SCIENTIFIC INVESTIGATIONS

JCSM
Journal of Clinical Sleep Medicine

pii: jc-00075-14
http://dx.doi.org/10.5664/jcsm.4456

Sleep-Wake Time Perception Varies by Direct or Indirect Query

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Study Objectives: The diagnosis of insomnia rests on self-report of difficulty initiating or maintaining sleep. However, subjective reports may be unreliable, and possibly may vary by the method of inquiry. We investigated this possibility by comparing within-individual response to direct versus indirect time queries after overnight polysomnography.

Methods: We obtained self-reported sleep-wake times via morning questionnaires in 879 consecutive adult diagnostic polysomnograms. Responses were compared within subjects (direct versus indirect query) and across groups defined by apnea-hypopnea index and by self-reported insomnia symptoms in presleep questionnaires. Direct queries required a time duration response, while indirect queries required clock times from which we calculated time durations.

Results: Direct and indirect queries of sleep latency were the same in only 41% of cases, and total sleep time queries matched in only 5.4%. For both latency and total sleep, the most common discrepancy involved the indirect value being larger than the direct response. The discrepancy between direct and indirect queries was not related to objective sleep metrics. The degree of discrepancy was not related to the presence of insomnia symptoms, although patients reporting insomnia symptoms showed underestimation of total sleep duration by direct response.

Conclusions: Self-reported sleep latency and total sleep time are often internally inconsistent when comparing direct and indirect survey queries of each measure. These discrepancies represent substantive challenges to effective clinical practice, particularly when diagnosis and management depends on self-reported sleep patterns, as with insomnia. Although self-reported sleep-wake times remains fundamental to clinical practice, objective measures provide clinically relevant adjunctive information.

Keywords: time perception, inconsistency, subjective, self-report

Citation: Alameddine Y, Ellenbogen JM, Bianchi MT. Sleep-wake time perception varies by direct or indirect query. *J Clin Sleep Med* 2015;11(2):123–129.

Patient self-report of sleep symptoms generally involves recollecting sleep-wake times, such as bed times, sleep latency, number and duration of awakenings, and final awakening times. This information plays a critical role in the clinical assessment and management of patients with sleep complaints such as insomnia. However, self-reported sleep-wake patterns have important limitations that should be recognized in both clinical and research contexts. For example, the time frame over which sleep is assessed (prior night versus longer-duration recollection) can affect self-reported sleep estimates.[1] In addition, the presence of a mood disorder can impact the self-reported sleep duration.[2] Finally, the best studied source of uncertainty involves what has been termed misperception: a mismatch between subjective and objective sleep-wake times.[3] Specifically, patients with insomnia generally overestimate how long it takes to fall asleep and underestimate the total amount of sleep in a given night. The uncertainty surrounding self-reporting complicates the clinical approach to insomnia because the diagnosis and evaluation of treatment effectiveness is explicitly reliant upon this information.[4]

Misperception among insomnia patients may involve overestimation of sleep latency, underestimation of total sleep time, or both, when compared to objective measures such as polysomnography (PSG). Misperception of sleep remains poorly understood.[3] We previously investigated potential roles for suspected mediators of misperception, such as sleep fragmentation or excessive stage N1, but no clear relationship was discernible.[5] Others have explored time perception, alpha-delta EEG patterns, and personality influences.[6–11] There are likely multiple mechanisms and factors involved, as no single factor has shown general predictive value to date.[3]

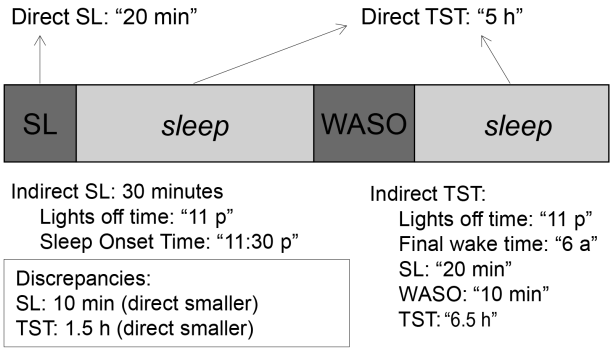
One potential source of variability in patient reporting could involve the manner in which the questions of sleep-wake times are posed. In our clinical sleep laboratory, every patient who undergoes PSG completes a postsleep questionnaire, in which they are asked to report their subjective estimate of sleep latency (SL), total sleep time (TST), number of

BRIEF SUMMARY

Current Knowledge/Study Rationale: Self reporting sleep-wake times is fundamental to the diagnosis and management of insomnia patients. However, much uncertainty exists in regard to mismatch between subjective and objective measures of sleep in this population. We tested the hypothesis that subjective reports might differ, within individuals, according to the nature of the time query.

Study Impact: Sleep-wake time responses depended on whether the query was direct or indirect. The results highlight an additional dimension of uncertainty when assessing sleep patterns by clinical history. This is particularly relevant for patients with insomnia, in whom objective measures are not routinely obtained.

Figure 1—Schematic of direct and indirect time queries.



