121	2,114	3,677
No. of cases for short sleep duration	719	526	76	89
Incidence rates per 1,000 person-years	73	65	36	24
Unadjusted	1.00	**0.89 (0.79, 0.99)**	1.00	**0.68 (0.50, 0.92)**
Adjusted for age and gender	1.00	0.94 (0.84, 1.05)	1.00	**0.72 (0.53, 0.98)**
Model 1[a]	1.00	0.98 (0.87, 1.10)	1.00	0.79 (0.58, 1.08)
Model 2[b]	1.00	0.96 (0.86, 1.08)	1.00	0.74 (0.53, 1.02)
Moderate high-intensity physical activity				
No. of person-years	16,106	1,862	4,967	824
No. of cases for short sleep duration	1,128	117	149	16
Incidence rates per 1,000 person-years	70	63	30	19
Unadjusted	1.00	0.90 (0.74, 1.09)	1.00	0.65 (0.39, 1.09)
Adjusted for age and gender	1.00	0.92 (0.76, 1.11)	1.00	0.66 (0.39, 1.10)
Model 1[a]	1.00	0.96 (0.80, 1.17)	1.00	0.69 (0.41, 1.16)
Model 2[b]	1.00	0.97 (0.80, 1.17)	1.00	0.65 (0.38, 1.10)
Vigorous-intensity physical activity				
No. of person-years	15,224	2,744	4,797	994
No. of cases for short sleep duration	1,087	158	143	22
Incidence rates per 1,000 person-years	71	58	30	22
Unadjusted	1.00	**0.81 (0.68, 0.95)**	1.00	0.74 (0.48, 1.17)
Adjusted for age and gender	1.00	**0.80 (0.68, 0.95)**	1.00	0.77 (0.49, 1.20)
Model 1[a]	1.00	0.86 (0.72, 1.01)	1.00	0.85 (0.54, 1.34)
Model 2[b]	1.00	0.85 (0.72, 1.01)	1.00	0.81 (0.51, 1.29)

Note: Boldface indicates statistical significance ($p < 0.05$).
[a]Adjusted for age, gender, BMI, smoking, alcohol consumption, days off from work, milk products intake, coffee intake, and sleep sufficiency.
[b]Additional adjustment of Model 1 for other intensity types of physical activity.

Tokyo, which is a major business center; some of the middle-aged workers may be more affected and stressed by their work than the older adults. Indeed, the latest survey data from 2013 confirms that middle-aged adults are more likely than older adults to have higher depression scores as assessed by K6[35] (Appendix Table 2). Work burden is a known risk factor for sleep problems,[22,23] and the current data may reflect this urban working population. As another large, Japanese cohort survey also confirmed that middle-aged adults experience short sleep duration and subjective insufficient sleep compared with older adults,[36] the current data may not be specific to Japan.

Incident subjective insufficient sleep was significantly prevented by MHPA and VPA in middle-aged adults and by MLPA in older adults. Some researchers have suggested that PA leads to better sleep via circadian rhythm adjustment, body temperature downregulation, restoration from fatigue, and reduction of stress and anxiety[17,18]; we believe the present epidemiologic results reflect the effect of a combination of these factors on sleep. When looking at HRs, MHPA and VPA indicated decreasing HRs for insufficient sleep in both middle-aged and older adults, but MLPA was significantly associated with sleep sufficiency only in older adults. Because physical fitness level gradually decreases with age,[20,21]

Table 4. Hazard Ratios of Incident Subjective Insufficient Sleep by Physical Activity Levels

	Middle-aged adults		Older adults	
	<1x/w	≥1x/w	<1x/w	≥1x/w
Moderate low-intensity physical activity				
No. of person-years	10,498	8,710	2,125	3,711
No. of cases for insufficient sleep	755	545	86	78
Incidence rates per 1,000 person-years	72	63	40	21
Unadjusted	1.00	**0.87 (0.78, 0.98)**	1.00	**0.52 (0.38, 0.71)**
Adjusted for age and gender	1.00	**0.89 (0.79, 0.99)**	1.00	**0.56 (0.41, 0.76)**
Model 1[a]	1.00	0.92 (0.83, 1.03)	1.00	**0.62 (0.45, 0.85)**
Model 2[b]	1.00	0.90 (0.81, 1.01)	1.00	**0.58 (0.42, 0.81)**
Moderate high-intensity physical activity				
No. of person-years	17,177	2,031	5,025	811
No. of cases for insufficient sleep	1,189	111	148	16
Incidence rates per 1,000 person-years	69	55	29	20
Unadjusted	1.00	**0.79 (0.65, 0.96)**	1.00	0.67 (0.40, 1.13)
Adjusted for age and gender	1.00	**0.79 (0.65, 0.96)**	1.00	0.68 (0.41, 1.14)
Model 1[a]	1.00	**0.81 (0.67, 0.99)**	1.00	0.78 (0.46, 1.32)
Model 2[b]	1.00	**0.81 (0.67, 0.98)**	1.00	0.70 (0.41, 1.19)
Vigorous-intensity physical activity				
No. of person-years	16,049	3,159	4,849	987
No. of cases for insufficient sleep	1,122	178	140	24
Incidence rates per 1,000 person-years	70	56	29	24
Unadjusted	1.00	**0.81 (0.69, 0.95)**	1.00	0.84 (0.55, 1.30)
Adjusted for age and gender	1.00	**0.81 (0.69, 0.95)**	1.00	0.86 (0.56, 1.32)
Model 1[a]	1.00	**0.83 (0.71, 0.98)**	1.00	0.92 (0.59, 1.43)
Model 2[b]	1.00	**0.83 (0.71, 0.97)**	1.00	0.83 (0.53, 1.30)

