Impaired Sleep in Chronic Fatigue Syndrome

How Is It Best Measured?

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JHP

Journal of Health Psychology

www.sagepublications.com
Vol 15(4) 596–607
DOI: 10.1177/1359105309355336

Abstract

The goal was to examine comparative efficacy of polysomnography, actigraphy, and self-report in evaluating the sleep/wake experience of individuals with chronic fatigue syndrome (CFS). Sleep parameters were evaluated by the three measurement modalities for the same night in 49 participants with CFS. Psychological and daytime functioning were measured by self-report. Results indicate that: (a) objectively measured nocturnal *sleep time* effectively approximated subjective experience although nocturnal *wakefulness* did not; (b) total sleep time and sleep efficiency differentiated individuals with and without insomnia complaints; (c) daytime sleepiness, fatigue, and non-refreshing sleep were not reflected by the objective sleep-related measures (polysomnography and actigraphy).

Keywords

- *actigraphy*
- *chronic fatigue syndrome*
- *polysomnography*
- *sleep*
- *sleep diary*

COMPETING INTERESTS: None declared.

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OBJECTIVE measurement of the nocturnal and daytime aspects of insomnia has been addressed in numerous studies. Subjective reports and objective measurements of sleep parameters often do not coincide (e.g. Campbell, Gillin, Kripke, Erikson, & Clopton, 1989; Edinger, Means, Carney, Andrew, & Krystal, 2008; Rosa & Bonnet, 2000). When reported daytime performance deficits cannot be objectively documented the experience is generally not considered 'real' as the implicit assumption has always been that the individual's report of his or her experience is not valid unless it is objectively measurable and unless the objective measure corroborates the subjective report. Multiple studies have stated that individuals with insomnia 'exaggerate' their sleep problem and 'misconstrue' their daytime impairment (Hart, Morin, & Best, 1995; Semler & Harvey, 2006). It is only recently that evidence has shown that daytime consequences of insomnia do exist—provided the objective measure is sensitive to the type of deficit (Edinger et al., 2008).

The gold standard of objective measurement for sleep quality is generally believed to be polysomnography (PSG). There is no question that despite the fact that it is expensive and intrusive, it is the diagnostic technique of choice for primary sleep disorders such as sleep apnea/hypopnea syndrome (SAHS) and periodic limb movement disorder (PLMD) (see Kushida et al., 2005). In terms of ecological validity, however, few would argue that spending the night in a sleep laboratory hooked up to an array of electrodes reflects an individual's usual sleep/wake pattern. Indeed, the use of polysomnography to diagnose insomnia has been formally questioned (Kushida et al., 2005; Littner et al., 2003) and the need for a better definition of the subjective experience of sleep has been encouraged (Harvey, Stinson, Whitaker, Moskovitz, & Virk, 2008).

Actigraphy is an alternative objective method for studying sleep/wake patterns in a naturalistic way, with individuals being able to follow their usual routine in their own home environment. Most studies that validate actigraphy as a measure of sleep used nonclinical samples (see Morgenthaler et al., 2007). A few studies have looked at participants with insomnia (Lichstein et al., 2006). Actigraphy data are limited in that sleep and wake cannot be distinguished either when lying very still while awake or during high motility sleep (Sadeh & Acedbo, 2002). Frequency of daytime activity/rest behaviors can be monitored, but not the individual's subjective experience of fatigue, sleepiness, or perception of impaired functioning.

Despite the prevailing belief that evaluating sleep problems by means of self-report is not quite 'scientific', the ubiquitous sleep diary, which typically evaluates both quantitative and qualitative aspects of the sleep/wake experience, is almost universally used in insomnia-related studies. Frequently, the function of the sleep diary is to help interpret the objective data derived from actigraphy or PSG. Yet, it is clear that there are sensations, perceptions, and the whole cognitive-affective dimension of the human sleep/wake experience that simply cannot be captured exclusively with objective measures—even when these are as highly sophisticated as neuroimaging tests. As has been recognized in recent clinical guidelines, the multidimensional aspects of insomnia and the experienced nocturnal and daytime impairment in chronic fatigue syndrome (CFS) can only be totally captured by subjective report (see Schutte-Rodin, Broch, Buysse, Dorsey, & Sateia, 2008). Objective measures can address the physiological and behavioral aspects and offer an additional dimension to quantify the subjective experience.

Sleep and insomnia problems are exceedingly common in CFS and form part of the clinical picture (Gurbaxani, Goertzel, Jones, & Maloney, 2006). In addition to having their sleep related complaints seen as exaggerated, individuals with CFS also have the whole range and intensity of their reported impairment questioned, both with respect to daytime functioning (Fossey et al., 2004) as well as nocturnal sleep quality (Reeves et al., 2006). Yet, we have found only three studies which examined sleep parameters as evaluated by different measures in CFS samples (Majer et al., 2007; Sharpley, 1996; Watson, Jacobsen, Goldberg, Kapur, & Buchwald, 2004). None, to our knowledge, has examined or compared sleep parameters using the three most popular measures: PSG, sleep diary, and actigraphy.

