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Insomnia Symptoms and Actigraph-Estimated Sleep Characteristics in a Nationally Representative Sample of Older Adults

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Background. Reports of insomnia symptoms are common among the elderly. However, little is known about the relationship between insomnia symptoms and objective assessments of sleep in the general population of older adults. We assessed concordance between insomnia symptoms and actigraphic sleep characteristics in a nationally representative sample of older Americans.

Methods. In a national probability sample of 727 adults aged 62–91 years in 2010–2011 from the National Social Life, Health, and Aging Project, respondents were asked how often they (a) feel rested when they wake up, (b) have trouble falling asleep, (c) have trouble with waking up during the night, and (d) have trouble waking up too early and not being able to fall asleep again. Responses to these questions were compared to sleep characteristics estimated from three nights of actigraphy for the same individuals. Statistical analyses were adjusted for age, gender, race and ethnicity, income, assets, and education.

Results. Feeling rested (Question (a), above) was not correlated with any actigraphy-estimated sleep characteristics. Questions (b)–(d) each had several significant correlations with the actigraphy metrics, but generally not with the specific objective sleep characteristics that each question intended to reference. In some cases, the associations were not in the expected direction.

Conclusions. Although three of four questions about insomnia symptoms were significantly associated with objectively estimated sleep characteristics, responses seem to be general indicators of sleep quality rather than reports of specific sleep characteristics.

Key Words: Epidemiology—Geriatric assessment—Sleep.

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INSOMNIA is a highly prevalent condition, with an estimated 30% of adults having some symptoms and 6–10% meeting clinical definitions (1). Insomnia is defined and diagnosed on the basis of patient-reported problems. While clinical definitions differ somewhat between the *Diagnostic and Statistical Manual of Mental Disorders* and *International Classification of Diseases,* and between editions, several key components are similar (2). These include reported difficulty initiating or maintaining sleep (specifically falling asleep, staying asleep, or waking up too early) and daytime sequelae, including feeling unrested.

The diagnostic criteria for insomnia rely on the presence or absence of a set of symptoms (3). Little is known about the extent to which reports of insomnia symptoms correspond to objective assessments of sleep. Although a few studies have tried to compare reports of insomnia to objective sleep assessments (4–7), the majority of them measure sleep characteristics identified by sleep specialists, in a series of patients who sought treatment for insomnia or related conditions. These patients are not representative of the general population seen in primary care settings or reporting such symptoms in surveys. There has been little attention to the relationship between insomnia symptom reports and objective sleep measures in the general population of older adults. Insomnia is very common among older adults. Prior studies suggested that nearly half of older adults report at least one insomnia symptom (8), and those with medical problems are particularly likely to have insomnia symptoms (9,10). Furthermore, insomnia has been linked to adverse health outcomes among older adults,

including declines in cognitive function (11–13), daytime functioning (14,15), falls (16,17), and heart disease (18). In addition, insomnia at old ages was associated with greater use of costly health services (19). Understanding the nature and correlates of insomnia symptom reports in relation to objective sleep measures in the general population of older adults would enhance our knowledge of how to interpret insomnia reports from population-based studies and in clinical practice.

In this study, we assessed the concordance between four survey questions about insomnia symptoms and actigraph-estimated sleep characteristics, using a nationally representative sample of community-dwelling older adults. Specifically, we compared each sleep question, as well as a composite score based on these questions, to several actigraph-estimated sleep characteristics. Because these questions asked respondents to recall specific characteristics of sleep, some of which are also estimated through actigraphy, we expected that insomnia symptoms would significantly correlate with actigraphic sleep characteristics.

Methods

National Social Life, Health, and Aging Project

This study used data from participants in the National Social Life, Health, and Aging Project (NSHAP). NSHAP is a population-based, longitudinal study of health, social life, and well-being of older Americans. A nationally representative probability sample of 3,005 community-dwelling individuals aged 57–85 was selected from households across the U.S. screened in 2004 and the first wave of the survey was conducted during 2005–2006. We relied on data from the second wave, which was conducted during 2010–2011.

Approximately one-third of the Wave 2 respondents were randomly invited to participate in an additional "Activity and Sleep Study." The design and detailed information on this study has been described previously (20). The activity and sleep study had two components: (a) a self-administered sleep booklet, which included questions about respondents' sleep experience and (b) 72 hours of wrist actigraphy using the Actiwatch Spectrum model from Phillips Respironics.