One night is shown with times spent in sleep (light shade) and wake (dark shade). The first wake period (SL) is the sleep latency, which can be queried directly, with a response in minutes (e.g., "20 min"), or indirectly, by asking time of lights off ("11 p") and time of sleep onset ("11:30 p"). WASO is only queried directly; although in the cartoon it is shown as a single block, we ask patients to sum the total time spent awake after sleep onset, which could involve multiple awakenings. Total sleep time (TST) can be queried directly ("5 h"), or indirectly by subtracting the direct queries of SL and WASO from the boundaries of lights off and final wake up time. In this example, the direct SL query is smaller than the indirect SL calculation; the direct query of TST is smaller than the indirect calculation.

awakenings during the night, and duration of wake after sleep onset (WASO). These aspects of sleep are commonly present in sleep diaries used in the clinical management of patients with insomnia. In addition, patients are asked to recall the clock time corresponding to lights out, sleep onset, and final wake time. Thus, sleep-wake times are assessed in two ways: one that we consider a direct response (e.g., the SL response could be "30 minutes"), and one that we consider an indirect response (lights out time: "11 pm", and sleep onset time: "11:30 pm"). We tested the hypothesis that patients reporting insomnia symptoms would show internal inconsistency between the direct and indirect measures of SL and TST.

METHODS

We analyzed consecutive clinical diagnostic PSGs performed in our center in 2012. We excluded pediatric cases, those in whom positive airway pressure was administered (e.g., split night or titration studies), and those with missing questionnaires. The total population considered was n = 908. We did not consider the reason for referral to PSG, although in most cases this was for evaluation of obstructive sleep apnea (OSA). Each patient completed a postsleep survey regarding subjective estimation of sleep-wake times. Complete postsleep survey data was available for n = 879 (partially complete postsleep surveys were accepted, but those with completely missing surveys were excluded).

In the postsleep surveys, patients are queried regarding their sleep wake times in different ways that allowed us to compare direct responses to indirect calculations within individuals. For example, the direct query of SL prompts a response of duration (such as "20 minutes"). By comparison, the indirect determination of SL was calculated based on two queries that prompt clock time answers; for SL, these queries referred to the time of lights-out and to the time of sleep onset. The difference between the two clock time responses represent what we are calling the indirect SL. For TST, the direct query prompted a response of duration ("6 hours"). The indirect TST was calculated using several answers: an outer boundary of time in bed (TIB) was first defined by the self-reported times of lights out and final awakening time, from which the subjective SL (direct) and the subjective WASO value were subtracted. Objective lights-out time and objective TST were obtained from the PSG recording, and the self-reported sleep-wake times and lights-out time were obtained from the postsleep survey. The rooms do not have clocks, but we do not restrict or track devices brought to the lab by patients (clocks, watches, phones).

We prespecified grouping of the 879 patients according to sleep disordered breathing as well as reported insomnia symptoms. The OSA group consisted of all patients with AHI > 5 (n = 453), while the no OSA group was defined by AHI < 5 and RDI < 10 (n = 255). A substantial group had AHI < 5 but RDI > 10 (n = 171), and these were not considered for analysis according to these groupings. Insomnia symptoms were derived from presleep inventories of medical history and sleep-related symptoms. Clinical phenotyping of insomnia was not possible beyond this symptom inventory, as the majority of patients are referred to our center for testing without evaluation by a sleep specialist. Inventory questions about insomnia symptoms included indicating "insomnia" as the reason for undergoing PSG from a list of check-box choices, indicating difficulties with sleep onset (defined as indicating ≥ 30–60 min or choosing "I have trouble falling sleep" from a list of check boxes) or difficulties with maintaining sleep (defined as selecting "When I wake up at night, it takes me a long time to fall back asleep," or "I have trouble staying asleep," or reporting waking up ≥ 3 times at night, from a list of check boxes). We note that the symptom questions do not map precisely to diagnostic criteria, including duration and frequency of symptoms or daytime consequences attributed to insomnia symptoms. We report insomnia grouping according to whether none of the insomnia symptoms were indicated, versus any insomnia symptom was indicated.

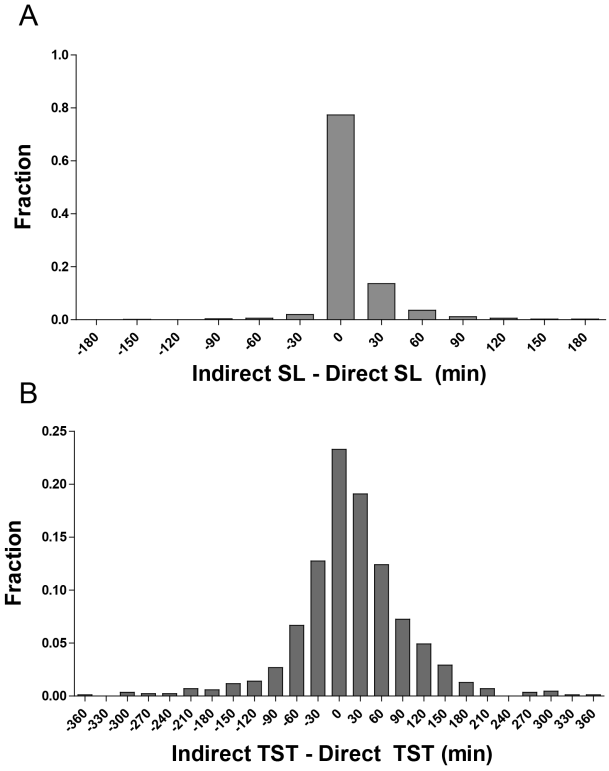
Statistics were performed using Prism (GraphPad software, La Jolla, CA). Most of the sleep measures were distributed nonnormally, and thus we used the nonparametric Kruskal-Wallis ANOVA (with Dunn multiple comparison post hoc testing) for group comparisons. For correlation analysis, nonparametric Spearman R values were calculated. Since this analysis was exploratory, we prespecified a cutoff R value of 0.2 to consider significant. In the supplement, we show the R values for this exploratory analysis, including those that had < 0.2 cutoff but had a significant p-value (we used a prespecified cutoff of 0.001 to take into account that we would be making 28 correlations for each category).