The present study focused on evaluating the qualitative and quantitative aspects of the sleep/wake experience in individuals with CFS where the contributions of self-report, actigraphy, and polysomnography are compared. In light of our premise that the role of objective testing is not to invalidate the subjective experience, but to help understand it more fully, the objectives of the present study are to: (1) examine the nature and extent of sleep problems and fatigue in a sample of individuals with chronic fatigue syndrome; (2) compare a subset of sleep parameters, for the same night, as evaluated by self-report (sleep diary) and objective measures (polysomnography and actigraphy);

(3) examine the role of diagnosed chronic insomnia when evaluating sleep/wake patterns using self-report and objective sleep measures; (4) explore the association between qualitative variables and quantitative sleep parameters as assessed by the three measures; (5) evaluate the relationship between daytime functioning and sleep parameters; and (6) compare results obtained in the sleep laboratory to those based on typical home sleep.

Method

Participants

Participants were recruited through physician referrals, CFS support groups, and media publicity. All were volunteers who were participating in a larger investigation (Libman et al., 2009) where the goal was to examine psychological characteristics and the presence of primary sleep disorders.

Inclusion criteria were: community resident; volunteer; sufficient cognitive and language skills to complete measures in English or French; and meeting criteria for CFS according to Reeves et al. (2005). Exclusion criteria included: failure to meet the CFS criteria; other medical conditions related to fatigue, sleepiness, arthralgia, or insomnia; and current major psychiatric illness. Participants with CFS who also had fibromyalgia were included. Participants were not excluded if they were taking hypnotic or sedating medication on a regular basis (i.e. > 3 times per week; $n = 13$).

The sample included 49 participants (41 women and eight men) with a mean age of 42.78 years (SD = 11.73, range, 16–73). Average education level was 14.57 years (SD = 2.98; range, 5–21). Twenty-nine participants were unemployed: 24 were unable to work due to their illness, one was a home-maker, three were retired, and one was seeking employment. Of the rest, five participants were employed full time, 11 were employed part-time and four were part-time students. All participants but one were diagnosed with CFS by a Montreal immunologist specializing in CFS. The average time between the diagnosis of CFS and participation in the study was 56.77 months (SD = 81.83; range, < 1 mo. to 426 mo.). CFS diagnosis was verified by our neurologist team member who also diagnosed the one participant who had not been previously formally diagnosed. Twenty-four (49%) participants had comorbid fibromyalgia.

Individuals who were subsequently diagnosed by our research team with a primary sleep disorder, including sleep apnea/hypopnea syndrome (SAHS), periodic limb movement disorder (PLMD), or chronic insomnia were not excluded from the sample. Although primary sleep disorder is generally considered an exclusion criterion for CFS (Carruthers et al., 2003; Fukuda et al., 1994; Reyes et al., 2003), our findings indicate that these do not influence the core CFS symptomatology and suggest that these are comorbidities of CFS (Libman et al., 2009).

Measures

Four sleep/wake measures were used: overnight polysomnography (PSG); actigraphy; sleep diary; and a retrospective (past month) Sleep Questionnaire that is a part of our test battery. Assessed variables common to all measures include: sleep efficiency; sleep onset latency (SOL); duration of wake after sleep onset (WASO); and total sleep time (TST). The latter three variables were measured in minutes. Sleep efficiency is expressed as a percentage of total sleep time divided by time in bed.

Polysomnography During polysomnographic evaluation participants were monitored in a supervised sleep laboratory from 10 pm to 7 am. Monitoring included: electrooculargram (EOG); electroencephalogram (EEG); bilateral anterior tibialis and chin electromyogram (EMG); electrocardiogram (ECG); pulse oximetry; nasal and oral airflow with thermistor and nasal pressure cannulae; microphone for snoring; and respitrace bands for measurement of respiratory effort. Leg movements, apnea events, and associated arousals were scored manually according to the scoring rules established by the Atlas Task Force of the American Sleep Disorders Association (1993) and the International Classification of Sleep Disorders (American Academy of Sleep Medicine, 2005).

Actigraphy The Actitrac (IM Systems Co, Baltimore, MD, USA) actigraphy monitor was used. It resembles a wristwatch. Activity was recorded every second from the non-dominant wrist. Actigraphic data during 30-second epochs were scored as sleep or wake by the IM Systems software and algorithm (version 8). Activity counts recorded during the measured epoch are modified by the level of activity in the surrounding two minute epochs to yield the final activity count for each epoch. If the summed activity count is above a

defined threshold the epoch is scored as wake. Otherwise it is scored as sleep.

For the night that both polysomnography and actigraphy were used, lights out and arising times were matched. Sleep onset latency was calculated from beginning of scoring (bedtime) until two minutes of inactivity, indicating sleep, was evident on the actigraph recording. WASO, in minutes, was based on total minutes of activity scored as wake between sleep onset and wakeup. TST, in minutes, was defined as total inactive time from actigraphic sleep onset until arising time. Sleep efficiency was calculated by dividing TST by Time in Bed (TIB). These are the same definitions as used by Landis et al. (2003), who studied correlates of actigraphy and sleep quality in women with fibromyalgia.

Sleep diary This 16-item modification of Lacks' measure (Lacks, 1987; Libman, Fichten, Bailes, & Amsel, 2000) allows participants to monitor their sleep experience on a daily basis. Variables of interest include: TIB, SOL ('At bedtime, how long did it take you to fall asleep last night?'), WASO ('If you woke up during the night, what is the total amount of time you were awake?'), TST ('How many hours did you sleep last night?'), Sleep Quality ('What was the quality of your sleep last night?' 1 = very poor, 10 = very good), Non-Refreshing Sleep Complaint (days/week where participants answer 'Yes' to ' I do not feel refreshed when I get up in the morning'), Non-Refreshing Sleep Severity (1 = not refreshed at all, 10 = very refreshed), and Insomnia Complaint (nights/week where participants answer 'Yes' to 'Did you have insomnia last night?').