The booklet and Actiwatch were mailed out with a prepaid return mailer a few days after the in-home NSHAP interview. Participants were instructed to wear the Actiwatch on the nondominant wrist (the one not used for writing) for three full days. Most participants did so but a few individuals wore the Actiwatch for fewer or more days. In total, 766 individuals aged 62–91 completed the Activity and Sleep Study. After excluding 39 individuals with no recorded or usable data from the actigraphs, the sleep study yielded a sample of 727 individuals with complete data. There were no systemic differences in social and demographic characteristics between the subsample and the NSHAP full sample. As such, the sleep subsample is also nationally representative.

Actigraphy and Actigraph-Estimated Sleep Characteristics

The Actiwatch records intensity and frequency of movement with a piezoelectric linear accelerometer in epochs (15-second epochs were selected for this study). The Actiwatch continually registers wrist movements, and the sum of all wrist movements during each epoch is saved as an activity score. These data were analyzed using manufacturer-developed Actiware software (version 5.59). In this study, we focused on nine actigraph-derived sleep parameters, capturing three aspects of older adults' sleep characteristics: duration, timing, and consolidation. The *duration variables* are sleep period (the total amount of time between when an individual first falls asleep and last awakens) and total sleep time (the total duration of all of the epochs scored as sleep during the sleep period). The *timing variables* are the clock time falling asleep (first epoch recorded as sleep) and clock wake up time (last epoch recorded as sleep). The *consolidation variables* are percent sleep (the percent of the sleep period scored as actual sleep), wake after sleep onset (or WASO, the minutes awake during the sleep period), number of wake bouts during the sleep period, sleep fragmentation (21) (an index of sleep disruption that is the sum of two percentages: the percentage of the sleep period spent moving and the percentage of immobile periods only 1 minute long, and latency (the amount of time it takes an individual to fall asleep initially after she or he begins to try falling asleep). Latency was only estimated for the subset of nights when participants remembered to press the event marker when they began trying to fall asleep, as instructed.

All actigraph-estimated measures except latency are three-night averages. For the 53 individuals (<7% of the total sample) with fewer than three nights of data, we averaged all available nights. Weekdays and weekends actigraph-estimated sleep characteristics were similar in this mostly retired population.

Insomnia Questions

The NSHAP core survey included a restorative sleep question asking "How often do you feel really rested when you wake up in the morning?" The sleep booklet included three additional questions related to initiating and maintaining sleep: "How often do you have trouble falling asleep?"; "How often do you have trouble with waking up during the night?"; and "How often do you have trouble with waking up too early and not being able to fall asleep again?" Response categories for all four questions were: most of the time = 2, sometimes = 1, and rarely/never = 0.

In addition to examining each of these questions separately, we constructed an insomnia symptom scale (total score ranging from 0 to 8) by reverse-coding the feeling rested question and then summing all four items.

Exploratory factor analysis showed that these four items loaded into a single factor and the reliability of the scale is within the acceptable range ($\alpha = 0.65$).

Expected Relationships between Actigraph-Estimated SLEEP and Insomnia Symptoms

Based on the insomnia questions and the definition of actigraphic sleep characteristics, we expected that individuals who reported feeling rested in the morning would have more total sleep time, higher percent sleep, less WASO, fewer wake bouts, and a lower sleep fragmentation score. For trouble falling asleep, we expected a positive association with earlier clock time falling asleep (as individuals with insomnia commonly get into bed too early) and longer latency. We expected that trouble waking up during the night would be inversely correlated with percent sleep and would positively correlate with WASO and number of wake bouts. Finally, we expected that individuals who reported waking up too early would have less total sleep time and an earlier wake up time.

Statistical Analyses

In our statistical analyses, the aforementioned insomnia questions and insomnia symptom scale were outcome variables of the statistical analyses and actigraphic parameters were predictors. We used ordered logistic regression to assess associations between each insomnia symptom question and each actigraph-estimated sleep parameter, controlling for age, age squared, gender, race/ethnicity, education, household income, and household assets. Although ordinal logistic regression is easy to fit and makes interpretation of the results straightforward, it assumes that the associations of the independent variables with each one-unit change in the dependent responses are the same (ie the proportional odds assumption). To ensure ordered logistic regression was a valid approach, we tested the proportional odds assumption. For a few models where the proportional odds assumption was violated, we used the partial proportional odds model, which models each one-category change in the dependent variable separately (22). When the insomnia symptom scale was the outcome variable, we used ordinary least squares (OLS) regressions and we used multiple imputation to recover missing values among control variables (23).

