ORIGINAL ARTICLE

An Aggregate Measure of Sleep Health Is Associated With Prevalent and Incident Clinically Significant Depression Symptoms Among Community-Dwelling Older Women

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Objectives: Sleep can be characterized along multiple dimensions. We investigated whether an aggregate measure of sleep health was associated with prevalent and incident clinically significant depression symptoms in a cohort of older women.

Methods: Participants were older women (mean age 80.1 years) who completed baseline (n = 6485) and follow-up (n = 3806) visits, approximately 6 years apart, in the Study of Osteoporotic Fractures (SOF). Self-reported sleep over the past 12 months was categorized as "good" or "poor" across 5 dimensions: satisfaction with sleep duration, daytime sleepiness, mid-sleep time, sleep onset latency, and sleep duration. An aggregate measure of sleep health was calculated by summing the number of "poor" dimensions. Clinically significant depression symptoms were defined as a score ≥6 on the Geriatric Depression Scale. Relationships between sleep health and depression symptoms were evaluated with multivariate logistic regression, adjusting for health measures and medications.

Results: Individual sleep health dimensions of sleep satisfaction, daytime sleepiness, mid-sleep time, and sleep onset latency were significantly associated with prevalent depression symptoms (odds ratios [OR] = 1.26–2.69). Sleep satisfaction, daytime sleepiness, and sleep onset latency were significantly associated with incident depression symptoms (OR = 1.32–1.79). The number of "poor" sleep health dimensions was associated in a gradient fashion with greater odds of prevalent (OR = 1.62–5.41) and incident (OR = 1.47–3.15) depression symptoms.

Conclusion: An aggregate, multidimensional measure of sleep health was associated with both prevalent and incident clinically-significant depression symptoms in a gradient fashion. Future studies are warranted to extend these findings in different populations and with different health outcomes.

Keywords: sleep health, depression, women, epidemiology, daytime sleepiness, sleep satisfaction, mid-sleep time, sleep onset latency, sleep duration.

Statement of Significance

Sleep and sleep problems can be measured across multiple dimensions of "sleep health," including satisfaction, sleepiness, timing, and sleep continuity or efficiency. An aggregate measure of these sleep health dimensions could plausibly be related to health and human functional outcomes including depression. We examined whether an aggregate measure of sleep health was associated with prevalent and incident clinically-significant depression symptoms in a large cohort of older women. An aggregate measure of sleep health was associated with greater odds of prevalent and incident clinically-significant depression symptoms in a gradient fashion. Our findings showed that assessing multiple sleep health dimensions may provide a richer understanding of how sleep is related to depression.

INTRODUCTION

Sleep problems and depression are highly comorbid conditions. While early diagnostic classifications presumed that sleep problems such as insomnia were most often secondary to depression, more recent evidence indicates that sleep problems often precede depressive episodes.[1] For instance, epidemiological studies indicate that sleep problems are associated with increased risk for depression, both cross-sectionally and longitudinally.[2,3] A meta-analysis of prospective epidemiological studies showed that, among adults without depression at baseline, those with insomnia symptoms were at higher risk for development of depression than those without insomnia symptoms at baseline.[2] This association has been also observed in longitudinal studies among older adults.[4,5]

Although previous epidemiological studies have focused mainly on the relationship between insomnia and depression, other measures of sleep–wake function have also been associated with incident depression.[3] For instance, previous cross-sectional studies have reported associations between depression and subjective sleep quality,[6–8] excessive daytime sleepiness,[7–10] chronotype,[8,11,12] sleep onset latency,[13] wake after sleep onset,[10] short and/or long sleep duration,[7,14,15] and napping.[10] Several prospective studies have reported an association between worsening depression symptoms or development of depression and baseline measures of subjective sleep quality,[16,17] excessive daytime sleepiness,[16,18] sleep onset latency,[17] sleep–wake rhythmicity/timing,[19,20] and short and long sleep duration.[21]

These studies show that different individual aspects of sleep are related to depression. However, individual characteristics of sleep do not occur in isolation. Sleep and sleep problems can be measured across multiple dimensions of "sleep health," including satisfaction, sleepiness, timing, sleep continuity or efficiency, and sleep duration. These aspects or sleep are not specific to any individual sleep disorder, and indeed can be used to characterize sleep in a multidimensional fashion across all individuals.[22] A composite measure of sleep health recognizes that individual dimensions of sleep always occur in conjunction with the other dimensions.

Aggregate measures of these sleep health dimensions could plausibly be related to health and functional outcomes

including depression.[22] Although most previous studies, including those reviewed above,[6–21] have focused on the associations between *individual* dimensions of sleep health and depression, few have examined whether *aggregate* measures of sleep health are associated with depression prevalence and risk. Soehner et al.[23] examined cross-sectional data from US participants meeting criteria for a major depression episode in the past year (n = 687) and reported that co-occurring insomnia and hypersomnia symptoms were associated with a more severe depression. A 7.5-year follow-up study in the United States (n = 1137) found that insomnia with short sleep duration showed higher odds of incident depression than insomnia with normal sleep duration.[24] Each of these studies investigated the association between 2 dimensions of sleep health and depression, suggesting that sleep health problems may indeed increase risk in a graded fashion. Therefore, it is reasonable to investigate whether an aggregate, multidimensional measure of sleep health is associated with both cross-sectional prevalence of depression as well as the longitudinal development of depression.