Sleep Questionnaire This brief retrospective measure (Alapin et al., 2002; Fichten et al., 1995) inquires about usual sleep experiences during the past typical month. The information provided allowed us to: (1) establish the presence of an insomnia complaint (i.e. Do you have insomnia? Yes/No); (2) specify the duration of the insomnia problem; (3) diagnose the presence or absence of difficulty initiating or maintaining sleep in accordance with typically used research criteria (Lichstein, Durrence, Taylor, Bush, & Riedel, 2003; Lichstein et al., 2006); and (4) assess distress associated with an insomnia problem (1 = not at all distressed, 10 = very distressed). Data indicate good test–retest reliability and high correlations between equivalent scores on this measure and on the sleep diary (Fichten et al., 1995; Libman et al., 2000).

Empirical Sleepiness and Fatigue Scales These were developed by Bailes et al. (2006) through correlation and factor analysis of all items from four popular measures purporting to measure sleepiness and fatigue. The two Empirical Scales represent different constructs that were found to have distinctive patterns of associations and were only minimally correlated with each other.

Beck Depression Inventory (BDI-II): Primary Care Subscale (PC) The seven-item PC Subscale of the BDI-II (Beck, Steer, & Brown, 1996) was used to evaluate affective and cognitive symptoms of depression independent of fatigue, sleepiness, insomnia, and agitation.

Spielberger State-Trait Anxiety Inventory – Form Y2 (STAI) (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) This frequently used valid measure consists of two separate 20-item self-report scales for measuring trait and state anxiety. In the present investigation only trait anxiety was evaluated.

SF-36 Health Survey (Ware, Snow, Kosinski, & Gandek, 2000) This popular 36-item measure was used to assess quality of life in eight health domains. Low scores on all subscales indicate disability due to illness; high scores indicate better functioning due to relatively good health.

Procedure

The research ethics committees of the Jewish General Hospital and the Mount Sinai Hospital of Montreal approved the protocol. Participants were screened to determine eligibility during a 15 minute telephone interview. Eligible participants were referred to our team neurologist for definitive diagnosis of CFS. They then completed all questionnaires as well as two weeks of Sleep Diaries. They subsequently had a general health and sleep assessment with the respirologist team member and went to the sleep laboratory for an overnight polysomnographic (PSG) assessment, where they wore an actigraph on their non-dominant wrist. Upon awakening, they recorded their subjective sleep experience in the sleep diary. The median number of weeks between the completion of the self-report measures and the sleep laboratory night was 7.9.

Data analysis

Descriptive statistics, including frequencies and percentages, were used to describe the sample. Chi-square tests assessed differences in the proportion

of participants who did and who did not (1) use sedative medication, (2) have a chronic insomnia, and (3) an apnea diagnosis. Repeated measures analysis of variance (ANOVA) comparisons were used to evaluate hypotheses related to differences among the three instruments. Correlations were used to test the instruments' concordance and to evaluate how scores on the instruments relate to the dependent variables of interest.

Results

Objective 1: nature and extent of sleep problems and daytime fatigue in CFS

Sleep complaints Sleep problems were reflected on a range of measures. On the Sleep Questionnaire, all CFS participants complained of some type of difficulty with their sleep. The majority ($n = 41$) reported poor Sleep Quality (rating below 6 on a 10-point scale with 10 indicating good sleep quality). The mean for the whole sample was 3.44 (SD = 1.81). In addition, 35 of the 49 participants (71%) reported an insomnia complaint (i.e. responding 'Yes' to the question: 'Do you have insomnia?'), 22 (45%) of them with a frequency at least three times a week. These 22 participants had a mean Insomnia Distress rating of 6.32 (SD = 2.8), with most (68%) reporting a rating greater than 5 on this 10-point scale. The average duration of insomnia was 9.69 years (SD = 10.02, range = 1–40). The most common type of sleep complaint was non-refreshing sleep, which was reported by 47 of the 49 participants (i.e. endorsing the statement 'I do not feel refreshed when I get up in the morning'). The mean rating of how refreshed these 47 participants usually felt in the morning was 2.5 (SD = 1.95) on a 10-point scale, with 1 indicating not refreshed at all and 10 indicating very refreshed. The next most common type of sleep complaint, reported by 24.5 percent of participants, was difficulty initiating and maintaining sleep consisting of mixed sleep onset (SOL), maintenance (SMI), and terminal insomnia. Sixteen percent of participants reported both SOL and SMI; 12 percent reported SMI alone, 6 percent reported terminal insomnia alone, and 22 percent reported none of these insomnia complaints.

Thirty-two of the 49 participants (65%) met all the criteria for chronic insomnia diagnosed using criteria suggested by Lichstein et al. (2003): (1) current complaint of insomnia; (2) duration at least six months; (3) impaired daytime functioning; and (4) SOL and/or WASO at least 31 minutes, at least three times per week. Criteria (1) and (2) were based on the Sleep Questionnaire, criterion (3) on the Empirical Fatigue Scale, and criterion (4) on two weeks of Sleep Diaries. A chi-square analysis indicates that chronic insomnia and sedative medication use are independent, χ^2 (1, 49) = 0.69, $p = .769$.