RESULTS

Sleep-Wake Time Queries

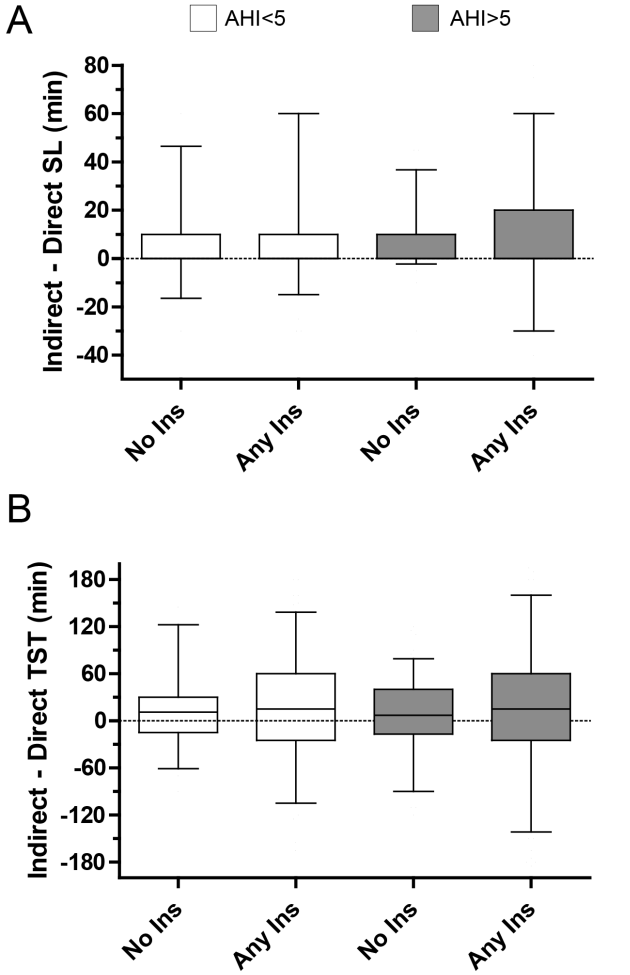
Patients undergoing clinical PSG in our lab are asked the morning after to answer a brief series of sleep-wake time

Figure 2—Distribution of discrepancies between indirect and direct time queries.



The frequency histograms of intra-individual differences between indirect and direct queries are shown for SL **(A)** and TST **(B)**. Bar height indicates the fraction of the cohort exhibiting any given discrepancy. Negative values indicate that the direct response was larger than the indirect response; positive values indicate the opposite.

Figure 3—Indirect versus direct time queries according to objective OSA metrics and self-reported insomnia symptoms.



The difference between indirect and direct queries of SL **(A)** and TST **(B)** are shown according to OSA category (gray indicates AHI > 5) and insomnia symptom reporting (none versus any). There were no differences detected by Kruskal-Wallis ANOVA in comparisons of discrepancy of SL or TST reporting by insomnia group among those with or without OSA.

questions. **Figure 1** illustrates what we have categorized as direct versus indirect queries of time. Direct queries required a response time (e.g., in minutes) for SL and TST. Indirect queries required a clock time response, from which we calculated time intervals (e.g., SL is calculated from time of lights off and time of sleep onset).

Comparing Direct and Indirect Measures of SL and TST

We calculated the within-individual difference between the indirect and direct measures of SL and TST. The histograms in **Figure 2** show the distributions of the differences. The direct and indirect measures of SL yielded the same value in 40.7% of the patients. The full distribution of differences between direct and indirect responses of SL is shown in **Figure 2A**. The direct response was less than the indirect calculation in 33%, by a median of 15 min (IQR: 10–30 min); it was greater than the indirect calculation by 15 min in 6.8%. In other words, the indirect measures were greater, on average, than the direct measures of SL.

The histogram in **Figure 2B** shows the distribution of the difference between the indirect calculations and direct responses for TST. The direct and indirect measures yielded the same value in only 5.4% of the cohort. The indirect measures were greater, on average, than the direct measures of TST. Among those in whom the indirect measure was greater, the median discrepancy was 45 minutes (IQR 25–90 min).

Next we examined the discrepancies between direct and indirect queries of SL and TST in subgroups based on objective OSA findings and self-reported insomnia symptoms (**Figure 3**). OSA was defined as AHI > 5, while No OSA was defined as AHI < 5 and RDI < 10. Insomnia symptom reporting was dichotomized as none versus any. There were no significant differences in group comparisons across insomnia categories, or with versus without OSA in those without insomnia symptoms (**Figure 3**).

To address the possibility that lumping onset and maintenance symptoms into the "any" insomnia group, we separately analyzed subgroups that reported only onset symptoms (> 30 min, without any maintenance symptoms), or reported only maintenance problems (> 3 awakenings per night and difficulty falling back to sleep, without any onset problems), in each case with or without OSA. There were no differences in the discrepancies observed in these small

Table 1—Patients with OSA (AHI > 5), according to insomnia category.