In the present study, we analyzed sleep and depression symptoms data from a large cohort of community-dwelling older women. Study aims were: (1) to examine associations between individual dimensions of sleep health and the cross-sectional prevalence and development of clinically-significant depression symptoms over 6-year period; and (2) to investigate whether an aggregate measure of sleep health is associated with the cross-sectional prevalence and development of clinically significant depression symptoms in a gradient fashion, that is, whether a greater number of "poor" sleep health dimensions is associated with greater odds of clinically significant depression symptoms. We hypothesized that individual dimension of sleep health would be associated with the cross-sectional prevalence and development of depression symptoms; and that an aggregate measure of sleep health would be associated with the prevalent and incident clinically significant depression symptoms in a gradient fashion.

METHODS

Study Participants and Data Collection

Participants were women enrolled in the Study of Osteoporotic Fractures (SOF), a multicenter, prospective cohort study of primarily Caucasian, community-dwelling women aged 65 years and older from 4 geographic areas (Portland, OR; Minneapolis, MN; Pittsburgh/Monongahela Valley, PA; Baltimore, MD). Women were recruited irrespective of bone mineral density and fracture history; those unable to walk without assistance and those with bilateral hip replacements were excluded. Women gave informed consent prior to enrollment in the study. The 9704 participants comprising the original cohort were recruited via community listings and mailed announcements between September 1986 and October 1988. Subsequently, 662 African American women were recruited between February 1997 and February 1998. A detailed description of this study was published previously.[25] The current analyses focused on women participating in SOF visit 6 (1997–1998; "baseline") and 8 (2002–2004; "follow-up"). There were 7670 participants at the baseline visit. Participants who were missing information on age (n = 127), the Geriatric Depression Scale (GDS) (n = 635), self-report sleep questions about 5 sleep health dimensions (n = 423) at the baseline visit were excluded from the analyses. We analyzed data from 6485 subjects in cross-sectional analyses. Of those, 5673 without clinically significant depression symptoms (GDS score ≥ 6) at the baseline visit were included in longitudinal analyses. We excluded those who did not complete the GDS (n = 1867) in the follow-up visit from the analyses. In total, we included data from 3806 subjects in longitudinal analyses (Figure 1).

Measures of Sleep Health

These SOF sleep questionnaire consisted of 12 items, including: falling asleep time, sleep onset latency, waking up time, sleep duration, napping, difficulty initiating sleep, difficulty maintaining sleep, early morning awakening, feeling unrested during the day, daytime sleepiness, satisfaction with sleep duration, and hypnotic medication use. Six self-report questions about sleep, assessed at baseline, were selected for our sleep health measure, based on 5 dimensions proposed in Buysse, 2014.[22] These 5 sleep dimensions have been associated with poor health outcomes in previous studies. Each of the questions had a time frame of the past 12 months. The 6 questions were used to construct 5 sleep dimensions, which were termed satisfaction, daytime sleepiness, mid-sleep time, sleep onset latency, and sleep duration (Table 1). The first dimension refers to a specific type of sleep satisfaction, that is, the perception of the adequacy of sleep amount, but for simplicity's sake, is termed "satisfaction" in this manuscript. Responses for each dimension were categorized as "good" or "poor" based on values previously reported in published studies,[10,13,26] or on the observed distribution in our sample. In accordance with a previous study,[27] mid-sleep time was calculated based on responses to falling asleep time and waking up time, using the following formula: "mid-sleep time" = "falling asleep time" + ("waking up time" − "falling asleep time")/2. Mid-sleep time was categorized based

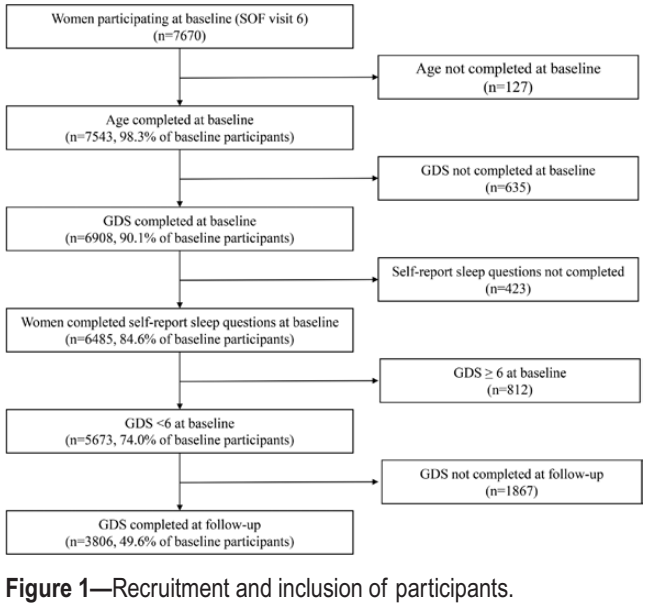

Figure 1—Recruitment and inclusion of participants.