When latency was the key explanatory variable, we performed the analysis using a subsample of actigraphy data with nonmissing start-event markers because the estimate of latency is imprecise when the start event marker is missing. This ensures that our analysis was based on the best available estimate of latency. The sample size for these analyses was 627. All analyses took into account the study design and survey weights using Stata 12 (24).

Table 1. Survey Weighted Descriptive Statistics of Older Adults Participated in the Activity and Sleep Study of the National Social Life, Health, and Aging Project (NSHAP), 2010–2011

	Mean or Proportion	Standard Deviation	Median	Interquartile Ranges
Insomnia symptoms				
Feeling rested in the morning ($N = 727$)				
Rarely/never	0.13			
Sometimes	0.20			
Most of the time	0.67			
Trouble falling asleep ($N = 629$)				
Rarely/never	0.42			
Sometimes	0.46			
Most of the time	0.12			
Trouble waking up during the night ($N = 629$)				
Rarely/never	0.26			
Sometimes	0.44			
Most of the time	0.30			
Trouble waking up too early ($N = 625$)				
Rarely/never	0.40			
Sometimes	0.47			
Most of the time	0.13			
Insomnia symptom scale (0–8)	4.04	1.43	4	2
Actigraphic sleep measures				
Sleep period (h)	7.90	1.34	7.89	1.55
Total sleep time (h)	7.25	1.27	7.31	1.53
Percent sleep (0–100)	82.09	14.28	86.54	20.17
Fragmentation (0–100)	14.36	6.03	13.60	7.95
WASO (min)	39.07	22.84	34.58	25.92
Clock time falling asleep (PM h)	10.44	1.56	10	1
Wake up time (AM h)	6.37	1.87	6	2
Number of wake bouts	46.15	21.50	42.67	24
Latency (min)	29.03	34.27	18.08	24.5
Covariates				
Age	71.79	7.25	71	12
Female	0.54			
Race/ethnicity				
White	0.83			
African-American	0.07			
Hispanic	0.06			
Others	0.04			
Education				
<High school	0.14			
High school	0.30			
Some college	0.34			
College or more	0.22			
Self-rated health				
Poor	0.04			
Fair	0.16			
Good	0.32			
Very good	0.34			
Excellent	0.14			
Household income ($10,000)	5.75	7.66	4.40	4.60
Household assets ($10,000)	57.60	10.94	25.00	51.00

RESULTS

Descriptive Statistics

Table 1 provides the weighted descriptive statistics. As the table shows, about 13% of older adults said that they rarely or never feel rested when waking up in the morning, 12% reported having trouble falling asleep most of the time, 30% indicated they had problems with waking up during the night most of the time, and 13% reported problems with waking up too early and not being able to fall asleep again most of the time.

With respect to actigraph-estimated sleep characteristics, the average duration of sleep period was 7.9 hours and the average total sleep time was 7.25 hours. The mean percent sleep was 82%, the mean sleep fragmentation index was 14%, mean WASO was 39 minutes, and the mean number of wake bouts was 46. The average clock time falling asleep of older adults averaged 10:27 PM and their average wake-up time was 6:22 AM.

Mean Actigraph-Estimated Sleep Characteristics by Insomnia Symptoms

Table 2 shows mean actigraphic sleep characteristics by the three response levels for each of the insomnia questions and for tertiles of the insomnia symptom scale. We tested for differences in actigraphic sleep characteristics for each quality question using a rank-based nonparametric test of trend (25). This test allowed for examining whether actigraphic sleep characteristics systematically increase or decrease over the frequencies of insomnia symptoms.

For the "feeling rested" question, we found no significant relationships to any of the actigraphic outcomes.

For the "trouble falling asleep" question, we expected associations with latency and perhaps earlier clock time falling asleep. We did not find a significant relationship with latency, and the relationship to clock time falling asleep was weak ($p = 0.06$) and in the unexpected direction. Instead, we observed that trouble falling asleep was associated with increasing sleep period, later wake up time, lower percent sleep, longer WASO, and more wake bouts.

For the "trouble waking up during the night" question, we observed significant relationships with longer WASO and lower percent sleep, as expected. However, we did not observe a relationship with number of wake bouts. In addition, we also observed trends in longer total sleep time and shorter latency with greater trouble waking up during the night.

