ARTICLES

Greater Night-to-Night Variability in Sleep Discrepancy Among Older Adults with a Sleep Complaint Compared to Noncomplaining Older Adults

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Research in younger adults suggests sleep discrepancy (objective/subjective measurement difference) is a consistent pattern that primarily occurs within individuals with insomnia. To examine whether older adults exhibit a similar pattern, this study compared night-to-night inconsistency in sleep discrepancy between older adults with and without sleep complaints. Older adults (N = 103; mean age = 72.81, SD = 7.12) wore an Actiwatch-L® (24 hr per day) and concurrently completed sleep diaries for 14 days. Sleep discrepancy = diary (sleep onset latency [SOL] or wake [time] after sleep onset [WASO]) − actigraphy (SOL or WASO). Both groups exhibited sleep discrepancy, but complainers exhibited significantly more night-to-night variability. Sleep discrepancy was a variable behavior that was not limited to insomnia, but instead manifested by degree throughout our older sample. Greater attention to variability in sleep research and clinical practice is warranted.

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Late-life insomnia is a prevalent and serious health problem, affecting roughly 30% of older adults (Foley et al., 1995). Epidemiological studies indicate the prevalence of insomnia increases with age. This increase may be the result of multiple age-related factors including changes in sleep architecture, the arousal systems, and cognitive processes (reviewed in Dzierzewski, O’Brian, Kay, & McCrae, 2010). Sleep discrepancy, broadly defined as a marked difference between objective measures and subjective accounts of sleep, is commonly observed in older adult samples (e.g., Buysse et al., 1991; Vitiello, Larsen, & Moe, 2004). Similar to insomnia, inaccurate perceptions of sleep increase with age, particularly after the age of 65 (Spiegel, 1981), suggesting sleep discrepancy may play a role in the high rates of late-life insomnia. Even occasional perceptions of longer sleep onset latency (SOL), greater wake (time) after sleep onset (WASO), or less total sleep time (TST) may lead to poor overall subjective evaluations of sleep and subsequent daytime functioning. This phenomenon appears to be particularly problematic when self-report of sleep difficulties far exceeds objective indicators of troubled sleep. This type of sleep discrepancy, sometimes called sleep misperception, may directly contribute to greater daytime impairment complaints and indirectly lead to protective behaviors (e.g., staying in bed longer) that disrupt sleep (Semler & Harvey, 2005). More research examining sleep perception in later life has been called for (Bonnet & Moore, 1982), as this line of research may lead to new preventative and therapeutic interventions for late-life insomnia.

The phenomenon of sleep discrepancy has not been studied extensively among older adults. Indeed, studies among older adults have largely been limited to comparing objective measures to subjective accounts of sleep, without quantifying sleep discrepancy as a distinct sleep variable per se (e.g., Haimov, Breznitz, & Shiloh, 2005; McCrae et al., 2005; O’Donnell et al., 2009; Spiegel, 1981, chap. 10; van Hilten et al., 1993; Webb, 1983). Collectively, these studies revealed relatively weak and inconsistent correlations between objective and subjective measures of sleep among older adults. For example, Hoch et al. (1987) found that objective measurement and subjective accounts of SOL or WASO did not correlate among men, and only correlated on one out of three nights in women. Another study found that the correlations between self-reported and polysomnographically recorded SOL were better for older women than older men, but were still relatively unimpressive (Spiegel, 1981, chap. 10). Based on preliminary data in which electroencephalographic measures and subjective reports of WASO were compared, Webb reported low interrelations among older adults. A more recent study in older adults found only small to medium correlations between polysomnography (PSG) and sleep diary reports of SOL ($r = .26$ and .32), and nonsignificant to small correlations between PSG and sleep diary reports of number of nighttime awakenings ($r = .24$; O’Donnell et al., 2009). Finally, one study comparing sleep diary estimates of SOL and WASO to actigraphy measures also found relatively weak correlations across gender, sleep quality, and sleep complaint groups ($r = -.63$--.59; McCrae et al., 2005).