	No Insomnia	Any Insomnia
N	127	326
Age	52.7 (23–79)	55.5 (20–88)
Male sex	63.8%	51.5%
BMI	30.9 (5.7)	32.2 (7.6)
ESS	7.9 (5.2)	8.4 (5.0)
TST (min)	380.6 (62.4)	356.8 (73.7)
SL (min)	9.0 (19.0)	10.4 (15.8)
Efficiency (%)	86.6 (12.8)	81.7 (14.9)
N1 (min)	63.1 (41.1)	63.6 (41.7)
N1 (%)	17.4 (12.8)	19.1 (14.4)
N2 (min)	205.4 (61.4)	190.3 (60.8)
N2 (%)	53.4 (12.4)	52.9 (12.3)
N3 (min)	52.4 (39.1)	49.3 (35.4)
N3 (%)	13.7 (10.1)	13.5 (9.3)
REM (min)	59.8 (28.4)	53.6 (32.4)
REM (%)	15.5 (6.6)	14.5 (7.8)
WASO (min)	50.0 (47.6)	**67.9 (57.7)**
AI (/h)	35.4 (18.0)	36.1 (19.5)
RDI (/h)	29.3 (15.4)	30.0 (17.2)
AHI (/h)	16.9 (14.4)	15.9 (13.0)
PLMI	12.9 (23.4)	16.8 (26.2)
Anxiety	9.4%	**36.2%**
Depression	16.5%	**31.6%**
Headache	15.8%	**30.4%**
HTN	34.7%	39.6%
Diabetes	9.4%	14.7%
CAD	5.5%	4.9%
Smoking	5.5%	8.9%
Sleeps Alone	22.1%	**40.5%**

% or mean (SD) are shown. Bold indicates significant difference compared to no-insomnia group by Kruskal-Wallis with Dunn post hoc comparison.

subgroups (n = 12–23) compared to the larger heterogeneous insomnia category (Kruskal-Wallis with Dunn post hoc test; data not shown).

We performed exploratory correlation analysis to determine if the degree of within-subject inconsistency was correlated with other factors within demographics, symptoms, or objective measures of sleep (i.e., PSG). Whether we examined the difference scores (as shown in **Figure 2** histograms), or their absolute values (i.e., how far from zero in either direction), there were no correlation coefficients greater than our prespecified exploratory cutoff value of 0.20 found with any metric. For example, the R-value for PSG metrics (sleep stages in minutes and as percent, AHI, RDI, PLMI, efficiency) showed smaller values, as did self-reported medical problems, sleep symptoms, and basic demographics (age, sex, BMI). Some correlations met statistical significance but the R-values were 0.1–0.15, and the clinical significance of these remains uncertain (**Table S1**, supplemental material) and will require future investigation in validation cohorts.

Subjective-Objective Mismatch for Sleep-Wake Times

We and others have previously reported TST underestimation and latency overestimation among patients with insomnia symptoms.[5–8,12–15] In the same manner described above, we separately analyzed subjects with versus without OSA, and within each of those groups, based on self-reported insomnia symptoms. Most subjects who reported insomnia symptoms showed a combination of sleep onset and maintenance symptoms, whereas < 20% reported only one or the other set of symptoms. **Figure 4A** shows that patients reporting any insomnia symptoms, with or without comorbid OSA, showed significant underestimation of their subjective direct TST compared to the objectively scored TST. SL was overestimated similarly in all groups regardless of OSA or insomnia status (**Figure 4B**). WASO was underestimated among those reporting insomnia symptoms, and in the OSA group without insomnia as well (**Figure 4C**).

When those with OSA (**Table 1**) versus without OSA (**Table 2**) were dichotomized according to insomnia symptoms as above, there were no differences across insomnia category by age, sex, BMI, and PSG metrics of sleep (with the exception of objective WASO being higher among OSA patients reporting insomnia). There were also no differences in self-reported coronary disease, diabetes, or hypertension. Those reporting insomnia symptoms were more likely to report anxiety and depression, regardless of the presence of OSA. Among those with OSA (**Table 1**), those reporting insomnia symptoms were more likely to report headaches and sleeping alone than those with no insomnia symptoms.

Finally, we evaluated the accuracy of recalling the time of lights off, as this might address the possibility that postPSG survey responses are confounded by inattention or a general challenge of recollection following sleep in the laboratory environment. The start of the study is marked by the technician alerting the patient over intercom that the lights will be turned off and the study will start. Recalling this time is not itself associated with any sleep-wake duration *per se* (although it is used in our indirect calculations). We found that recollection of the lights-off time was within 15 min in 57% of the cohort. In fact, those patients without OSA who exhibited > 60 min of TST underestimation showed significantly better accuracy of recollecting the lights-out time (**Figure S1**, supplemental material). This finding suggests that mismatch and inconsistencies are specific for sleep-wake durations rather than general problems with memory or attention that would be predicted to affect the seemingly straightforward response of recalling the lights-off time.