For the last question, "trouble waking up too early," we would expect earlier clock wake up time and perhaps shorter total sleep time. There were significant associations with both earlier clock time falling asleep and earlier wake up time, as well as shorter latency. However, we did not observe a trend in total sleep time, indicating that sleep was phase shifted to earlier in the day. Finally, higher scores on the insomnia symptom scale were related to longer wake after sleep onset and decreasing percent sleep as expected, but also with increases in sleep period and total sleep time.

Adjusted Models of Insomnia Symptoms and Actigraphic-Estimated Sleep Characteristics

Table 3 summarizes the results from ordered logistic regression models and OLS regression models using actigraph-estimated sleep characteristics to predict older adults' responses to the four survey questions and the insomnia symptom scale controlling for age, age squared, gender, race/ethnicity, education, income, and assets. Adjustment for these characteristics had little effect on the associations previously observed in Table 2. The three survey questions with the most significant associations with the actigraph-estimated sleep characteristics were trouble falling asleep, trouble with waking up during the night, and trouble with waking up too early. Trouble waking up too early was significantly associated with earlier wake up time, but also with earlier bedtime and shorter latency. Reports of waking up during the night were associated with lower percent sleep, longer WASO, and longer sleep period and total sleep time. Waking up too early was associated with earlier clock time falling asleep and earlier wake up time. Both longer sleep period and longer WASO were positively correlated with insomnia symptom scale. Percent sleep was negatively associated with the scale. We found no evidence (results not shown) that the associations between actigraph-estimated sleep characteristics and insomnia symptoms differed systematically by gender.

There were a few cases where the proportional odds assumption did not hold (data not shown). Although Table 3 suggests that there was no association between waking up too early and sleep duration variables, the partial proportional odds model showed that both sleep period and total sleep time were associated with waking up too early from "sometimes" to "most of the time." These results suggest that sleep duration variables have stronger effects on frequent sleep complaints but not occasional sleep disturbances. We also performed sensitivity analyses excluding participants with fewer than three nights of actigraphy data. There were 53 individuals with fewer than three nights of data (44 individuals had 2 nights and 9 one night). Results were very similar. We also stratified the sample by three age groups—(a) 62–70, (b) 71–80, (c) 81 above—to examine if the relationships between self-report insomnia symptoms and actigraphic measures vary. Although patterns were similar across age groups, many of the associations of the second and third age groups were nonsignificant which in part might due to the relative small sample size of the last two groups. Finally, we tested the role of cognitive ability in affecting the reported-actigraphic relationships by

Table 2. Mean Actigraphic Sleep Characteristics by Insomnia Symptoms and by Response Categories

	Sleep Period (h)	Total Sleep Time (h)	Clock Time Falling Asleep (PM h)	Wake Up Time (AM h)	Percent Sleep (0–100)	WASO (min)	Number of Wake Bouts	Fragmentation (0–100)	Latency (min)
Feeling rested (N = 725)									
Rarely/never	7.87	7.18	10.53	6.28	80.76	40.27	46.26	14.68	28.95
Sometimes	7.98	7.31	10.44	6.68	82.73	40.15	47.98	14.92	29.72
Most of the time	7.89	7.25	10.41	6.29	82.17	38.48	45.55	14.11	29.31
P_{trend}	.823	.976	.660	.275	.777	.459	.425	.295	.894
Trouble falling asleep (N = 629)									
Rarely/never	7.74	7.15	10.26	6.10	83.56	35.25	43.97	13.77	26.77
Sometimes	7.94	7.28	10.49	6.46	81.38	39.20	45.88	14.01	30.01
Most of the time	8.28	7.51	10.66	6.86	80.53	46.43	53.33	15.90	30.53
P_{trend}	.021*	.108	.062	.014*	.046*	.000***	.012*	.071	.259
Trouble waking up during the night (N = 629)									
Rarely/never	7.65	7.04	10.72	6.50	84.80	35.94	45.89	14.48	33.96
Sometimes	7.93	7.32	10.30	6.24	83.16	36.93	44.00	13.51	27.93
Most of the time	8.09	7.36	10.33	6.44	78.56	43.12	49.12	14.84	24.55
P_{trend}	.005**	.019*	.057	.857	.004**	.017*	.281	.566	.018*
Trouble waking up too early (N = 625)									
Rarely/never	7.86	7.21	10.61	6.56	82.61	38.67	46.09	14.33	33.15
Sometimes	8.01	7.39	10.36	6.33	81.95	37.50	45.61	13.86	26.24
Most of the time	7.60	6.87	10.26	5.84	80.31	43.73	48.52	15.44	25.09
P_{trend}	.769	.652	.018*	.020*	.265	.488	.717	.732	.024*
Insomnia symptom scale (N = 620)									
Low (0–2)	7.61	6.97	10.74	6.77	82.00	36.34	46.31	14.90	33.96
Medium (3–5)	7.89	7.25	10.35	6.23	80.11	38.02	45.42	13.97	27.44
High (6–8)	8.25	7.52	10.38	6.59	75.96	44.03	49.92	14.80	25.87
P_{trend}	.008**	.018*	.162	.632	.009**	.015*	.271	.968	.120