The absence of robust relationships between objective and subjective accounts of sleep variables (e.g., SOL and WASO) among community-dwelling older adults (McCrae et al., 2005; O’Donnell et al., 2009) and healthy seniors (Hoch et al., 1987, Webb & Schneider-Helmer, 1984) may be explained, in part, by a high degree of intraindividual variability in the relationship between objective and subjective measures of sleep in older adults. In younger samples, sleep discrepancy has been described as a consistent pattern of behavior found among a subset of individuals with insomnia (Edinger & Krystal, 2003; Fernandez-Mendoza et al., 2011; Trajanovic, Radivojevic, Kaushansky, & Shapiro, 2007). However, there is some evidence
that sleep discrepancy may be more inconsistent from night to night among older adults (Fichten, Creti, Amsel, Bailes, & Libman, 2005). For example, Spiegel (1981) showed that the magnitude of the correlation between objective and subjective measures changed across 3 nights of recording, particularly among men (Day 2 = .291, Day 3 = .476, and Day 4 = .298). The relationship between subjective measures (such as SOL) and objective measures of sleep in older individuals may depend greatly on the particular night on which sleep is sampled. This may make accurate classification of older adults into insomnia subtypes (e.g., sleep state misperception) more difficult.

A high degree of intraindividual variability (also called night-to-night inconsistency) in sleep parameters is a common characteristic of insomnia, particularly among older adults with insomnia (Buysse et al., 2010; van Hilten et al., 1993). Within older adults, oscillations in sleep variables such as napping, TST, SOL, and WASO are common over the course of multiple days and weeks, regardless of whether the measurement tool is PSG, actigraphy, or sleep diaries (Buysse et al., 2010; Dzierzewski et al., 2008; Wohlgemuth, Edinger, Fins, & Sullivan, 1999). This variability is being increasingly recognized as an important health-related factor among older adults (Buysse et al., 2010), but continues to be neglected in the research literature. Although night-to-night variability in sleep has recently been quantified using sleep diaries and actigraphy (Edinger & Krystal, 2003), the sleep discrepancy between these measures for either SOL or WASO has yet to be quantified and described in a large sample of older adults. The aim of this study was to compare the relative amount of night-to-night variability in sleep discrepancy among older adults with and without a sleep complaint. A significant difference in night-to-night variability in sleep discrepancy would illustrate the importance of quantifying such variability to more fully understand the sleep of older adults. Because older adults with insomnia demonstrate greater night-to-night variability in many sleep parameters, we hypothesized that sleep discrepancy would demonstrate higher night-to-night variability among older adults with a sleep complaint than would be found among noncomplaining older adults.

METHOD

Participants and Procedures

This study involved secondary analyses of sleep data obtained from 103 older adults (McCrae et al., 2005). All participants lived in their own homes during the study. At the initiation of the study, participants completed a health survey that consisted of 13 items concerning demographics, sleep complaint status, physical health, and mental health (Lichstein, Durrence, Riedel, Taylor, & Bush, 2004). Complaint status was based on responses to the following items from the demographics and health survey:

1. “Do you have a sleep problem? If yes, describe (e.g., trouble falling asleep, long or frequent awakenings, sleep apnea).”
2. “How long have you had this sleep problem?”

Participants were classified as complaining if they reported a complaint of insomnia for at least 6 months ($M = 6.81$ years, $SD = 5.76$); otherwise, they were classified as noncomplaining.
Patients who self-reported sleep disorders other than insomnia (apnea, narcolepsy, or restless leg syndrome), or reported symptoms of sleep diagnoses other than insomnia (e.g., heavy snoring or gasping for breath), were disqualified.