Daytime complaints On the Empirical Fatigue Scale all participants scored 9 or above (9 is the midpoint of the scale as well as the mean of the healthy control group in the Bailes et al. (2006) study, with a mean of 15.37 (SD = 2.57). On the Empirical Sleepiness Scale, where the mean in the Bailes et al. study for healthy controls was 3.1 (SD = 3.1), the mean was 7.07 (SD = 4.25). Thus, the majority of participants complained of daytime fatigue and sleepiness.

Primary sleep disorders The PSG assessment resulted in 34 participants being diagnosed with SAHS and/or PLMD: 27 with SAHS only, two with PLMD only, and five with both. Twenty-four of those 32 who were diagnosed with chronic insomnia also had one of these primary sleep disorders. Chi-square analyses indicate that chronic insomnia and primary sleep disorder are independent, χ^2 (1, 49) = 1.76, $p = .185$, as are primary sleep disorder and sedative medication use, χ^2 (1, 49) = 8.45, $p = .542$.

Objective 2: compare sleep parameters for the same night using three instruments: sleep diary; polysomnography; and actigraphy

We performed a series of four one-way repeated measures analysis of variance (ANOVA) comparisons (three instruments: Actigraphy, Sleep Diary, PSG) to evaluate whether the three measures produce similar values. Dependent variables were SOL, WASO, TST and Sleep Efficiency. Means and standard deviations are shown in Table 1 (Whole Sample). Results indicate significant findings on SOL, F (2, 92) = 24.22, $p < .0001$, and WASO, F (2, 86) = 11.08, $p < .001$. Post hoc tests (Least Significant Difference) revealed significant differences among all three measures for both SOL and WASO. These show that Actigraphy resulted in the lowest and Sleep Diary the highest SOL, with the reverse being the case for WASO. PSG always had intermediate results, with the differences among the three groups being significant on both SOL and WASO.

Table 1. Means and standard deviations of sleep parameters as measured by three instruments as a function of chronic insomnia diagnosis

	Chronic insommnia diagnosis		*No chronic insomnia diagnosis*			*Whole sample*	
Sleep parameters	*Mean*	*SD*	*Mean*	*SD*	*post hocs*	*Mean*	*SD*
SOL (min)[a]							
Sleep diary (SD)	79.35	79.18	43.75	56.11	SD>PSG>ACT	67.23[a]	73.53
PSG	34.54	36.42	24.31	36.54		31.06[a]	36.39
Actigraphy (ACT)	6.34	7.51	6.19	5.99		6.29[a]	6.97
WASO (min)[b]							
Sleep diary (SD)	97.12	113.34	34.33	33.05	ACT>PSG>SD	75.72[b]	98.12
PSG	114.40	46.01	77.37	48.10		101.78[b]	49.47
Actigraphy (ACT)	144.07	65.54	103.73	62.56		130.32[b]	66.68
TST (min)[c]							
Sleep diary (SD)	333.55	116.17	434.00	83.99	NS	366.30	116.01
PSG (Polysomnography)	326.44	95.12	405.61	70.76		352.25	94.86
Actigraphy (ACT)	322.48	83.65	400.47	62.16		347.91	85.05
Sleep efficiency (%)[d]							
Sleep diary (SD)	66	21	84	15	NS	70	21
PSG	67	15	80	13		71	16
Actigraphy (ACT)	67	15	80	11		71	15

Notes: Means in a column sharing superscripts are significantly different at $p<.05$ or better. SOL = sleep onset latency, WASO = wake after sleep onset, TST = total sleep time. For SOL and WASO, higher means indicate worse sleep; for TST and Sleep Efficiency, higher means indicate better sleep

[a] Significant main effect for Measure, $F(1,45) = 23.71$, $p < .001$

[b] Significant main effect for Measure, $F(1,42) = 16.16$, $p < .001$ and for Diagnosis, $F(1,42) = 6.96$, $p < .05$

[c] Significant main effect for Diagnosis, $F(1,44) = 10.76$, $p < .01$

[d] Significant main effect for Diagnosis, $F(1,42) = 9.84$, $p < .003$

We examined correlations among the three instruments as an additional evaluation of their concordance. Pearson *r* values for each pair of instruments for each sleep parameter are shown in Table 2. Given the large number of *r* values calculated, we used $p < .01$ as our significance criterion. For the sample as a whole, there were significant moderate to high correlations among all instruments on TST (*r* ranged from 0.72 to 0.84), Sleep Efficiency (*r* ranged from 0.65 to 0.81), and WASO (*r* ranged from 0.45 to 0.59), with coefficients being highest for TST and lowest for WASO. For SOL, only Sleep Diary and PSG scores were significantly correlated, $r(47) = 0.52$, $p < .001$; Actigraphy scores were not significantly related to either PSG or Sleep Diary scores. Correlations between PSG and Sleep Diary scores were generally the highest.

Concordance among the three measures on the four sleep parameters varied, however, depending on whether there was a diagnosis of chronic insomnia (see Table 2). Given the large number of *r* values calculated, we again used $p < .01$ as our significance criterion.

Scores of participants who had a diagnosis of chronic insomnia reflected the pattern for the whole sample, with significant moderate to high correlations among all measures on TST (*r* ranged from 0.65 to 0.80), Sleep Efficiency (*r* ranged from 0.56 to 0.76), and WASO (*r* ranged from 0.45 to 0.61), with coefficients being highest for TST and lowest for WASO. Participants without a chronic insomnia diagnosis had significant and high correlations among all measures only on TST (*r* ranged from 0.72 to 0.82). The only other significant correlations were between PSG and Sleep Diary for SOL, $r(47) = 0.86$, $p < .001$, and Sleep Efficiency, $r(47) = 0.83$, $p < .001$.