Note: All analyses were survey weighted. Data from latency was based on a subsample of respondents whose bedtime event marker was presented.
***p <.001, **p <.01, *p < .05

Table 3. Summary of Ordinal Logistic Regression and OLS Regression Models, Regressing Insomnia Symptoms and the Insomnia Symptom Scale on Each Actigraphic Sleep Measures, Adjusted for Social, and Demographic Characteristics

	Feeling Rested (N = 725)	Trouble Falling Asleep (N = 629)	Trouble Waking Up During the Night (N = 629)	Trouble Waking Up Too Early (N = 625)	Insomnia Symptom Scale (N = 620)
	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Coefficient (SE)
Sleep duration					
Sleep period (h)	1.020 (0.890–1.170)	1.162 (0.983–1.372)	1.178** (1.052–1.320)	**0.947 (0.843–1.065)**	0.091* (.045)
Total sleep time (h)	1.001 (0.854–1.173)	1.113 (0.923–1.343)	1.127* (1.002–1.278)	**0.936 (0.819–1.071)**	0.072 (0.051)
Sleep timing					
Clock time falling asleep (h)	1.029 (0.901–1.176)	1.140 (0.981–1.326)	0.905 (0.812–1.009)	0.893* (0.805–0.992)	−0.050 (0.041)
Wake up time (h)	1.045 (0.955–1.143)	1.134* (1.007–1.277)	0.996 (0.891–1.114)	0.858* 0(.766–0.960)	−0.025 (0.038)
Sleep consolidation					
Percent sleep (0–100)	0.995 (0.979–1.011)	0.993 (0.982–1.005)	0.975** (0.960–0.990)	0.997 (0.986–1.009)	−0.010* (0.004)
WASO (min)	1.004 (0.996–1.013)	1.011*** (1.004–1.018)	1.013* (1.004–1.023)	1.002 (0.993–1.011)	0.006* (0.003)
Number of wake bouts	1.003 0(.996–1.011)	1.012** (1.002–1.021)	**1.007 (0.995–1.018)**	1.002 (0.993–1.011)	0.005 (0.003)
Fragmentation (0–100)	1.025 (0.988–1.060)	1.030 (0.994–1.067)	1.016 (0.976–1.058)	1.006 (0.967–1.046)	0.006 (0.014)
Latency (min)	0.999 (0.995–1.005)	1.004 (0.999–1.009)	0.995* (0.991–0.999)	0.994* (0.988–0.999)	−0.002 (0.003)

Note: All analyses were survey weighted. Data from latency was based on a subsample of respondents whose bedtime event marker was presented. Numbers in bold indicated the cases where proportional odds assumption did not hold. Actigraphic sleep characteristic was only significantly associated with insomnia symptom from "sometimes" to "most of the time".
***p < .001, **p < .01, * p < .05.

controlling for scores of cognitive assessment and interactions between cognitive scores and actigraphic measures. Most of the interaction terms were nonsignificant. Thus, there was no strong evidence that the observed relationships between self-report sleep experience and actigraphic measures varied systematically by cognitive scores.

Discussion

This study compared survey reports of insomnia symptoms collected in the context of a general survey to objectively estimated sleep characteristics in a large nationally representative study population of older adults, focusing on four survey questions that measure key components of

clinical definitions of insomnia. These questions have also been included in many general health surveys. Researchers have found that responses to these questions correlate with and predict other aspects of health, but there has been relatively little attention paid to their relation to objective measures of sleep in a nonclinical population.