Table 1—Sleep Questions and Sleep Health Dimensions

Sleep health dimension	Sleep survey question	Responses	Definition of "poor" sleep health
Satisfaction	Do not get enough sleep	Never (0)	Often (5–15/mo) or almost always (16–30/mo)
		Rarely (1/mo)	
		Sometimes (2–4/mo)	
		Often (5–15/mo)	
		Almost always (16–30/mo)	
Daytime sleepiness	Feel excessively (overly) sleepy during the day	Never (0)	Often (5–15/mo) or almost always (16–30/mo)
		Rarely (1/mo)	
		Sometimes (2–4/mo)	
		Often (5–15/mo)	
		Almost always (16–30/mo)	
Mid-sleep time	At what time do you usually fall asleep?	Clock time	Earlier than 2:00 am or later than/equal to 4:00 am
	At what time do you usually wake up?	Clock time	
Sleep onset latency	How many minutes does it usually take you to fall asleep at bedtime?	Number of minutes	≥30 min[10,13]
Sleep duration	How many hours of sleep do you usually get at night?	Number of hours	<7 h or ≥9 h[26]

on octiles of the mid-sleep time, and then the first (lowest score: <2:00 am) and eighth (highest score: ≥4:00 am) octiles were combined. These octiles, constituting approximately one quartile of the participants, were defined as "poor."

An aggregate measure of sleep health was calculated by summing the number of dimensions with "poor" sleep health, and classified into 5 categories: 0, 1, 2, 3, 4, or more.

Depression Symptoms

Depression symptoms at baseline and follow-up were assessed with the 15-item GDS. The GDS was designed specifically to assess symptoms of depression in older adults, with a 1-week time frame, and does not include sleep items.[28] The GDS includes binary item responses (i.e., "yes" or "no") for the 15 items, which are summed to provide a single score (range: 0–15). Higher scores indicate increasing severity of depression symptoms. A score of 6 or higher was used to define clinically significant depression symptoms; this cutoff has a sensitivity of 90.9% and a specificity of 64.5% compared with diagnosis by DSM-IV.[29]

Other Measures

Sociodemographic information (race, years of education) was recorded at the original assessment. Cognitive function was assessed using the Mini Mental State Examination (MMSE),[30] expressed as a continuous variable. Body mass index (BMI) was calculated using body weight and height measurements on physical examination or obtained by interview.

Additional variables obtained by self-report included age, self-reported health status, physical activity (walking for exercise), smoking status, alcohol consumption, caffeine intake, and medical history. Self-reported average daily intake of caffeinated beverages (coffee, tea, and cola with caffeine) was used to estimate the average daily caffeine intake,[31] and expressed as continuous variable. Medications use during the prior 30 days was categorized according to a computerized coding dictionary.[32] Hypnotic medication use in the past 12 months was assessed by self-report. Participants were asked if they had ever received a physician diagnosis of medical conditions, including hyperthyroidism, osteoporosis, Parkinson's disease, and diabetes. For Caucasian women, data on smoking status and medical diagnoses were obtained at visit 1, because these data were not collected at baseline visit 6.

Statistical Analyses

Differences in participant characteristics according to categories of an aggregate measure of sleep health and clinically significant depression symptoms at baseline were compared using χ^2 tests for categorical variables and Kruskal–Wallis or Wilcoxon rank-sum tests for continuous variables with skewed distributions (MMSE and caffeine consumption). Baseline covariates were included in multivariate models if they were significantly associated with an aggregate measure of sleep health or clinically significant depression symptoms at baseline with $p < .10$. These included age, race, years of education, MMSE score, BMI, self-reported health status, physical activity, alcohol use, smoking status, caffeine consumption, antidepressant use, benzodiazepine use, hypnotic medication use, and medical diagnoses (hyperthyroidism, osteoporosis, Parkinson's disease, and diabetes).

We computed Pearson correlation coefficients among the 5 dimensions of poor sleep health at baseline. Correlations were computed for all participants, including those in the cross-sectional and longitudinal surveys.

Associations between the 5 individual dimensions of sleep health and clinically significant depression symptoms were analyzed using univariate and multivariate logistic regression. Cross-sectional analyses using data from baseline were conducted using a series of logistic regressions analyses for individual dimensions of sleep health, adjusting for covariates and scores on the other sleep health dimensions. Longitudinal analyses were restricted to participants without clinically significant depression symptoms (GDS score ≥ 6) at baseline. We conducted a series of logistic regression analyses to examine the association between each of the 5 dimensions of sleep health at baseline and the development of clinically significant depression symptoms at follow-up, adjusting for covariates and the other sleep health dimensions. The relationship between the aggregate measure of sleep health and clinically significant depression symptoms was analyzed using univariate and multivariate logistic regressions adjusting for the covariates listed above. All analyses were performed using SPSS 19.0 for Windows. Results were expressed as odds ratios (OR) and 95% confidence intervals (CI).

RESULTS

Characteristics of the Study Population by an Aggregate Measure of Sleep Health

Baseline characteristics of participants stratified by scores on the aggregate measure of sleep health are shown in Table 2. All covariates, except for smoking status and a diagnosis of Parkinson's disease, were significantly associated with sleep health scores at baseline. In general, participants with a larger number of poor sleep health dimensions were older, less educated, had less alcohol use, less caffeine consumption and had more indicators of poor health status.