Table 2. Pearson correlations between three measures on sleep parameters as a function of chronic insomnia diagnosis

	Sleep parameters			
Measures	*SOL*	*WASO*	*TST*	*Sleep efficiency*
Whole sample (n = 49)				
PSG -Sleep diary	0.523 ***	0.574 ***	0.838 ***	0.813 ***
PSG-Actigraphy	–0.036	0.586 ***	0.792 ***	0.673 ***
Sleep diary-Actigraphy	–0.154	0.448 **	0.721 ***	0.648 ***
Chronic insomnia diagnosis (n = 32)				
PSG-Sleep diary	0.393 *	0.608 ***	0.803 ***	0.764 ***
PSG-Actigraphy	0.069	0.594 ***	0.785 ***	0.648 ***
Sleep diary-Actigraphy	–0.103	0.448 *	0.646 ***	0.564 **
No chronic insomnia diagnosis (n = 17)				
PSG -Sleep diary	0.864 ***	0.364	0.822 ***	0.830 ***
PSG-Actigraphy	–0.305	0.407	0.649 **	0.570 *
Sleep diary-Actigraphy	–0.365	0.273	0.720 **	0.641 *

Note: PSG = polysomnography. SOL = sleep onset latency, WASO = wake after sleep onset, TST = total sleep time. Because of the large number of tests, only those with a significance of .01 or better should be considered significant. ***p<.001; **p<.01; *p<.05

Objective 3: evaluate the role of diagnosed chronic insomnia in sleep/wake patterns when using subjective and objective sleep measures

To better understand the reasons for the differing patterns of the correlations between scores of participants with and without chronic insomnia, we explored similarities and differences on the three measures between these participants. We carried out four 2 x 3 between-within ANOVAs (two Diagnosis Groups (Chronic Insomnia, No Chronic Insomnia) x three Measures (Sleep Diary, PSG, Actigraphy)), followed by post hoc tests (Least Significant Difference). Means, standard deviations, and post hoc test results are shown in Table 1.

The ANOVA for SOL indicates only a significant main effect for Measure, F (1, 45) = 23.71, p < .001. Post hoc testing indicates significant differences among all three measures with a minimum of p < .01, with Actigraphy showing the shortest SOL and Sleep Diary the longest for both Diagnosis Groups. For WASO, results indicate significant main effects for both Measure, F (1, 42) = 16.16, p < .001, and Diagnosis Group, F (1, 42) = 6.96, p < .05. The No Chronic Insomnia group spent significantly less time awake during the night than the Chronic Insomnia group. Post hoc testing showed that WASO was shortest when measured by the Sleep Diary and longest when measured by Actigraphy for both groups. The ANOVAs for TST and Sleep Efficiency indicate significant main effects for Diagnosis, F (1, 44) = 10.76, p < .01, and F (1, 42) = 9.84, p < .003, respectively. These show that the Chronic Insomnia group had lower TST and worse Sleep Efficiency, regardless of Measure, than the No Chronic Insomnia group. There were no significant findings on Measure on either TST or Sleep Efficiency.

Objective 4: how do perceptions of the qualitative aspects of sleep relate to quantitative sleep parameters as measured by the three instruments?

Pearson correlations were used to examine the relationship between self-reported qualitative aspects of sleep (Sleep Quality, Non-Refreshing Sleep) and quantitative sleep parameters (SOL, WASO, TST, Sleep Efficiency)—all measured at the sleep laboratory. Here, again, we used p < .01 as our significance criterion because of the large number of r values calculated.

Coefficients indicate that in the Chronic Insomnia group, Sleep Quality achieved moderate to high correlations for all the quantitative sleep parameters (r ranged from 0.44 to 0.61) other than

SOL, which was significant for the Sleep Diary only, r (30) = .4, $p < .001$. TST as measured by all three measures achieved the highest correlation with Sleep Quality in this group (r ranged from 0.54 to 0.61). This is in contrast to the results in the No Insomnia group, where Sleep Quality was not significantly related to TST or to most of the other parameters. Only Actigraphy measured WASO, r (15) = –0.65, $p < .01$, and Sleep Efficiency, r (15) = 0.61, $p < .01$, were significantly correlated to Sleep Quality. In neither group were sleep parameters highly correlated with non-refreshing sleep, regardless of how sleep parameters were measured.

Examination of the intercorrelations of the qualitative sleep variables indicates that Sleep Quality was significantly correlated with Non-Refreshing Sleep in both the Insomnia group, r (30) = .48, $p < .01$, and the No Chronic Insomnia group, r (15) = .58, $p < .05$.

Objective 5: validity: evaluating the relationship between daytime fatigue and sleepiness, psychological functioning, and sleep parameters as measured by the three instruments

We correlated scores on fatigue and sleepiness (Empirical Scales), anxiety (Spielberger STAI), depression (Beck Depression Inventory), and health related functioning (eight subscales of the SF-36) with sleep parameters (i.e. SOL, WASO, TST, Sleep Efficiency) as measured by Actigraphy, Polysomnography, and the Sleep Diary. Again, we did this separately for the Chronic Insomnia and the No Chronic Insomnia groups. Because this resulted in 144 correlation coefficients for each group we applied a Bonferroni correction to the alpha level. No significant correlations were found between daytime functioning and sleep parameters, regardless of how these were measured.