Although we found significant associations between the three questions tapping into initiating sleep and maintaining sleep and several actigraphic-estimated sleep characteristics, some associations were not specific to the aspect of sleep queried. For example, while reports of trouble falling asleep would logically be linked to long latency, we did not find a statistically significant association between the two. Instead, reported trouble falling asleep significantly correlated with more WASO and an increased number of wake bouts. These associations suggest that the reports of trouble falling asleep may also relate to trouble staying asleep during the night and a longer sleep period. The finding that awaking too early was not only associated with earlier wake time but also earlier clock time falling asleep and shorter latency similarly suggests that this question may tap into a circadian phase advance that affects both bedtime and waking time (26). Older adults may complain of waking up too early despite accumulating substantial hours of sleep. The finding that respondents who reported waking up more frequently during the night had more total sleep time is also unexpected. These associations may be a consequence of poorer health, as longer sleep duration and poorer sleep quality may be both markers of illness at older ages (27).

Lastly, feeling rested was not systematically related to any actigraphic measures. This is consistent with prior studies suggesting that global ratings of sleep are unlikely to relate to single physiological sleep measures in a consistent manner (28). It is also possible that feeling rested correlates with other objective sleep outcomes that are not measured by actigraphy, such as amount of slow-wave sleep or absence of sleep disorders such as obstructive sleep apnea. However, polysomnography studies have reported no correlation between feeling rested and sleep characteristics in a clinical adult sample (29), which suggests that a question about feeling rested may tap into other aspects of older adults' everyday health or psychological experience. Taken together, these unexpected findings suggest that answers to these survey questions are not shaped solely by objective sleep characteristics. Instead, they may reflect older adults' subjective evaluation of overall sleep experience as well as other dimensions of health and wellbeing.

Several large population-based studies of older adults, including the Established Populations for the Epidemiological Study of the Elderly and the Health and Retirement Study, have included these survey questions about sleep problems, which tap into the definition of insomnia. Data from these questions have been used to investigate hypotheses related to sleep problems and insomnia among older adults (8,9,19,30–33). Our findings suggest that reports of what seem like specific sleep problems from survey questions may be more accurately viewed as indicators of general problems or dissatisfaction with sleep that may be due to complex environmental, physiologic, psychological, and social processes. These survey questions and actigraphy may measures different domains of sleep experience.

We acknowledge several limitations. First, we only had three nights of actigraphy data, which may not fully capture the within-subject variability of sleep behavior in older adults. We did not ask whether these three nights were typical of the individual's sleep schedule or quality. However, our large sample compensates for the greater noise in our data compared to longer observation periods, and the three-night observation introduces no systematic bias in our estimates as population-level sleep characteristics were very similar based on the full sample and the sample that excluded participants with fewer than three nights of data. Second, actigraphy provides good estimates but not perfect measures of sleep. However, there is no perfect measure. Although polysomnography is often consider as the gold standard in sleep research, it has a very limited role in the current clinical practice and evaluation of patients with insomnia (34). Furthermore, it may interrupt normal sleep behaviors and thus overestimate the sleep problems of insomnia patients. Several clinical studies comparing sleep estimates from actigraphy and polymnography suggested that actigraphy may modestly overestimate insomnia patients' sleep time and underestimate wake time by scoring motionless periods in bed as sleep (35–37). Accordingly, actigraphy may underestimate the differences in sleep duration, percent sleep, WASO, wake bouts, and latency among older adults with and without insomnia. However, this would give us conservative estimates of the correlations between insomnia report and actigraphic measures, and yet we found many significant associations. Third, we cannot exclude the possibility that the absence of association between latency and trouble falling asleep could be due to imprecisely pushing the event marker. However, the mean latency (e.g., 29 min) in our sample was not substantially different from other studies (38). Fourth, there is no specific timeframe for insomnia questions. For clinical diagnosis of insomnia, symptoms must persist for 6 months. As such, these questions are best viewed as screening tools for insomnia symptoms for the general population of older adults rather than diagnostic. It is also possible that the limitation in survey questions led to weaker correlations between self-report and actigraphic sleep measures than expected. Fifth, the Sleep Booklet did not ask questions about diagnosis of sleep apnea. As such, we were not able to adjust it in our analysis. However, we performed a sensitivity analysis by stratifying the sample into a "higher-risk apnea" group (rarely or never, $N = 81$) and a "lower-risk apnea" group (most of the time and sometimes, $N = 646$) based on answers of the feeling rested question and comparing the reported-actigraphic relationship in these two groups. As individuals with apnea would be very

likely to answer "rarely" or "never" to this question, this sensitivity can provide additional insights on the potential influence of sleep apnea on the reported-actigraphic relationship. Our results from these two groups were similar although many of the coefficients from the "higher-risk apnea" group were nonsignificant because of the very small sample size of the "higher-risk apnea" group. Thus, results from this sensitive analysis offer some suggestive evidence that sleep apnea may not be an influential factor in shaping reported-actigraphic relationship. Finally, individuals may answer these survey questions differently than they might answer similar questions in a clinical encounter.