Participants completed a sleep diary each morning (Lichstein, Riedel, & Means, 1999), and concurrently wore an Actiwatch-L® wrist device continuously for 14 days (Mini Mitter Co. Inc., 2001). The Actiwatch-L was used to determine objective SOL (SOLo) and WASO (WASOo), as described previously (McCrae et al., 2005). The subscript o is used to demark objective variables. A validated algorithm was used to identify the activity of each epoch as wake or sleep (Oakley, 1997). The high sensitivity setting of the actigraph was employed. For this study, two subjective sleep measures were obtained from sleep diaries: SOLs (perceived time from lights out until sleep onset) and WASOs (perceived total time spent awake between initial sleep onset and last awakening). The subscript s demarks subjective variables.

The methodology and utility of using actigraphy and sleep diaries in quantifying and studying sleep discrepancy in research and clinical practice has been reported previously (Tang & Harvey, 2004, 2006). Raw daily subjective reports of SOL and WASO were subtracted from respective daily actigraphy measures to compute daily SOLd and WASOd (subscript d denotes sleep discrepancy occurring during SOL or WASO), as has been done previously to calculate sleep discrepancy (Tang & Harvey, 2004). The equation for calculating sleep discrepancy during SOL was SOLd = SOLs - SOLo; and for calculating sleep discrepancy that occurred during WASO, the equation WASOd = WASOs - WASOo was used. Traditionally, sleep researchers have combined SOLd and WASOd to create a more robust sleep misperception variable (Means, Edinger, Glenn, & Fins, 2003). Because combining multiple nights of SOLd and WASOd into one variable creates a more robust variable, it is likely that these variables co-occur on some level. However, we recently showed that this relationship may not occur on the daily level. Indeed, we found that SOLd and WASOd did not correlate on the daily level among older adults (Kay & McCrae, 2008). Concerning the utility of these methods, actigraphy and sleep diaries provide (a) low cost and nonintrusive means of studying sleep in older adults, (b) a metric of sleep discrepancy in a naturalist sleep environment, and (c) daily data collected over several weeks with low burden on participants.

The Beck Depression Inventory–Second Edition (BDI–II; Beck, Steer, & Brown, 1996) and the State–Trait Anxiety Inventory, Form Y (STAI–Y1; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) were completed at the conclusion of the 14-day sleep recording period. A more extensive description of recruitment, the informed consent process, study procedures, and demographics of participants has been previously published (McCrae et al., 2005).

Data Analyses

Demographic information was compared between complaining and noncomplaining older adults using independent-samples t tests or chi-squares (see Table 1). The amount of night-to-night variation in SOLd and WASOd over 14 days in a general sample of community-dwelling older adults was calculated. Individually (sample standard deviation) and night-to-night (intraindividual) variability (individual standard deviation) were computed for both SOLd and WASOd. Thus, each individual’s individual standard deviation for SOLd and WASOd was determined by calculating their standard deviation from their own average amount of sleep discrepancy for each variable. Then, to place the night-to-night variability in an easily
# TABLE 1

Demographics and Health-related Characteristics for the Total Sample and by Sleep Complaint Status