DISCUSSION

Our study examined the relation between direct and indirect queries of sleep-wake times. That different answers arose for direct versus indirect queries for both SL and TST raises two important issues of clinical relevance. First, the method of inquiry in surveys of sleep complaints can affect the response, whether in research or in clinical practice of obtaining sleep diary information. Second, the lack of internal consistency further supports the idea that fundamental aspects of the sleep history are subject to significant uncertainty beyond that

Table 2—Patients without OSA (AHI < 5, RDI < 10), according to insomnia category.

	No Insomnia	Any Insomnia
N	59	196
Age	41.7 (17–86)	42.0 (16–83)
Male sex	50.9%	30.6%
BMI	27.0 (6.2)	29.3 (7.4)
ESS	8.8 (6.2)	7.5 (5.0)
TST (min)	374.8 (80.0)	370.3 (69.7)
SL (min)	15.23 (26.3)	10.8 (16.7)
Efficiency (%)	85.1 (16.8)	83.5 (14.6)
N1 (min)	41.1 (24.1)	44.2 (30.9)
N1 (%)	12.5 (11.45)	12.6 (9.1)
N2 (min)	196.3 (61.5)	193.6 (53.6)
N2 (%)	51.5 (11.0)	52.5 (11.1)
N3 (min)	71.7 (37.3)	70.3 (44.4)
N3 (%)	19.3 (10.9)	18.7 (11.0)
REM (min)	65.7 (31.0)	62.2 (34.1)
REM (%)	16.8 (7.2)	16.2 (7.9)
WASO (min)	50.1 (68.7)	59.3 (55.7)
AI (/h)	14.2 (14.4)	13.5 (11.5)
RDI (/h)	4.1 (2.9)	4.3 (2.7)
AHI (/h)	1.1 (1.2)	1.5 (1.3)
PLMI	18.8 (40.4)	12.0 (21.8)
Anxiety	22.0%	**49.5%**
Depression	18.6%	**43.9%**
Headache	37.3%	38.8%
HTN	22.0%	21.4%
Diabetes	5.1%	9.7%
CAD	0%	2.6%
Smoking	6.8%	10.7%
Sleeps Alone	28.8%	43.9%

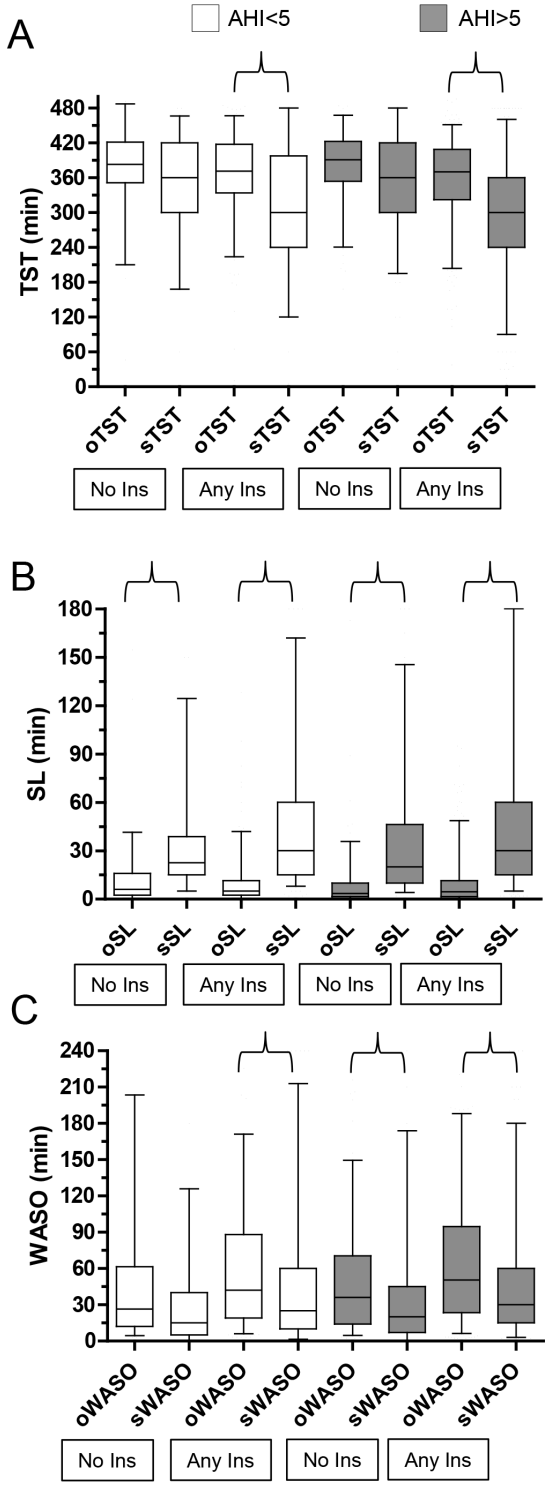
% or mean (SD) are shown. Bold indicates significant difference compared to no-insomnia group by Kruskal-Wallis with Dunn post hoc comparison.

raised by the increasingly recognized phenomenon of misperception. Although the basis of direct versus indirect response inconsistency remains uncertain, clinicians should be aware of this potential confound to self-reported time information since the assessment of sleep patterns and complaints does not commonly include objective sleep measurements in clinical practice. Although the manner of query may be relevant for only a subset of insomnia patients, we speculate that the degree of internal inconsistency may itself represent an additional factor to consider in the phenotyping of insomnia.