In sum, our findings suggest that three of four insomnia symptom reports correlated with estimates of sleep characteristics of older adults based on actigraphic measures but often not to the objective features that seemed to be indexed by these questions. We conclude that insomnia symptom reports among older adults may act as more general indicators of sleep satisfaction that tap into various dimensions of sleep and perhaps also other aspects of health.

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References

1. Ancoli-Israel S, Roth T. Characteristics of insomnia in the United States: results of the 1991 National Sleep Foundation Survey. I. *Sleep*. 1999;22(suppl 2):S347–S353.
2. Ohayon MM, Riemann D, Morin C, Reynolds CF 3rd. Hierarchy of insomnia criteria based on daytime consequences. *Sleep Med*. 2012;13:52–57. doi:10.1016/j.sleep.2011.06.010
3. Harvey AG. Insomnia: symptom or diagnosis? *Clin Psychol Rev*. 2001;21:1037–1059. doi:10.1016/S0272-7358(00)00083-0
4. Brower KJ, Aldrich MS, Robinson EA, Zucker RA, Greden JF. Insomnia, self-medication, and relapse to alcoholism. *Am J Psychiatry*. 2001;158:399–404. doi:10.1016/S1087-0792(03)90005-0
5. Kryger MH, Steljes D, Pouliot Z, Neufeld H, Odynski T. Subjective versus objective evaluation of hypnotic efficacy: experience with zolpidem. *Sleep*. 1991;14:399–407. doi:10.1016/S0304-3959(97)00207-8
6. Ouellet MC, Morin CM. Subjective and objective measures of insomnia in the context of traumatic brain injury: a preliminary study. *Sleep Med*. 2006;7:486–497. doi:10.1016/j.sleep.2006.03.017
7. Wilson KG, Watson ST, Currie SR. Daily diary and ambulatory activity monitoring of sleep in patients with insomnia associated with chronic musculoskeletal pain. *Pain*. 1998;75:75–84.
8. Foley DJ, Monjan AA, Brown SL, Simonsick EM, Wallace RB, Blazer DG. Sleep complaints among elderly persons: an epidemiologic study of three communities. *Sleep*. 1995;18:425–432.
9. Foley D, Ancoli-Israel S, Britz P, Walsh J. Sleep disturbances and chronic disease in older adults: results of the 2003 National Sleep Foundation Sleep in America Survey. *J Psychosom Res*. 2004;56:497–502. doi:10.1016/j.jpsychores.2004.02.010
10. Giron MS, Forsell Y, Bernsten C, Thorslund M, Winblad B, Fastbom J. Sleep problems in a very old population: drug use and clinical correlates. *J Gerontol A Biol Sci Med Sci*. 2002;57:M236–M240. doi:10.1093/gerona/57.4.M236
11. Blackwell T, Yaffe K, Ancoli-Israel S, et al.; Study of Osteoporotic Fractures Group. Poor sleep is associated with impaired cognitive function in older women: the study of osteoporotic fractures. *J Gerontol A Biol Sci Med Sci*. 2006;61:405–410.
12. Cricco M, Simonsick EM, Foley DJ. The impact of insomnia on cognitive functioning in older adults. *J Am Geriatr Soc*. 2001;49:1185–1189. doi:10.1046/j.1532-5415.2001.49235.x
13. Haimov I, Hanuka E, Horowitz Y. Chronic insomnia and cognitive functioning among older adults. *Behav Sleep Med*. 2008;6:32–54. doi:10.1080/15402000701796080
14. Goldman SE, Ancoli-Israel S, Boudreau R, et al.; Health, Aging and Body Composition Study. Sleep problems and associated daytime fatigue in community-dwelling older individuals. *J Gerontol A Biol Sci Med Sci*. 2008;63:1069–1075.
15. Stenholm S, Kronholm E, Sainio P, et al. Sleep-related factors and mobility in older men and women. *J Gerontol A Biol Sci Med Sci*. 2010;65:649–657. doi:10.1093/gerona/glq017
16. Brassington GS, King AC, Bliwise DL. Sleep problems as a risk factor for falls in a sample of community-dwelling adults aged 64-99 years. *J Am Geriatr Soc*. 2000;48:1234–1240.
17. Latimer Hill E, Cumming RG, Lewis R, Carrington S, Le Couteur DG. Sleep disturbances and falls in older people. *J Gerontol A Biol Sci Med Sci*. 2007;62:62–66.
18. Phillips B, Mannino DM. Do insomnia complaints cause hypertension or cardiovascular disease? *J Clin Sleep Med*. 2007;3:489–494.
19. Kaufmann CN, Canham SL, Mojtabai R, et al. Insomnia and health services utilization in middle-aged and older adults: results from the Health and Retirement Study. *J Gerontol A Biol Sci Med Sci*. 2013;68:1512–1517.
20. Lauderdale DS, Schumm P, Kurina LM, McClintock M, Thisted RA, Chen J, Waite J. Assessment of sleep in the National Social Life, Health and Aging Project. *J Gerontol B Psychol Sci Soc Sci*. In press.
21. Ancoli-Israel S, Cole R, Alessi C, Chambers M, Moorcroft W, Pollak CP. The role of actigraphy in the study of sleep and circadian rhythms. *Sleep*. 2003;26:342–392.
22. Williams R. Generalized ordered logit/partial proportional odds model for ordinal dependent variables. *Stata J*. 2007;6(1): 58–82.
23. Allison DP. *Missing Data*. Thousand Oaks, CA: Sage; 2002.
24. StataCorp. STATA Statistical Software. Version 12. College Station, TX: StataCorp LP; 2011.
25. Cuzick J. A wilcoxon-type test for trend. *Stat Med*. 1985. 4(4): 543–547.
26. Bliwise DL. Sleep in normal aging and dementia. *Sleep*. 1993;16:40–81.
27. Gangwisch JE, Heymsfield SB, Boden-Albala B, et al. Sleep duration associated with mortality in elderly, but not middle-aged, adults in a large US sample. *Sleep*. 2008;31:1087–1096.
28. Krystal AD, Edinger JD. Measuring sleep quality. *Sleep Med*. 2008;9(suppl 1):S10–S17. doi:10.1016/S1389-9457(08)70011-X
29. Armitage R, Trivedi M, Hoffmann R, Rush AJ. Relationship between objective and subjective sleep measures in depressed patients and healthy controls. *Depress Anxiety*. 1997;5:97–102. doi:10.1002/(SICI)1520-6394
30. Cirillo DJ, Wallace RB. Restless legs syndrome and functional limitations among American elders in the Health and Retirement Study. *BMC Geriatr*. 2012;12:39. doi:10.1186/1471-2318-12-39
31. Divani AA, Hoonjan A, Hesselbirg J, Halik L, Dunbar S, Khan S. Analysis of poststroke sleep abnormality from health and retirement study survey. *Stroke*. 2006; 37(2): 687–688.