Characteristics of the 5 Sleep Health Dimensions at Baseline

Individual sleep health dimensions and their prevalence at baseline are shown in Table 3. The prevalence of poor sleep ranged from 10.7 for daytime sleepiness to 41.6 for sleep duration.

Table 2—Baseline Characteristics of Participants According to an Aggregate Measure of Sleep Health

	All participants		The number of "poor" sleep health dimensions										
	(*n* = 6485)		0 (*n* = 1917)		1 (*n* = 2138)		2 (*n* = 1483)		3 (*n* = 656)		≥4 (*n* = 291)		
Baseline characteristics	***n***	**%**	***N***	**%**	***N***	**%**	***N***	**%**	***N***	**%**	***N***	**%**	***p***
Age (y)													<.001
70–74	328	5.1	77	4.0	106	5.0	85	5.7	49	7.5	11	3.8	
75–79	3063	47.2	1004	52.4	1008	47.1	659	44.4	267	40.7	125	43.0	
80–84	2041	31.5	584	30.5	672	31.4	477	32.2	225	34.3	83	28.5	
85+	1053	16.2	252	13.1	352	16.5	262	17.7	115	17.5	72	24.7	
Race													<.001
Caucasian	5919	91.3	1813	94.6	1966	92.0	1315	88.7	563	85.8	262	90.0	
African American	545	8.4	98	5.1	169	7.9	160	10.8	89	13.6	29	10.0	
Other	21	0.3	6	0.3	3	0.1	8	0.5	4	0.6	0	0.0	
Years of education (y)													<.001
≤8	509	7.9	111	5.8	154	7.2	128	8.7	75	11.5	41	14.3	
9–12	3400	52.7	990	51.7	1108	52.1	800	54.4	368	56.5	134	46.7	
≥13	2542	39.4	813	42.5	866	40.7	543	36.9	208	32.0	112	39.0	
MMSE score (mean ± SD)	27.8 ± 2.3		28.1 ± 2.0		27.6 ± 2.5		27.6 ± 2.3		27.4 ± 2.4		27.8 ± 2.4		<.001
Self-reported health status													.001
Excellent or good	1022	15.8	260	13.6	339	15.9	270	18.2	117	17.9	36	12.4	
Fair, poor, or very poor	5462	84.2	1657	86.4	1799	84.1	1213	81.8	538	82.1	255	87.6	
Takes walks for exercise													<.001
No	3985	61.6	1049	54.9	1298	60.9	989	67.0	430	65.5	219	75.3	
Yes	2483	38.4	862	45.1	835	39.1	488	33.0	226	34.5	72	24.7	

Table 2—Continued

Baseline characteristics	All participants (*n* = 6485)		The number of "poor" sleep health dimensions										*p*
			0 (*n* = 1917)		1 (*n* = 2138)		2 (*n* = 1483)		3 (*n* = 656)		≥4 (*n* = 291)		
	n	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	
BMI, kg/m^2													.012
Underweight or normal weight (BMI < 25)	2136	39.9	664	40.6	726	41.3	458	38.1	206	38.8	82	35.0	
Overweight (BMI = 25–30)	1978	36.9	633	38.7	634	36.0	445	37.1	184	34.7	82	35.0	
Obese (BMI ≥ 30)	1246	23.2	337	20.6	400	22.7	298	24.8	141	26.6	70	29.9	
Smoking status													.349
Never smoked	3971	61.4	1185	62.0	1275	59.7	939	63.7	397	60.8	175	60.1	
Former smoker	1936	29.9	566	29.6	662	31.0	413	28.0	207	31.7	88	30.2	
Current smoker	558	8.6	159	8.3	200	9.4	122	8.3	49	7.5	28	9.6	
Alcohol use													<.001
No	3886	60.0	1028	53.6	1261	59.1	951	64.2	441	67.2	205	70.4	
≤2 d/wk	1788	27.6	601	31.4	578	27.1	373	25.2	168	25.6	68	23.4	
≥3 d/wk	806	12.4	288	15.0	296	13.9	157	10.6	47	7.2	18	6.2	
Caffeine consumption, mg/d (mean ± SD)	155.5 ± 164.6		164.4 ± 162.9		159.9 ± 165.0		144.8 ± 164.0		145.5 ± 166.2		141.6 ± 167.6		<.001
Current antidepressant use													<.001
No	5894	90.9	1782	93.0	1956	91.6	1327	89.5	576	87.8	253	86.9	
Yes	589	9.1	135	7.0	180	8.4	156	10.5	80	12.2	38	13.1	
Current benzodiazepine use													<.001
No	6053	93.4	1831	95.5	2008	94.0	1364	92.0	591	90.1	259	89.0	
Yes	430	6.6	86	4.5	128	6.0	119	8.0	65	9.9	32	11.0	
Hypnotic medication use													<.001
Never (0), Rarely (1/mo), or Sometimes (2–4/mo)	5781	89.4	1803	94.1	1946	91.3	1287	87.3	532	81.2	213	74.2	
Often (5–15/mo) or Almost always (16–30/mo)	684	10.6	113	5.9	186	8.7	188	12.7	123	18.8	74	25.8	
Medical conditions													
Hyperthyroid disease													.002
No	5852	92.2	1766	93.9	1929	92.1	1332	91.5	575	90.1	250	89.0	
Yes	496	7.8	114	6.1	165	7.9	123	8.5	63	9.9	31	11.0	
Osteoporosis													<.001
No	5599	87.3	1667	88.0	1872	88.6	1283	87.3	549	84.9	228	79.7	
Yes	811	12.7	228	12.0	241	11.4	186	12.7	98	15.1	58	20.3	
Parkinson's disease													.900
No	6451	99.6	1908	99.6	2127	99.6	1474	99.5	652	99.4	290	99.7	
Yes	29	0.4	7	0.4	9	0.4	8	0.5	4	0.6	1	0.3	
Diabetes													<.001
No	6081	94.0	1842	96.1	2014	94.4	1376	93.2	583	89.1	266	91.4	
Yes	390	6.0	74	3.9	120	5.6	100	6.8	71	10.9	25	8.6	