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total Sample</th>
<th>Sleep Complainers&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Sleep Noncomplainers&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Cohen’s d&lt;sup&gt;c&lt;/sup&gt;</th>
<th>t/df&lt;sup&gt;2&lt;/sup&gt;</th>
<th>df</th>
<th>p</th>
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</thead>
<tbody>
<tr>
<td>Age</td>
<td>72.81 7.12</td>
<td>74.00 5.50</td>
<td>72.47 7.32</td>
<td>0.24</td>
<td>1.02 101</td>
<td>.312</td>
<td></td>
</tr>
<tr>
<td>Years of education</td>
<td>16.34 2.92</td>
<td>13.00 2.70</td>
<td>13.70 2.70</td>
<td>0.26</td>
<td>−2.20 100</td>
<td>.030*</td>
<td></td>
</tr>
<tr>
<td>Gender (% female)</td>
<td>66 —</td>
<td>19 —</td>
<td>47 —</td>
<td>0.04</td>
<td>1</td>
<td>.519</td>
<td></td>
</tr>
<tr>
<td>Ethnicity (% Caucasian)</td>
<td>99 —</td>
<td>73 —</td>
<td>26 —</td>
<td>4.93</td>
<td>2</td>
<td>.085</td>
<td></td>
</tr>
<tr>
<td>Marital status (% married)</td>
<td>61 —</td>
<td>45 —</td>
<td>16 —</td>
<td>3.85</td>
<td>3</td>
<td>.384</td>
<td></td>
</tr>
<tr>
<td>BDI–II score</td>
<td>5.71 4.91</td>
<td>6.41 5.23</td>
<td>5.00 4.59</td>
<td>0.29</td>
<td>1.35 101</td>
<td>.179</td>
<td></td>
</tr>
<tr>
<td>STAI–Y1 score</td>
<td>30.71 8.53</td>
<td>32.32 8.63</td>
<td>29.10 8.42</td>
<td>0.38</td>
<td>1.70 100</td>
<td>.092</td>
<td></td>
</tr>
<tr>
<td>No. of medications</td>
<td>3.15 2.14</td>
<td>3.62 2.13</td>
<td>2.68 2.15</td>
<td>0.44</td>
<td>2.01 101</td>
<td>.047*</td>
<td></td>
</tr>
<tr>
<td>No. of comorbid complaints</td>
<td>2.50 1.60</td>
<td>3.28 1.94</td>
<td>1.72 1.26</td>
<td>0.95</td>
<td>4.81 101</td>
<td>&lt; .001**</td>
<td></td>
</tr>
</tbody>
</table>

Sleep variables

| SOL actigraph | 22.690 11.960 | 26.110 12.890 | 19.270 11.030 | 0.27 | 2.70 101.00 | < .010*** |
| WASO actigraph | 58.535 23.165 | 63.540 22.690 | 53.530 23.640 | 0.21 | 1.95 100.00 | .054 |
| SOL sleep diary | 26.745 18.295 | 33.140 22.690 | 20.350 13.900 | 0.32 | 2.83 36.53 | < .010*** |
| WASO sleep diary | 32.130 24.430 | 44.270 29.060 | 19.990 19.800 | 0.44 | 4.87 38.62 | < .001*** |
| SOL discrepancy | 3.895 18.200 | 6.760 24.150 | 1.030 12.250 | 0.15 | 1.22 33.80 | .230 |
| WASO discrepancy | −24.300 30.590 | −14.800 34.940 | −33.800 26.240 | 0.29 | 2.61 39.09 | < .050* |

Note. N = 103. BDI–II = Beck Depression Inventory–Second Edition; STAI–Y1 = State–Trait Anxiety Inventory, Form Y; SOL = sleep onset latency; WASO = wake after sleep onset.

<sup>a</sup>n = 29, <sup>b</sup>n = 74.

<sup>c</sup>p < .05 (indicates significant differences in respective variable between sleep complaining and noncomplaining older adults).

<sup>**</sup>p < .01 (indicates significant differences in respective variable between sleep complaining and noncomplaining older adults).

<sup>***</sup>p < .001 (indicates significant differences in respective variable between sleep complaining and noncomplaining older adults).

understandable metric, a Nightly Variability Index was calculated by dividing the individual standard deviation for both variables by their respective sample standard deviations. Thus, the Nightly Variability Index for SOL<sub>d</sub> = Individual Standard Deviation for SOL<sub>d</sub>/Sample Standard Deviation for SOL<sub>d</sub>. The Nightly Variability Index for WASO<sub>d</sub> = Individual Standard Deviation for WASO<sub>d</sub>/Sample Standard Deviation for WASO<sub>d</sub>. These indexes provided the proportion of between-person variability that is found within-persons (or stated differently: Compared to the amount of variability in the sample from person to person, how much variation was located within-persons from night to night?—How much night-to-night variability did they display?). Nightly Variability Indexes = 1 would indicate equal amounts of night-to-night variability and interindividual variability, Nightly Variability Indexes < 1 would indicate greater amounts of interindividual variability compared to night-to-night variability, and Nightly Variability Indexes > 1 would indicate greater amounts of night-to-night variability compared to interindividual variability.