Direct versus Indirect Approaches to Sleep-Wake Time Reporting

The heuristics that patients use when reflecting on their own sleep-wake times are not well studied. It is possible that some patients naturally think of SL or TST in terms of duration (what we termed the "direct" measure). Others might use "anchors" that represent moments in time. When stitching together these moments, one can derive a duration value (what we termed the

Figure 4—TST misperception across subgroups defined by objective OSA metrics and self-reported insomnia symptoms.



The objective TST (oTST) and subjective TST (sTST) are shown according to OSA category (gray indicates AHI > 5) and insomnia symptom reporting (any versus none) **(A)**. Similar plots are given for SL **(B)** and WASO **(C)**. The boxes represent the 25% to 75% range, with a bar at the median value and whiskers spanning the 5% to 95% range. Brackets indicate significant differences between subjective and objective values for each panel (Kruskal-Wallis ANOVA with Dunn post hoc test, $p < 0.05$, performed separately for each panel).

"indirect" measures). The most striking finding was that the direct and indirect methods, across a large and diverse group of patients, was internally inconsistent in the majority of patients. This occurred even for the simpler case of SL, which involves only two anchoring time points and a relatively brief duration. The findings have implications for clinical practice and research studies alike, since sleep diary entries may differ in how they query SL and TST responses. Some diaries for example will supply blocks corresponding to hour or half-hour intervals that can be shaded to indicate when sleep occurred. The consensus statement on sleep diaries utilizes direct queries,[16] although no formal comparisons of diaries using direct versus indirect queries are available.

One difference between SL and TST relates to the quantity of time involved, and it may be easier to estimate short time periods than long ones. Another difference is that the latter involves multiple steps of "internal" estimate, and also multiple steps of calculation. Indirect TST is calculated from variables that include one that is typically overestimated (SL) and one that is typically underestimated (WASO). Also, because we only queried total WASO duration (and not individual awakening times), we were not able to perform indirect calculations for WASO. The observation that TST was far more commonly associated with a difference in the direct versus indirect responses (exact in 5% of cases versus 41% of cases for SL) suggests that either the heuristics for estimating TST are more complex, or that recognizing the relation between the direct and indirect questions is less immediately apparent as might be expected for SL queries. Finally, TST estimation refers to time spent asleep, while SL and WASO refer to time spent awake. The SL period is bounded by lights off and sleep onset, while blocks of WASO are bounded by sleep. These factors may also influence heuristics and/or memory for time duration.

We found no clear associations of internal consistency with objective PSG parameters. One might expect that decreased sleep efficiency or increased time spent in stage N1 sleep might impact subjective postPSG time estimation, as might sleep disturbances such as sleep apnea or periodic limb movements. However, this was not the case. Education level might also be expected to play a role, but this factor showed low correlation coefficient values with internal consistency, whether the raw value or the absolute value (i.e., "any error") was considered (**Table S1**). Furthermore, the presence of insomnia symptoms did not predict either the degree or direction of the discrepancy between direct versus indirect queries. However, insomnia symptoms were associated with TST misperception (direct query being an underestimation compared to objective TST). Misperception of SL was similar with versus without insomnia, and WASO was underestimated in all groups except those without insomnia or OSA.

Clinical Implications of Sleep-Wake Self-Reporting

A number of potential contributors, including medical and psychiatric comorbidities, might impact sleep disturbance in chronic insomnia. A systematic approach to the insomnia patient addresses potentially reversible contributors, as well as targeting insomnia itself (for example through behavioral or pharmacological methods). Understanding the degree of misperception may be informative for patient care. PSG is not considered part of the routine clinical assessment of patients with insomnia.[17] Rather, the practice parameter for evaluation of insomnia underlines the use of PSG for certain circumstances, such as excluding comorbid sleep disorders (e.g., OSA or PLMS). Of particular interest, occult OSA has been reported in 20% to 70% of insomnia patients.[18–23] Clinical clues available by history and physical exam, such as elevated BMI, snoring, or crowded airway anatomy, may support the use of PSG for ruling out OSA in the workup of chronic insomnia. The parameters do not include the use of PSG to identify misperception. The measurement of objective sleep time in the home versus laboratory environment as the gold standard against which to compare subjective perception is another point of uncertainty. Home testing with actigraphy allows a more natural environment, minimal disruption of sleep, and ease of repeated measures; the downside is that actigraphy tends to overestimate total sleep time.[24] The gold standard of PSG for sleep stage scoring is balanced by the unusual environment, the potential sleep disturbance from the sensors themselves, and the single-night paradigm.

Knowing where on the misperception spectrum a particular patient resides may be important for treatment decision including the nature of treatment monitoring. For example, objective measures such as actigraphy or PSG may be more relevant for the patient with more pronounced misperception as an adjunct to sleep diaries or other self-reported measures in response to treatment. It is also worth noting that more recent data cast doubt on prior self-reported data from large epidemiological studies by performing PSG testing in a large sample of patients.[25] The addition of objective testing suggested that the medical risks associated with self-reported insomnia are carried mainly by those who also showed objectively short sleep duration on PSG testing.