N, Percent or mean ± SD shown; χ^2 tests for categorical variables and Kruskal–Wallis tests for continuous variables with skewed distributions.

Correlation Among the 5 Dimensions of Sleep Health

Pearson correlation coefficients among the 5 dimensions of sleep health are shown in Table 4. All Pearson correlation coefficients were <0.3, suggesting relatively weak relationships among the 5 dimensions of sleep health.

Table 3—Characteristics of the 5 Sleep Health Dimensions at Baseline

Baseline characteristics of dimensions of sleep health	Participants	
	n	(%)
Satisfaction		
Never	1787	27.6
Rarely 1/mo	2131	32.9
Sometimes 2–4/mo	1514	23.3
Often 5–15/mo	472	7.3
Almost always 16–30/mo	581	9.0
Daytime sleepiness		
Never	1823	28.1
Rarely 1/mo	2231	34.4
Sometimes 2–4/mo	1740	26.8
Often 5–15/mo	491	7.6
Almost always 16–30/mo	200	3.1
Mid-sleep time		
<2:00	883	13.6
≥2:00 and <4:00	4796	74.0
≥4:00	806	12.4
Sleep onset latency		
<30 m	4351	67.1
≥30 m	2134	32.9
Sleep duration		
<7 h	1848	28.5
≥7 h and <9 h	3785	58.4
≥9 h	852	13.1

Association Between Individual Sleep Health Dimensions and Presence/Development of Clinically Significant Depression Symptoms

Associations between the 5 individual dimensions of sleep health and clinically significant depression symptoms in the cross-sectional and longitudinal studies are shown in Table 5.

The prevalence of clinically significant depression symptoms at baseline was 12.5%. Multivariate logistic regression analyses revealed that 4 of the 5 dimensions of poor sleep health, including satisfaction, daytime sleepiness, mid-sleep time, and sleep onset latency were significantly associated with clinically significant depression symptoms at baseline, with ORs ranging from 1.26 for mid-sleep time to 2.69 for daytime sleepiness (Figure 2).

Among individuals without clinically significant depression symptoms at baseline, the prevalence of such symptoms at follow-up was 10.9%. Multivariate logistic regression analyses revealed that 3 of 5 dimensions of poor sleep health, including satisfaction, daytime sleepiness, and sleep onset latency were significantly associated with incident clinically significant depression symptoms over 6 years, with ORs ranging from 1.32 for sleep onset latency to 1.79 for daytime sleepiness (Figure 2).

Associations Between an Aggregate Measure of Sleep Health and Presence/Development of Clinically Significant Depression Symptoms

Associations between the aggregate measure of sleep health and clinically significant depression symptoms in cross-sectional and longitudinal studies are shown in Table 6. Multivariate logistic regression analyses revealed that the aggregate measure of sleep health showed a gradient effect: higher levels of poor sleep health were associated with greater odds of prevalent clinically significant depression symptoms (ORs 1.62–5.41; p-trend < .001) and the longitudinal development of clinically significant depression symptoms (ORs 1.47–3.15; p-trend < .001). To illustrate these relationships, Figure 3 presents the associations between the aggregate measure of sleep health and clinically significant depression symptoms in cross-sectional and longitudinal analyses.

Additional Analyses

Associations of mid-sleep time (early, intermediate, and late) and sleep duration (short, normal, and long) with the presence/development of clinically significant depression symptoms

Table 4—Pearson Correlation Coefficient Among 5 Dimensions of Sleep Health at Baseline

	Satisfaction	Daytime sleepiness	Extreme mid-sleep time	Long sleep onset latency	Extreme sleep duration
Satisfaction	—	0.276	0.080	0.174	0.165
Daytime sleepiness	0.243	—	0.072	0.085	0.106
Extreme mid-sleep time	0.071	0.039	—	0.074	0.140
Long sleep onset latency	0.168	0.066	0.048	—	0.139
Extreme sleep duration	0.198	0.105	0.128	0.164	—

Numbers in the upper right portion of the figure are participants including in the cross-sectional survey. Numbers in the left lower portion of the figure are participants including in the longitudinal survey.