Note: Boldface indicates statistical significance ($p < 0.05$).
[a]Adjusted for age, gender, BMI, smoking, alcohol consumption, days off from work, milk products intake, coffee intake, and sleep duration.
[b]Additional adjustment of Model 1 for other intensity types of physical activity.

the required PA intensity that leads to better sleep would differ through different age stages: MLPA may be insufficient for middle-aged adults, whereas older adults may benefit from this level of PA. To provide a PA program that leads to better sleep, relative intensity of PA should correspond to an individual's fitness level.

Similar to subjective insufficient sleep, people who engaged in PA were less likely to have incident short sleep duration, but this association was not significant. As adequate sleep duration can vary greatly among individuals,[37] the absolute cut-off point of sleep duration (i.e., ≥6.0 hours/day) may not necessarily correspond to an individual's required sleep duration. A previous study assessed a gap between required sleep duration and actual sleep duration as an assessment of insomnia.[38] If using this gap as an insomnia assessment, its association with PA may be similar to that between PA and sleep sufficiency.

As mentioned previously, the level of intensity of PA that can lead to better sleep differs by age. However, when looking at HRs, in general, PA was more effective at improving sleep in older adults than in middle-aged adults. Insomnia among middle-aged adults is frequently due to work-related stressors, including working long hours,[22,23] whereas older adults' insomnia is mainly caused by circadian phase shifts.[24] Because PA can help readjust circadian rhythm,[39,40] older adults' sleep may be more directly and strongly affected by PA than middle-aged adults. However, we have not determined the reason for this trend. Future studies should examine the sociologic and physiologic reasons why older adults' sleep is more affected by PA.

Limitations

Although this study has the advantage of being a prospective cohort study that reveals the association between PA intensity types and incident sleep problems in middle-aged and older adults, there are still some limitations. First, PA and sleep variables were assessed by a self-reported questionnaire, which may induce recalling/reporting bias. Second, although people who had a history of mental illness were excluded from the study population, psychological status at baseline could not be adjusted; this limits confidence in the results. Third, the sample size of older adults was smaller than the sample size of middle-aged adults. If this study used similar sample sizes of older and middle-aged adults, a more significant effect may be observed. Additionally, PA items were categorized into dichotomous variables to obtain sufficient statistical power, and this study could not reveal a dose–response relationship between PA and sleep. Future studies should confirm a dose–response relationship based on an adequately large sample size. Fourth, this study assessed sleep duration primarily corresponding to a weekday sleep pattern. Because weekend sleep duration is typically longer than weekday sleep duration, especially in middle-aged adults,[41] the association between PA and sleep duration may differ between weekday and weekend sleep patterns. Finally, the influence of selection bias cannot be excluded: the majority of participants were employees and their spouses living in Tokyo, and they might have a higher social status than a rural population. There was a general lack of socioeconomic variability such as education and income in the study's participants. The 2013 survey included education level, which revealed that the tertiary education rate of the cohort (84.1% of middle-aged and 62.9% of older adults) was higher than the general Japanese population (40.8% of middle-aged and 13.7% of older adults).[42] Generalization of the study findings should be confirmed, especially in rural areas.

Conclusions

This study explored the PA intensities that could effectively prevent future incident short sleep duration and subjective insufficient sleep in both middle-aged and older adults. Through a prospective investigation, this study found that PA helps to maintain subjective sleep sufficiency, but it was not significantly associated with sleep duration. Additionally, this study revealed an age difference in the association between PA intensity and sleep sufficiency: MHPA to VPA in middle-aged adults, and MLPA in older adults, effectively prevents incident insufficient sleep. Further prospective and intervention studies are needed to clarify the optimal PA pattern for better sleep in various populations.

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Appendix

Supplementary data

Supplementary data associated with this article can be found at http://dx.doi.org/10.1016/j.amepre.2014.12.006.