We observed that indirect calculations were more likely to exceed the direct queries. For SL, this means that indirect methods will suggest a greater degree of misperception. However, for TST, where the indirect measures were also more likely to be larger than the direct measures, the degree of misperception would appear reduced compared to that obtained using direct queries of TST. This means that indirect measures for TST are more likely to be in accord with objective measures. Sleep diaries often utilize direct queries, and we suspect that patients have a more natural inclination to consider their own sleep-wake times in the "direct query" manner. The consensus statement on sleep diaries provides recommendations that may reduce potential bias especially from variation in query types as direct queries are suggested.[16]

Limitations

We acknowledge several limitations to our study. First, the data was taken from a clinical sample, in whom clinical diagnostic phenotyping was not possible beyond the self-reported data we described, including the frequency, duration, or severity of symptoms. Although we cannot characterize the insomnia according to current diagnostic standards using our questionnaires, the large size and likely heterogeneity of the sample may suggest that our findings are more likely to generalize. A related limitation is that our use of symptom number as a surrogate for severity or prominence of insomnia symptoms

has not been validated. Second, the data were obtained during the course of routine clinical testing, and thus we cannot evaluate the attention or motivation of patients responding to the postPSG queries. The finding of accurate lights-out time recollection, especially in the misperception group, argues, however, against a general problem with patient cooperation in survey responses. A related issue is that patients may differ in baseline ability to perform mental calculations required to assess agreement between direct and indirect responses, and that the degree of inconsistency observed reflects this source of variation. Another source of uncontrolled variation involves the presence and use of technology displaying time (watches, phones, etc.), which may have influenced the responses. Further, our analysis was limited to a single night of PSG, and thus we cannot address night-to-night variability in sleep-wake time reporting.

REFERENCES

1. Fichten CS, Creti L, Amsel R, Bailes S, Libman E. Time estimation in good and poor sleepers. J Behav Med 2005;28:537–53.
2. Bliwise DL, Friedman L, Yesavage JA. Depression as a confounding variable in the estimation of habitual sleep time. J Clin Psychol 1993;49:471–7.
3. Harvey AG, Tang NK. (Mis)perception of sleep in insomnia: a puzzle and a resolution. Psychol Bull 2012;138:77–101.
4. American Academy of Sleep Medicine. International classification of sleep disorders: diagnostic and coding manual. 2nd ed. Westchester, IL: American Academy of Sleep Medicine, 2005.
5. Bianchi MT, Williams KL, McKinney S, Ellenbogen JM. The subjective-objective mismatch in sleep perception among those with insomnia and sleep apnea. J Sleep Res 2013;22:557–68.
6. Fernandez-Mendoza J, Calhoun SL, Bixler EO, et al. Sleep misperception and chronic insomnia in the general population: role of objective sleep duration and psychological profiles. Psychosom Med 2011;73:88–97.
7. Martinez D, Breitenbach TC, Lenz Mdo C. Light sleep and sleep time misperception--relationship to alpha-delta sleep. Clin Neurophysiol 2010;121:704–11.
8. Parrino L, Milioli G, De Paolis F, Grassi A, Terzano MG. Paradoxical insomnia: the role of CAP and arousals in sleep misperception. Sleep Med 2009;10:1139–45.
9. Bonnet MH, Arand DL. Insomnia, metabolic rate and sleep restoration. J Intern Med 2003;254:23–31.
10. Bonnet MH, Arand DL. Physiological activation in patients with sleep state misperception. Psychosom Med 1997;59:533–40.
11. Tang NK, Harvey AG. Time estimation ability and distorted perception of sleep in insomnia. Behav Sleep Med 2005;3:134–50.
12. Manconi M, Ferri R, Sagrada C, et al. Measuring the error in sleep estimation in normal subjects and in patients with insomnia. J Sleep Res 2010;19:478–86.
13. Edinger JD, Krystal AD. Subtyping primary insomnia: is sleep state misperception a distinct clinical entity? Sleep Med Rev 2003;7:203–14.
14. Mercer JD, Bootzin RR, Lack LC. Insomniacs' perception of wake instead of sleep. Sleep 2002;25:564–71.
15. Vanable PA, Aikens JE, Tadimeti L, Caruana-Montaldo B, Mendelson WB. Sleep latency and duration estimates among sleep disorder patients: variability as a function of sleep disorder diagnosis, sleep history, and psychological characteristics. Sleep 2000;23:71–9.
16. Carney CE, Buysse DJ, Ancoli-Israel S, et al. The consensus sleep diary: standardizing prospective sleep self-monitoring. Sleep 2012;35:287–302.
17. Schutte-Rodin S, Broch L, Buysse D, Dorsey C, Sateia M. Clinical guideline for the evaluation and management of chronic insomnia in adults. J Clin Sleep Med 2008;4:487–504.
18. Ong JC, Gress JL, San Pedro-Salcedo MG, Manber R. Frequency and predictors of obstructive sleep apnea among individuals with major depressive disorder and insomnia. J Psychosom Res 2009;67:135–41.
19. Lichstein KL, Justin Thomas S, Woosley JA, Geyer JD. Co-occurring insomnia and obstructive sleep apnea. Sleep Med 2013;14:824–9.
20. Krakow B, Ulibarri VA. Prevalence of sleep breathing complaints reported by treatment-seeking chronic insomnia disorder patients on presentation to a sleep medical center: a preliminary report. Sleep Breath 2013;17:317–22.
21. Luyster FS, Buysse DJ, Strollo PJ Jr. Comorbid insomnia and obstructive sleep apnea: challenges for clinical practice and research. J Clin Sleep Med 2010;6:196–204.
22. Krakow B, Ulibarri VA, Romero E. Persistent insomnia in chronic hypnotic users presenting to a sleep medical center: a retrospective chart review of 137 consecutive patients. J Nerv Ment Dis 2010;198:734–41.
23. Krakow B, Ulibarri VA, Romero EA. Patients with treatment-resistant insomnia taking nightly prescription medications for sleep: a retrospective assessment of diagnostic and treatment variables. Prim Care Companion J Clin Psychiatry 2010;12(4).
24. Sadeh A. The role and validity of actigraphy in sleep medicine: an update. Sleep Med Rev 2011;15:259–67.
25. Vgontzas AN, Fernandez-Mendoza J, Liao D, Bixler EO. Insomnia with objective short sleep duration: the most biologically severe phenotype of the disorder. Sleep Med Rev 2013;17:241–54.