Table 5—Association Between Individual Sleep Health Dimensions and Presence/Development of Clinically Significant Depression Symptoms in the Cross-Sectional and the Longitudinal Studies

Baseline items	Cross-sectional study				Longitudinal study (6 y later)			
	OR	95% CI		p	OR	95% CI		p
Dimensions of sleep health								
Satisfaction (poor vs. fair)								
Univariate model	2.31	1.95	2.74	<.001	1.87	1.46	2.41	<.001
Multivariate model 1	1.99	1.59	2.49	<.001	1.70	1.26	2.28	<.001
Multivariate model 2	1.34	1.05	1.72	.017	1.39	1.01	1.90	.042
Daytime sleepiness (poor vs. fair)								
Univariate model	4.36	3.64	5.22	<.001	2.48	1.83	3.35	<.001
Multivariate model 1	3.19	2.50	4.06	<.001	2.08	1.45	2.99	<.001
Multivariate model 2	2.69	2.08	3.48	<.001	1.79	1.23	2.61	<.001
Mid-sleep time (<2:00 and ≥4:00 vs. ≥2:00 and <4:00)								
Univariate model	1.79	1.54	2.09	<.001	1.43	1.15	1.79	<.001
Multivariate model 1	1.42	1.15	1.75	<.001	1.30	1.00	1.69	.047
Multivariate model 2	1.26	1.02	1.56	.034	1.24	0.95	1.61	.119
Sleep onset latency (≥30 m vs. <30 m)								
Univariate model	2.02	1.74	2.35	<.001	1.72	1.39	2.12	<.001
Multivariate model 1	2.01	1.65	2.44	<.001	1.44	1.13	1.85	<.001
Multivariate model 2	1.78	1.45	2.18	<.001	1.32	1.03	1.71	.031
Sleep duration (<7 h and ≥9 h vs. ≥7 h and <9 h)								
Univariate model	1.95	1.68	2.26	<.001	1.27	1.03	1.56	.024
Multivariate model 1	1.49	1.23	1.81	<.001	1.27	1.00	1.61	.051
Multivariate model 2	1.19	0.97	1.47	.089	1.07	0.83	1.38	.589

Model 1: Adjusted for age, race, years of education, MMSE, self-reported health status, takes walks for exercise, BMI, alcohol use, smoke status, caffeine consumption, antidepressant use, benzodiazepine use, hypnotic medication use, hyperthyroidism, osteoporosis, Parkinson's disease, and diabetes. Model 2: Adjusted for age, race, years of education, MMSE, self-reported health status, takes walks for exercise, BMI, alcohol use, smoke status, caffeine consumption, antidepressant use, benzodiazepine use, hypnotic medication use, hyperthyroidism, osteoporosis, Parkinson's disease, diabetes, and other sleep health dimensions.

in cross-sectional and longitudinal analyses are shown in Supplementary Table S1. In the univariate cross-sectional analyses, both mid-sleep time and sleep duration showed a U-shaped association with presence of clinically significant depression symptoms. Multivariate logistic regression analyses showed that early mid-sleep time (<2:00), short sleep duration (<7 h), and long sleep duration (≥9 h) were significantly associated with prevalent clinically significant depression symptoms at baseline. Multivariate logistic regression analyses showed that early mid-sleep time (<2:00), and short sleep duration (<7 h) were significantly associated with incident clinically significant depression symptoms over 6 years.

DISCUSSION

In a large sample of community-dwelling older women in the United States, we found that both individual sleep dimensions and an aggregate measure of sleep health were associated with prevalent depression and the longitudinal development of clinically significant depression symptoms. For the aggregate measure, the increased odds of depression symptoms occurred in a graded fashion: the greater the number of "poor" sleep health dimensions, the greater the cross-sectional and longitudinal risk for clinically significant depression symptoms. To our knowledge, this is the first study to investigate associations between an aggregate measure of sleep health dimensions and the presence and development of clinically significant depression symptoms. Although many previous studies have documented health risks associated with individual dimensions of sleep health such as short and long sleep duration,[26] our findings suggest that other characteristics of sleep may also confer risk, and that these sleep characteristics have additive effects. Examining multivariate sleep health profiles may advance our understanding of the relationships between sleep, health, and disease.

In the present study, poor satisfaction (specifically, the feeling of not getting enough sleep) was significantly associated with prevalence of clinically significant depression symptoms at baseline, as well as being significantly associated with

greater odds of development of clinically significant depression symptoms. Several previous cross-sectional epidemiological studies in Western and Asian countries reported the association between sleep satisfaction and depression.[6–8] Significant associations between sleep satisfaction and the onset of depression have also been reported in several prospective studies across different countires.[16,17] The results of present study are consistent with these previous studies. However, measures of sleep satisfaction differ among these studies. Our item measured the individual's judgment of whether they got "enough sleep," which likely incorporates some judgment about sleep duration as well as satisfaction. Assessments used in other studies more specifically measured sleep quality or sleep satisfaction.[17,33,34] Nevertheless, we observed a low Pearson's correlation between the sleep satisfaction item and the actual sleep duration item, suggesting that participants distinguished these 2 dimensions of sleep.