A multivariate analysis of covariance (MANCOVA) was then used to compare the Nightly Variability Indexes in SOL<sub>d</sub> and WASO<sub>d</sub> between older individuals with and without sleep complaints, controlling for the number of comorbid health complaints and number of current medications. The Nightly Variability Indexes for SOL<sub>d</sub> and WASO<sub>d</sub> for each sleep complaint group (complainers vs. noncomplainers) were the dependent variables. Variables found to be non-normally distributed were normalized via a square root transformation. The individual standard deviations for SOL<sub>d</sub> and WASO<sub>d</sub> were not normally distributed for the two complaint status groups, and a square root transformation was used to make the variables more normal.
After this transformation, SOL\(_d\) was successfully normalized (skewness & kurtosis < 1.00), and the distributional properties of WASO\(_d\) were greatly improved (skewness = 1.44; kurtosis = 3.12). More important, both assumptions essential to MANCOVA assessed in this aim were met: Box’s sphericity assumption of equality and Levene’s assumption of equality of variance. We chose to investigate SOL\(_d\) and WASO\(_d\) individually, rather than combined, in a total wake time discrepancy (TWT\(_d\)) variable, as has been done in one previous study (Means et al., 2003), because on previous analyses of our data, we found that SOL\(_d\) and WASO\(_d\) did not positively covary on a daily level. In other words, nights that individuals had higher SOL\(_d\), did not predict that WASO\(_d\) would also be high (Kay & McCrae, 2008).

**RESULTS**

See Table 1 for demographic and health-related characteristics for the total sample and by sleep complaint status. Older adults with a sleep complaint had significantly more comorbid health complaints, used more medications, and had fewer number of years education than older adults without a sleep complaint (all \(p_s < .05\)). Concerning relevant sleep-related characteristics, complainers had significantly more actigraphically and sleep diary measured SOL. Sleep diary measurement of WASO was significantly greater for complainers than noncomplainers. This was supported by trend level differences in actigraphic measurement of WASO. It is interesting to note that mean level differences in sleep discrepancy were significantly different for complainers than noncomplainers, but SOL sleep discrepancy was no different between groups.

**Night-to-Night Variability in SOL\(_d\) and WASO\(_d\)**

The sample standard deviations (interindividual variability), individual standard deviations (night-to-night variability), and Nightly Variability Indexes for SOL\(_d\) and WASO\(_d\) are shown in Table 2. An examination of the sample standard deviations and individual standard deviations for SOL\(_d\) and WASO\(_d\) indicated that this sample of older participants exhibited considerable amounts of variation in sleep (both interindividual and night to night) across the 14-day recording period. An examination of the Nightly Variability Index for SOL\(_d\) and WASO\(_d\) revealed greater night-to-night variability in SOL\(_d\) and almost as much night-to-night variability as interindividual variability in WASO\(_d\). Specifically, SOL\(_d\) was found to be 150% more variable from night to night as compared to interindividual variability. Moreover, night-to-night variability in WASO\(_d\) was 95% of the amount of interindividual variability.