SUBMISSION & CORRESPONDENCE INFORMATION

Submitted for publication February, 2014
Submitted in final revised form September, 2014
Accepted for publication October, 2014

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DISCLOSURE STATEMENT

Support for this study was provided by the Department of Neurology, Massachusetts General Hospital; Young Clinician Award, Center for Integration of Medicine and Innovative Technology; Harvard Catalyst KL2 Medical Research Investigator Fellowship. Dr. Bianchi has consulting agreement with Sunovion, is on the advisory board of Foramis and is a co-inventor on a pending patent for a sleep monitoring device. Dr. Bianchi receives funding from the Department of Neurology, Massachusetts General Hospital, and a Young Clinician Award from the Center for Integration of Medicine and Innovative Technology. The other authors have indicated no financial conflicts of interest.

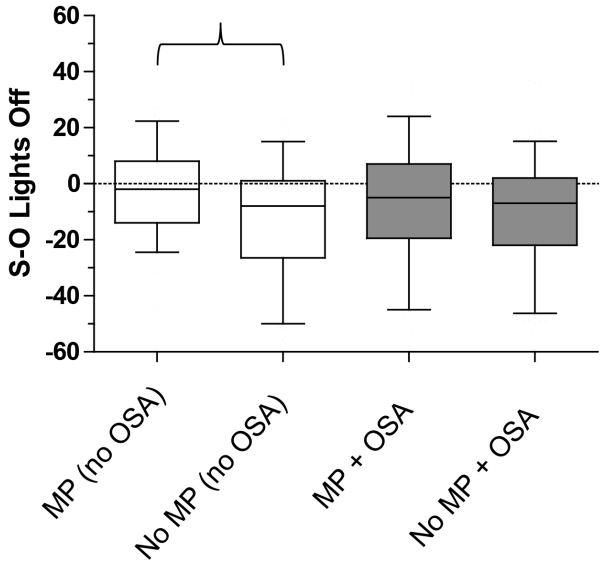
SUPPLEMENTAL MATERIAL

Table S1—Spearman correlation with direct-indirect discrepancies as the raw difference or as the absolute value of the difference.

	TST: Raw Difference	TST: Absolute Value	SL: Raw Difference	SL: Absolute Value
Age	−0.02	0.06	0.02	0.04
Male sex	−0.08	−0.07	−0.06	−0.06
BMI	0.04	−0.02	−0.01	0.00
ESS	0.11	0.06	0.02	0.04
TST (min)	0.06	−0.05	−0.03	−0.07
SL (min)	0.04	0.04	−0.01	0.04
Efficiency (%)	−0.02	−0.15[a]	−0.01	−0.08
N1 (min)	0.05	0.11	−0.04	0.02
N1 (%)	0.02	0.13[a]	−0.03	0.03
N2 (min)	0.03	−0.03	0.02	−0.02
N2 (%)	−0.02	0.00	0.08	0.03
N3 (min)	0.01	−0.11[a]	−0.04	−0.09
N3 (%)	−0.01	−0.09	−0.04	−0.08
REM (min)	0.02	−0.09	−0.04	−0.06
REM (%)	−0.01	−0.08	−0.04	−0.04
WASO (min)	0.03	0.16[a]	0.00	0.06
AI (/h)	0.01	0.03	0.07	0.06
RDI (/h)	−0.01	0.01	0.04	0.03
AHI (/h)	0.01	0.03	0.04	0.05
PLMI	−0.03	0.06	0.01	0.01
Anxiety	0.01	0.00	−0.01	0.05
Depression	0.07	0.06	0.01	0.02
Headache	−0.03	0.03	−0.01	0.04
HTN	−0.03	0.03	−0.03	0.02
Diabetes	0.09	0.13[a]	0.05	0.04
CAD	−0.02	0.03	−0.04	−0.03
Smoking	0.02	−0.03	0.05	0.03
Insomnia #	0.04	0.14[a]	0.04	0.08
Educ >HS	−0.12[a]	−0.07	−0.05	−0.07

[a] $p < 0.0001$. Educ > HS, Education level of high school or less; Insomnia #, number of symptoms reported from a list of insomnia symptoms.

Figure S1—Accuracy of recollection of PSG lights-out time according to OSA and misperception categories.



The difference between subjectively recalled and objective lights out time, according to the presence (gray) or absence of OSA, and the presence ("MP") or absence "No MP" of misperception. Misperception is defined as > 60 minutes of underestimation of TST. Brackets indicate significant differences between sTST and oTST (Kruskal-Wallis ANOVA with Dunn post hoc test, $p < 0.05$).