Objective 6: how representative is the sleep lab experience of typical home sleep experience?

It is commonly believed that one night's sleep in the sleep laboratory is not representative of home sleep. Since the data were available, we tested this belief. Sleep Diary scores obtained at the sleep lab and at home (seven day average) were examined in a series of two-way between-within ANOVA comparisons (two Diagnosis Group (Chronic Insomnia, No Chronic Insomnia) x two Setting (Home, Lab)). Of interest are Setting main effects and Setting x Group interactions. Results show no significant interactions on any of the variables and no significant differences between the two Settings for SOL and Sleep Efficiency. WASO, however, was significantly longer in the Lab (Mean = 75.72, SD = 98.12), compared to Home (Mean = 41.98, SD = 43.77), F (1, 42) = 4.09, $p < .05$, whereas TST was significantly longer at Home (Mean = 430.25, SD = 95.41) than in the Lab (Mean = 366.3, SD = 116.01), F (1, 44) = 14.89, $p < .001$. Also, three out of four of the sleep parameter scores at home and in the sleep laboratory were significantly and highly correlated: WASO, r (42) = 0.38, $p = .01$; TST, r (44) = 0.55. $p < .001$; and Sleep Efficiency, r (42) = .68, $p < .001$. The correlation for SOL was not significant: r (45) = .23, $p = .13$.

Discussion

Nature and extent of sleep problems in individuals with CFS

In this sample, almost all participants reported poor sleep quality, non-refreshing sleep and daytime fatigue as well as daytime sleepiness. Although most also reported that they suffered from insomnia, not all fell into the diagnostic category of chronic insomnia. A very high percentage was found to have a primary sleep disorder, mainly sleep apnea. This suggests that sleep apnea/hypopnea syndrome is more appropriately considered a comorbidity of CFS rather than an exclusion criterion, as it is traditionally used (see Libman et al., 2009). Clearly, individuals with CFS experience a challenging array of sleep-related nocturnal and daytime problems.

Comparative measurement of quantitative sleep parameters

For this sample, consistency between self-report and objective nocturnal measurements differed depending on whether one looks at sleep parameters associated with amount of nocturnal *wakefulness* or nocturnal *sleep*. With respect to how much of the nocturnal sleep period was spent actually sleeping, both objective measures reflected the individual's subjective experience.

The most important difficulty with actigraphy appears to be the estimation of SOL, which it

underestimated compared to both PSG and Sleep Diary. Nocturnal *wakefulness*, in general, was not reflected accurately or consistently by PSG or actigraphy. Possibly, nocturnal wakefulness, where the aversiveness of the experience can affect perceived duration (Fichten, Creti, Amsel, Bailes, & Libman, 2005), is an experience most accurately captured by subjective report.

Are measures consistent in documenting sleep disturbance in participants with and without chronic insomnia?

All three measures were able to distinguish participants with chronic insomnia from those without this diagnosis based on TST, Sleep Efficiency, and WASO but not SOL. The three measures differed in their assessments of SOL and WASO, with self-report overestimating SOL and underestimating WASO relative to the two objective measures in both the Chronic Insomnia and the No Chronic Insomnia groups. These results have implications regarding choice of sleep parameter and measurement modality. It appears that for this sample TST and Sleep Efficiency provide similar results regardless of measurement instrument, and differentiate individuals with CFS who have chronic insomnia from those without insomnia. The findings also demonstrate, consistent with findings for non-CFS samples (e.g. Libman, Creti, Levy, Brender, & Fichten, 1997), that self-report overestimates SOL and underestimates WASO in individuals both with and without chronic insomnia.

How do perceptions of the qualitative aspects of sleep relate to quantitative sleep parameters, as measured by the three instruments?

Although feeling unrefreshed in the morning has often been interpreted as a sign of poor sleep, in this sample it was not associated with any of the quantitative sleep variables, regardless of measurement instrument. It was, however, associated with perceived sleep quality. The subjective experience of non-refreshing sleep, particularly upon awakening after adequate sleep length, is an important but poorly defined concept (Stone, Taylor, McCrae, Kalsekar, & Lichstein, 2008). It is, nevertheless, interesting that the complaint of feeling unrefreshed in the morning, whether insomnia was present or not, was unrelated to nocturnal wake or sleep times.

We found sleep quality to be associated with reported estimates of quantitative sleep parameters such as WASO, TST, and Sleep Efficiency on both of the objective sleep measures, but only for the Chronic Insomnia group. For the No Chronic Insomnia group only actigraphy measured scores were significantly associated. These relationships have not been previously regularly examined in CFS populations. Our findings contrast with those found in a non-CFS insomnia sample (Bastien et al., 2003), where sleep quality and PSG measures were not found to be related. Perhaps, the relationship between sleep parameters and sleep quality reflects some unique aspects of CFS. For example, previous studies indicate that patients with CFS report poor sleep quality that is not reflected in objective measurement (Fischler, 1999; Reeves et al., 2006; Watson et al., 2003, 2004). However, a recent investigation reported that, paradoxically, when objective and self-report measures were compared, it was consistently the non-fatigued controls who overestimated the time to fall asleep rather than their counterparts with CFS (Majer et al., 2007). These authors suggested that individuals with CFS may monitor their sleep behavior more closely, and this may contribute to their experienced sleep problems.