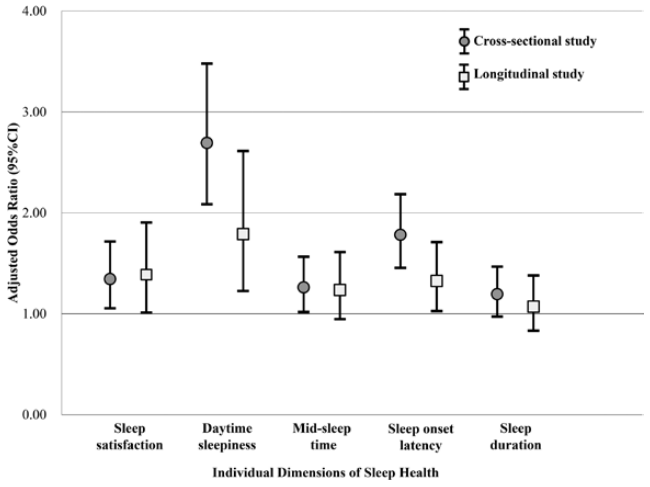

Figure 2.—Association between individual sleep health dimensions and presence/development of clinically significant depression symptoms in the cross-sectional (SOF, V6) and longitudinal (SOF, V6–V8) studies.

Of the individual sleep health dimensions, daytime sleepiness had the strongest positive association with clinically significant depression symptoms in both the cross-sectional and longitudinal analyses. Numerous previous cross-sectional studies have reported significant associations between increased daytime sleepiness and depression, independent of insomnia symptoms and sleep duration.[7–9] Extending beyond cross-sectional data, prospective studies in young[18] and older adults[16] have reported that excessive daytime sleepiness is a significant predictor of subsequent depression. Thus, the results of the present study are again in agreement with findings from previous studies.

Previous cross-sectional epidemiological studies have revealed that chronotype is associated with depression, with increased risk in self-reported "evening types," that is, individuals who prefer sleeping at later times.[8,11,12] However, the association between early sleep timing and depression is controversial, with some epidemiological studies reporting lower prevalence of depression in morning types compared to intermediate types,[8,12] and at least one study suggesting that the prevalence of depression was higher in morning type compared to intermediate types.[11] Others have evaluated mid-sleep time as a behavioral index of chronotype, finding that both late and early timing was associated with greater symptoms of depression compared to intermediate sleep timing.[35,36] In the present study,

Table 6—Association Between an Aggregate Measure of Sleep Health and Presence/Development of Clinically Significant Depression Symptoms in the Cross-Sectional and the Longitudinal Analyses

Baseline items	Participants	Univariate model				Multivariate model[a]			
An aggregate measures of sleep health	(%)	OR	95% CI		*p*-trend	OR	95% CI		*p*-trend
Cross-sectional study									
0	29.6	1.00	(reference)		<.001	1.00	(reference)		<.001
1	33.0	2.05	1.60	2.63		1.62	1.19	2.20	
2	22.9	3.46	2.70	4.42		2.71	1.99	3.68	
3	10.1	6.07	4.64	7.94		4.17	2.96	5.89	
≥4	4.5	9.61	7.01	13.18		5.41	3.58	8.19	
Longitudinal study (6 y later)									
0	34.1	1.00	(reference)		<.001	1.00	(reference)		<.001
1	33.2	1.51	1.15	2.00		1.47	1.07	2.02	
2	21.1	2.10	1.57	2.81		1.95	1.40	2.73	
3	8.5	2.14	1.47	3.12		2.00	1.30	3.09	
≥4	3.1	4.62	2.91	7.32		3.15	1.81	5.47	

[a]Adjusted for age, race, years of education, MMSE, self-reported health status, takes walks for exercise, BMI, alcohol use, smoke status, caffeine consumption, antidepressant use, benzodiazepine use, hypnotic medication use, hyperthyroidism, osteoporosis, Parkinson's disease, and diabetes.

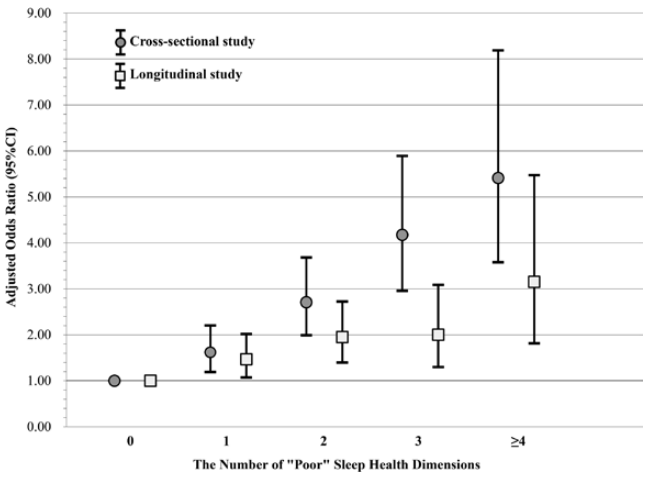

Figure 3—Associations between an aggregate measure of sleep health and presence/development of clinically significant depression symptoms in the cross-sectional (SOF, V6) and longitudinal (SOF, V6–V8) studies.

mid-sleep time showed a U-shaped association with concurrent clinically significant depression symptoms in the univariate analyses. Therefore, categorization of both very early and very late mid-sleep times into a single "poor" category seemed appropriate. Cross-sectional analyses indicated a significant association between extreme mid-sleep times and the prevalence of clinically significant depression symptoms. In longitudinal analyses, extreme mid-sleep times were again associated with increased odds ratio for the development of clinically significant depression symptoms, although the association was no longer significant after adjustment for the other sleep health, suggesting that longitudinal associations between extreme mid-sleep time and development of clinically significant depression symptoms are mediated by the other sleep health dimensions. Further studies are required to examine the complex interactions among mid-sleep time, the other sleep health dimensions, and depression. Furthermore, distinctions between chronotype as a habitual measure of sleep timing preference, and actual mid-sleep times, may be important.