**Night-to-Night Variability in SOL\(_d\) and WASO\(_d\) by Complaint Status**

Overall, MANCOVA revealed that complainers exhibited a significantly larger Nightly Variability Index, on average, than did noncomplainers: Pillai’s Trace = .15, \(F(2, 95) = 8.29, p < .001\) (\(\eta^2 = .15\)). Covariates were not significant. Follow-up analyses of variance (ANOVA) revealed that complainers exhibited larger Nightly Variability Indexes, on average, for both SOL\(_d\) and WASO\(_d\) than noncomplainers, \(F(1, 96) = 9.21, p < .05 (\eta^2 = .09)\) and \(F(1, 96) = 13.70, p <
## DISCUSSION

This study revealed high night-to-night variability in sleep discrepancy in a sample of community-dwelling older adults. Results suggest that within older individuals, objective and subjective measures of sleep may not be constantly discrepant from night to night, as has been shown in younger samples (Edinger & Krystal, 2003; Fernandez-Mendoza et al., 2011; Trajanovic et al., 2007). This study also showed that older sleep complainers exhibited significantly more night-to-night variability in the two sleep discrepancy variables tested in this study (i.e., SOL and WASO) than did noncomplainers. Thus, our hypothesis that complainers would be significantly more variable than noncomplainers was confirmed. Finally, this study confirms previous reports that older adults with a sleep complaint have more comorbid health complaints and use more medications than older adults without a sleep complaint (Ancoli-Israel & Cooke, 2005; Stewart et al., 2006). Notably, these medical considerations were not significantly related to variability in sleep discrepancy, suggesting that the relation between insomnia and sleep discrepancy cannot be explained by general health or medication use.
FIGURE 1  Sleep noncomplaining and complaining older adults’ bi-week night-to-night variability in sleep onset latency sleep discrepancy.
FIGURE 2  Sleep noncomplaining and complaining older adults’ bi-week night-to-night variability in wake (time) after sleep onset sleep discrepancy.
Nosology of Sleep Discrepancy

The term *sleep discrepancy* was used in this study, rather than *sleep misperception*, the more widely used term, for two reasons. First, sleep misperception, or sleep state misperception, implies that individuals perceive the sleeping states as wakefulness. Therefore, the term *sleep misperception* is more appropriately used to describe a discrepancy between objective (PSG) indexes of wake/sleep states compared to self-reports of those states. Second, sleep misperception has been conceptualized as a consistent and unidirectional pattern of pathology. Therefore, the term *sleep discrepancy* is more appropriate when studying inconsistent patterns of bidirectional (positive and negative) discrepancy between objective measures and self-reports of sleep parameters. Sleep discrepancy in the negative direction might be an adequate indirect measure of sleep misperception; however, because this investigation is interested in both subjective over- and underestimates of sleep parameters and because sleep states were not assessed directly, the term *sleep misperception* was not utilized.

Clinical Relevance

As actigraphy becomes more widely utilized in conjunction with sleep diaries and more fully integrated into clinical practice (Morgenthaler et al., 2007), high night-to-night variability in sleep discrepancy may have clinical implications for the (a) assessment, (b) diagnosis, and (c) treatment of insomnia complaints in older adults.

First, a detailed assessment of night-to-night sleep patterns is essential for diagnosis and treatment planning for complaining older adults. This study found that night-to-night variability in SOL<sub>d</sub> was significantly different between complaining and noncomplaining older adults, but the average magnitude of SOL<sub>d</sub> was not. This highlights how the standard practice of averaging sleep data over multiple days may fail to properly characterize the sleep problems of older adults. When assessing sleep of older adults, greater attention to daily patterns may provide a more accurate clinical picture of patients’ sleep problems than can be obtained from averaged characterizations alone.