Relationship between daytime functioning, psychological functioning, and sleep parameters measured by the three instruments

In this sample, sleep parameters, no matter how these were measured, were unrelated to any aspect of daytime functioning. Also, neither daytime fatigue nor sleepiness was related to the presence of chronic insomnia in this sample. Nor were sleep parameters related to anxiety, depression or health-related quality of life, regardless of measurement modality. In this regard our findings are similar to those of Sharpley et al. (1997) who also found no significant correlation between PSG measured time awake at night and Sleep Efficiency on the one hand, and daytime fatigue, stiffness, and weakness on the other. One might speculate that individuals with CFS present with a distinctive symptom constellation that includes both sleep and wake aspects that do not vary in predictable ways. A direct comparison with a healthy group would be required to interpret the poor relationship between nighttime and daytime experiences in this sample.

Is one night of sleep at the sleep laboratory representative of home sleep?

Sleep quality on the first night in a sleep laboratory is generally not considered representative of usual sleep. In the present study, too, all diary measured sleep parameters (i.e. total sleep time, sleep onset latency, time awake after sleep onset, and sleep efficiency) reflected poorer sleep in the sleep laboratory compared to home sleep, as is usually found in sleep research. This was true of both individuals with and without chronic insomnia. Nevertheless, participants' scores for home and lab sleep on three of the four sleep parameters were highly correlated.

Limitations

It should be noted that our participants spent only one night in the sleep lab; thus they were all influenced by the 'first night effect'. Also, the median duration of the CFS diagnosis in our sample was three-and-a-half years; therefore these findings may not apply to those with shorter or longer illness duration. In addition, this sample was relatively well functioning, in that participants were able to come to the research office to complete questionnaires and to go to the sleep laboratory. Less functional individuals with CFS were likely not volunteers for this study, and these results may not apply to them.

Conclusions

Self-rated total sleep time (Sleep Diary) was the sleep parameter most consistently reflected by both objective measurement modalities. Total sleep time and sleep efficiency were also able to differentiate individuals with and without insomnia, suggesting that these may be used as shorthand indicators of a sleep problem. Daytime sleepiness, fatigue, and feeling refreshed in the morning were not related to either quantitative or qualitative sleep variables. Thus, daytime aspects represent an area of the sleep/fatigue/insomnia experience that is accessible mainly by self-report and not by more objective sleep-related measures. The experience of non-refreshing sleep—a major component of conditions like CFS, fibromyalgia, and depression—continues to elude both the subjective and the objective measurement of sleep parameters, at least as used in this study.

References

Alapin, I., Fichten, C. S., Libman, E., Creti, L., Bailes, S., & Wright, J. (2002). Sleep questionnaire. *Health and Psychosocial Instruments (HaPI)*. Available from Behavioral Measurement Database Services (BMDS), PO Box 110287, Pittsburgh, PA 15232–0787 (Tel. +1 412 687 6850; fax +1 412 687 5213; email: bmdshapi@aol.com). Accession Number 225527.

American Academy of Sleep Medicine. (2005). *International Classification of Sleep Disorders (ICSD): Diagnostic and coding manual*, 2nd edn. Westchester, IL: American Academy of Sleep Medicine.

Atlas Task Force of the American Sleep Disorders Association. (1993). Recording and scoring leg movements. *Sleep*, *16*, 749–759.

Bailes, S., Libman, E., Baltzan, M., Amsel, R., Schondorf, R., & Fichten, C. S. (2006). Brief and distinct empirical sleepiness and fatigue scales. *Journal of Psychosomatic Research*, *60*, 605–613.

Bastien, C. H., Fortier-Brochu, E., Rioux, I., LeBlanc, M., Daley, M., & Morin, C. M. (2003). Cognitive performance and sleep quality in the elderly suffering from chronic insomnia: Relationship between objective and subjective measures. *Journal of Psychosomatic Research*, *54*, 39–49.

Beck, A., Steer, R., & Brown, G. (1996). *BDI-II: Beck Depression Inventory manual*, 2nd edn. San Antonio, TX: The Psychological Corporation, Harcourt Brace & Company.

Campbell, S. S., Gillin, J. C., Kripke, D. F., Erikson, P., & Clopton, P. (1989). Gender differences in the circadian temperature rhythms of healthy elderly subjects: Relationships to sleep quality. *Sleep*, *12*, 529–536.

Carruthers, B. M., Jain, A. K., de Meirleir, K. L., Peterson, D. L., Klimas, N. G., Lerner, A. M. et al. (2003). Myalgic encephalomyelitis/chronic fatigue syndrome: Clinical working case definition, diagnostic and treatment guidelines, a consensus document. *Journal of Chronic Fatigue Syndrome*, *11*, 107–115.

Edinger, J. D., Means, M. K., Carney, C. E., Andrew, D., & Krystal, A. D. (2008). Psychomotor performance deficits and their relation to prior nights' sleep among individuals with primary insomnia. *Sleep*, *31*, 599–607.

Fichten, C. S., Creti, L., Amsel, R., Bailes, S., & Libman, E. (2005). Time estimation in good and poor sleepers. *Journal of Behavioral Medicine*, *28*, 537–553.

Fichten, C. S., Creti, L., Amsel, R., Brender, W., Weinstein, N., & Libman, E. (1995). Poor sleepers who do not complain of insomnia: Myths and realities about psychological and lifestyle characteristics of older good and poor sleepers. *Journal of Behavioral Medicine*, *18*, 189–223.