Our results showed that longer sleep onset latency (≥30 m) was significantly associated with both the prevalence and the development of clinically significant depression symptoms. Findings from epidemiological studies that examined associations between sleep onset latency and depression have shown variable results. For example, a cross-sectional study in older adults showed an association between long sleep onset latency and depression,[13] whereas no significant associations were reported between depression and longer sleep onset latency,[10] or sleep latency assessed with the Pittsburgh Sleep Quality Index.[37] In prospective studies among older adults, longer sleep onset latency indicated a significant association with worsening of depression symptoms in one study,[17] whereas it exhibited no significant association with depression in another study.[34] Although our findings demonstrated cross-sectional and longitudinal associations between sleep onset latency and clinically significant depression symptoms in older women, other indicators of sleep continuity or efficiency should be examined in subsequent studies.

Multiple studies have reported associations between both short and/or long sleep duration and depression, and some cross-sectional studies have revealed a U-shaped association.[7,14,15,38] In the present study, both short and long sleep duration were significantly associated with prevalence of clinically significant depression symptoms. Therefore, the categorization of both short and long sleep duration into single "poor" sleep duration group in our study seems appropriate. Results of prospective studies have been inconsistent, with some studies reporting significant associations between short sleep duration and depression,[39] and other studies failing to find such an effect.[5,17,34,39–41] A recent meta-analysis of prospective studies reported a significant increase in the risk of onset of depression in both short- and long-sleepers.[21] However, as Zhai et al.[21] pointed out, confounding factors were not well addressed in that report. In the present study, extreme sleep duration was associated with an increased odds ratio for the prevalence and development of clinically significant depression symptoms in unadjusted models. However, these associations were no longer significant after adjustment for multiple health problems, medications, and the other individual indices of sleep health. Thus, complex interactions among sleep dimensions and other health factors may explain our findings.

This is the first study to demonstrate a significant association between the presence/development of clinically significant depression symptoms and an aggregate multivariate measure of sleep health. Several previous studies have reported that a more limited number of sleep health, most notably insomnia (poor satisfaction/quality) with short objective sleep duration, are associated with adverse health outcomes, including hypertension,[42,43] diabetes,[42] neurocognitive impairment,[42] and mortality.[42] Taken together, our findings and previous studies suggest that multivariate measures of sleep may prove to be more useful than individual measures for assessing health risks.

There are several possible interpretations of our findings. First, the number of "poor" sleep health dimensions may be a marker for overall severity of sleep disturbances. Previous studies have reported that the severity of sleep problems is associated with the onset of depression,[24,41] perceived mental health status,[44] and quality of life.[45] Second, it is possible that each sleep health dimension increases depression risk via different mechanisms. To date, no definitive psychophysiological mechanisms identified to explain the pathways through which disturbed sleep increases depression symptoms or risk. Hypothesized pathways include neurotransmitter imbalance,[3] phase-advance theories,[3] the S-deficiency hypothesis,[3] overactivity of the hypothalamic-pituitary-adrenal axis,[3] and sleep-related alterations in neural circuits regulating affect.[46] The interaction of several such mechanisms, indicated by different types of sleep disturbance, may increase the presence/development of depression. Finally, disturbed sleep and depression may reflect a common background factors such as chronic stress or unmeasured medical disease.

Despite the richness of these cross-sectional and longitudinal data, several limitations deserve consideration. First, the sample comprised exclusively older women. Despite

statistical adjustment for confounding variables, other unmeasured factors may have influenced these results. Nor do our data address associations among sleep health and depression in men or racial/ethnic minority groups. Second, the sleep evaluation consisted only of retrospective self-report questionnaire data. Future studies may examine multivariate sleep measures based on behavioral (actigraphy) or physiological (polysomnography) methods. Third, the present study used the GDS to define clinically significant depression symptoms, but a previous medical history of depression and existence of other mental disorders were not investigated. Fourth, the sleep questions used a time frame of the past 12 months, which does not reflect normal variations in sleep, or shorter-term changes in sleep that might be associated more strongly with depression. Finally, the results from cross-sectional study could not determine whether depression preceded or resulted from poor sleep health.

Our findings suggest that assessing multiple sleep health dimensions may provide a richer understanding of how sleep is related to other health problems, compared to the traditional approach of examining one dimension at a time. This approach recognizes that different sleep characteristics occur in conjunction with each other, and may have additive or interactive effects on health. The results also raise the possibility that interventions focusing on multiple sleep health dimensions could potentially reduce risk for other health problems. Further studies examining multivariate measures of sleep health in other samples and with other health outcomes are warranted.

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SUPPLEMENTARY MATERIAL

Supplementary material is available at *SLEEP* online.

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