Second, these findings have potential clinical relevance for increasing the utility of actigraphy in making a differential insomnia diagnosis. In patients for whom sleep state misperception is suspected, the examination of night-to-night variability in sleep diary and actigraphic data (through the calculation of the Nightly Variability Index described in this study) could provide useful information to assist with the differential diagnosis. A diagnosis of paradoxical insomnia (also called sleep state misperception) is made when all criteria for insomnia are met, but (a) subjective complaints far exceed objective evidence of sleep disturbance or (b) daytime impairments do not reflect the level of reported sleep disturbance (Sateia, 2005). This diagnosis is restricted to only those individuals who (a) report a chronic pattern of little or no sleep most nights, (b) show an average sleep time well below published age-adjusted norms, or (c) show “a consistent [italics added] marked mismatch between objective findings from [PSG] or actigraphy and subjective sleep estimates” (American Academy of Sleep Medicine, 2005). Depending on how a clinician assesses sleep discrepancy in older adults, the diagnosis may be very different. If only one night of objective sleep is assessed, the diagnosis will be almost entirely determined by the day in which the sleep is assessed due to high night-to-night variability in sleep discrepancy. Alternatively, if an average of sleep discrepancy is used,
older adult complainers with highly variable patterns in sleep discrepancy are likely to be misclassified. In either case, due to the high level of night-to-night variability in sleep discrepancy, complaining older adults may be more likely to have the nature of their sleep complaint mischaracterized, and ultimately receive an incorrect diagnosis. Third, older adults incorrectly diagnosed with sleep state misperception may receive little or inappropriate treatment for their insomnia. Several authors have made recommendations for the treatment of sleep discrepancy that rely on the assumed consistency of this symptom. For example, Mercer, Bootzin, and Lack (2002) suggested that cognitive therapy may be appropriate for correcting sleep discrepancy, and that showing patients that their subjective estimates do not match objective measures may aid in this treatment. However, as has been pointed out by others (Sateia, 2005), this technique is not typically helpful. As another example, Edinger et al. (2000) suggested that treating mood, anxiety, and dysfunctional beliefs about sleep may be beneficial to individuals with sleep state misperception, whereas individuals with objective sleep disturbance would benefit from “strategies designed to eradicate actual sleep deficits” (p. 592).

These treatment plans may be inappropriate without a thorough assessment of night-to-night variability in sleep discrepancy. Nevertheless, given that high night-to-night variability in sleep discrepancy is observed, it may be beneficial for clinicians to provide feedback about what a patient is reporting and what actigraphy is recording, and to review these patterns of sleep discrepancies with patients. Clinicians who use this tool appropriately (not to disprove the patients’ perceptions, but to better understand the discrepancy) may help patients identify factors that contributed to the discrepancy and how discrepancy may be impacting subsequent behaviors (sleep protection behaviors).

Limitations

These results must be considered in light of important limitations. First, this secondary analysis was based on a convenience sample consisting of highly educated, mostly Caucasian, community-dwelling older adults. Thus, the results may not generalize to populations that are less educated, non-community dwelling, more diverse, or younger. Moreover, these results may not apply to many older adults with organic sleep complaints (sleep apnea or periodic leg movements), who make up approximately one-half of the elderly population (Ancoli-Israel, Kripke, Mason, & Kaplan, 1985).

Second, the interpretation of these results was based on the assumption that actigraphy is a viable objective measure of SOL and WASO. Although measurement error is one possible explanation for this night-to-night variability, we believe that this was not the case. Previous research suggests that actigraphy is a satisfactory objective measure of SOL and WASO across a wide age range of individuals with insomnia (Lichstein et al., 2006), and that sleep diaries and actigraphy share a systematic and directional (not variable) relationship (Tryon, 2004). Therefore, although additional research utilizing PSG is warranted, night-to-night variability in sleep discrepancy is best explained by older adults with sleep complaints misperceiving their sleep more dramatically, but randomly, than their noncomplaining peers.

Third, the limitation that actigraphy is less reliable than PSG in indentifying sleep/wake states in relationship to studying sleep discrepancy has been previously discussed (Tang & Harvey, 2004). However, because we used an actigraphy algorithm that has been validated in older adults, these weaknesses are slightly mitigated. Moreover, actigraphy has greater utility
in measuring objective sleep over the course of days and weeks because it is much more
cost effective and less disruptive to normal sleep than PSG, making its use in this study an
advantage. Nevertheless, because PSG was unavailable, a subset of participants included in this
study may have medically undiagnosed sleep apnea or periodic limb movement disorders that
may have impacted the results, as actigraphy may be less reliable in these patient populations.
Although this research should be interpreted with caution, we feel that the results warrant
further investigation using PSG and a younger adult comparison sample.