32. Divani AA, Majidi S, Barrett AM, Noorbaloochi S, Luft AR. Consequences of stroke in community-dwelling elderly: the health and retirement study, 1998 to 2008. *Stroke*. 2011;42:1821–1825.
33. Dowd JB, Todd M. Does self-reported health bias the measurement of health inequalities in U.S. adults? Evidence using anchoring vignettes from the Health and Retirement Study. *J Gerontol B Psychol Sci Soc Sci*. 2011;66:478–489. doi:10.1161/STROKEAHA.110.607630
34. Reite M, Buysse D, Reynolds C, Mendelson W. The use of polysomnography in the evaluation of insomnia. *Sleep*. 1995;18:58–70.
35. Hauri PJ, Wisbey J. Wrist actigraphy in insomnia. *Sleep*. 1992;15:293–301. doi:10.1093/geronb/gbr050
36. Kushida CA, Chang A, Gadkary C, Guilleminault C, Carrillo O, Dement WC. Comparison of actigraphic, polysomnographic, and subjective assessment of sleep parameters in sleep-disordered patients. *Sleep Med*. 2001;2:389–396. doi:10.1016/S1389-9457(00)00098-8
37. Lichstein KL, Stone KC, Donaldson J, et al. Actigraphy validation with insomnia. *Sleep*. 2006;29:232–239.
38. McCrae CS, Rowe MA, Tierney CG, Dautovich ND, Definis AL, McNamara JP. Sleep complaints, subjective and objective sleep patterns, health, psychological adjustment, and daytime functioning in community-dwelling older adults. *J Gerontol B Psychol Sci Soc Sci*. 2005;60:P182–P189. doi:10.1093/geronb/60.4