Research Implications and Future Directions

Our findings of considerable night-to-night variability in sleep discrepancy illustrate the inherent
limitations in the common methodological practices of (a) collecting only a single night of sleep
data and (b) averaging sleep data over multiple nights. Because these techniques are commonly
used to estimate the prevalence of sleep state misperception, the high degree of night-to-night
variability in sleep discrepancy among older adults may be an unrecognized confound. A large,
clinic-based study \( (N = 1,214) \) found that 9.2% of insomnia patients met criteria for sleep state
misperception (Coleman et al., 1982). Other studies have suggested that between 25% and 50%
of insomnia cases can be subsumed as sleep state misperceptions (Edinger & Krystal, 2003).
The wide range in rates of sleep state misperception may be at least partially attributable
to the variable nature of sleep discrepancy. Consideration of night-to-night variability may
be needed to establish reliable prevalence estimates of sleep state misperception, particularly
among older adults.

When levels of intraindividual variability approach or exceed levels than can be reason-
ably attributed to error, there is reason for concern because this variability is routinely ex-
cluded/considered error. We believe such variability is representative of naturally occurring
fluctuations in behavior that may provide meaningful information distinct from averaged es-
timates. In the cognitive aging literature, for example, indexes of intraindividual variability
in cognition are unique predictors of meaningful outcomes (e.g., neuropathology and health
status) above and beyond mean levels of cognitive functioning (Hultsch, MacDonald, Hunter,
Levy-Bencheton, & Strauss, 2000). More specific to sleep, examination of the night-to-night
patterns of sleep in patients with primary insomnia suggests that insomnia follows a predictable
sleep course in which a better than average night of sleep follows 1 to 3 nights of poor sleep
(Perlis et al., 2010). More research on the night-to-night variability in sleep is needed to
determine what predicts greater night-to-night variability in sleep discrepancy, and whether
this variability is involved in the etiology of late-life insomnia complaints.

It may be interesting to assess how night-to-night changes in sleep discrepancy correspond
with night-to-night changes in complaints of insomnia (Buysse et al., 2010). Future research
may help determine if, as has been found with interindivdual differences in sleep discrepancy
(Haimov et al., 2005), night-to-night changes in sleep discrepancy are related to day-to-day
changes in self-esteem and sense of cohesion. Finally, although more research is clearly needed
before recommendations for the use of the Nightly Variability Index for clinical purposes
can be made, it seems a worthy research endeavor to explore whether the combination of
significant sleep discrepancy and a lower Nightly Variability Index (indicative of greater or
lesser night-to-night variability in sleep misperception) would be associated with sleep state
misperception, and whether the combination of significant sleep discrepancy and a higher
Nightly Variability Index (indicative of greater night-to-night variability) can help to “rule out” sleep state misperception.

CONCLUSION

In summary, the results of this study highlight the need for sleep researchers and clinicians to consider night-to-night variability in how they conceptualize sleep among older adults, in general, and in sleep discrepancy/misperception research among older adults, specifically. In contrast to previous research in young adults suggesting that sleep discrepancy is a consistent behavior that occurs primarily in individuals with insomnia, sleep discrepancy appears to follow a variable pattern in older adults and appears to be ubiquitous, occurring in both complainers and noncomplainers (albeit to a greater degree in complainers). Future research exploring potential age-related differences in the night-to-night variability of sleep discrepancy is warranted. Because insomnia increases with age and sleep discrepancy has been implicated in the etiology of insomnia, such research has important implications for the diagnosis and treatment of late-life sleep disorders. In particular, future research examining the clinical utility of night-to-night variability in sleep discrepancy for the differential diagnosis of sleep state misperception is warranted.

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