Fischler, B. (1999). Review of clinical and psychobiological dimensions of the chronic fatigue syndrome: Differentiation from depression and contribution of sleep dysfunctions. *Sleep Medicine Reviews*, *3*, 131–146.

Fossey, M. E., Libman, E., Bailes, S., Baltzan, M., Schondorf, R. Amsel, R., & Fichten, C. S. (2004). Sleep quality and psychological adjustment in chronic fatigue syndrome. *Journal of Behavioral Medicine*, *27*, 581–605.

Fukuda, K., Strauss, S. E., Hickie, I., Sharpe, M. C., Dobbins, J. G., & Komaroff, A. (1994). The chronic fatigue syndrome: A comprehensive approach to its definition and study. *Annals of Internal Medicine*, *121*, 953–959.

Gurbaxani, B. M., Goertzel, B. N., Jones, J. F., & Maloney, E. B. (2006). Linear data mining the Wichita Clinical Matrix suggests sleep and allostatic load involvement in chronic fatigue syndrome. *Pharmacogenomics*, *7*, 455–465.

Hart, R., Morin, C., & Best, A. (1995). Neuropsychological performance in elderly insomnia patients. *Aging and Cognition*, *2*, 268–278.

Harvey A. G., Stinson, K., Whitaker, K. L., Moskovitz, D., & Virk, H. (2008). The subjective meaning of sleep quality: A comparison of individuals with and without insomnia. *Sleep*, *31*, 383–393.

Kushida, C. A., Littner, M. R., Morgenthaler, T., Alessi, C. A., Bailey, D., Coleman, J., Jr et al. (2005). Practice parameters for the indications for polysomnography and related procedures: An update for 2005. *Sleep*, *28*, 499–519.

Lacks, P. (1987). *Behavioral treatment for persistent insomnia*. Oxford: Pergamon Books.

Landis, C. A., Frey, C. A., Lentz, M. J., Rothermel, J., Buchwald, D., & Shaver, J. L. (2003). Self-reported sleep quality and fatigue correlates with actigraphy in midlife women with fibromyalgia. *Nursing Research*, *52*, 140–147.

Libman E., Creti, L., Baltzan, M., Rizzo, D., Fichten, C.S. & Bailes, S. (2009). Sleep apnea and psychological symptoms in Chronic Fatigue Syndrome. *Journal of Health Psychology*, 14, 1251-1257.

Libman, E., Creti, L., Levy, R. D., Brender, W., & Fichten, C. S. (1997). A comparison of reported and recorded sleep in older poor sleepers. *Journal of Clinical Geropsychology*, *3*, 199–211.

Libman, E., Fichten, C. S., Bailes, S., & Amsel, R. (2000). Sleep questionnaire versus sleep diary: Which measure is better? *International Journal of Rehabilitation and Health*, *5*, 205–209.

Lichstein, K. L., Durrence, H. H., Taylor, D. J., Bush, A. J., & Riedel, B. W. (2003). Quantitative criteria for insomnia. *Behaviour Research and Therapy*, *41*, 427–445.

Lichstein, K. L., Stone, K. C., Donaldson, J., Nau, S. D., Soeffing, J. P., Murray, D. et al. (2006). Actigraphy validation with insomnia. *Sleep*, *29*, 232–239.

Littner, M., Hirshkowitz, M., Kramer, M., Kapenm, S., McDowell, A.W., Bailey, D. et al. (2003). Practice parameters for using polysomnography to evaluate insomnia. *Sleep*, *26*, 754–760.

Majer, M., Jones, J. F., Unger, E. R., Youngblood, L. S., Decker, M. J., Gurbaxani, B. et al. (2007). Perception versus polysomnographic assessment of sleep in CFS and non-fatigued control subjects: Results from a population-based study. *BMC Neurology*, *7*, 40–48.

Morgenthaler, T., Alessi, C., Friedman, L., Owens, J., Kapur, V., Boehlecke, B. et al. (2007). Practice parameters for the use of actigraphy in the assessment of sleep and sleep disorders: An update for 2007. *Sleep*, *30*, 519–529.

Reeves, W. C., Heim, C., Maloney, E. M., Youngblood, L. S., Unger, E. R., Decker, M. J. et al. (2006). Sleep characteristics of persons with chronic fatigue syndrome and non-fatigued controls: Results from a population-based study. *BMC Neurology*, *6*, 41–48.

Reeves, W. C., Wagner, D., Nisenbaum, R., Jones, J. F., Gurbaxani, B., Solomon, L. et al. (2005). Chronic fatigue syndrome: A clinically empirical approach to its definition and study. *BMC Medicine*, *3*, 19–27.

Reyes, M., Nisenbaum, R., Hoaglin, D. C., Emmons, C., Stewart, G., Randall, B. et al. (2003). Prevalence of chronic fatigue syndrome in Wichita, Kansas. *Archives of Internal Medicine*, *163*, 76–80.

Rosa, R. R., & Bonnet, M. H. (2000). Reported chronic insomnia is independent of poor sleep as measured by electroencephalography. *Psychosomatic Medicine*, *62*, 474–482.

Sadeh, A., & Acedbo, C. (2002). The role of actigraphy in sleep medicine. *Sleep Medicine Reviews*, *6*, 113–124.

Schutte-Rodin, S., Broch, L., Buysse, D., Dorsey, C., & Sateia, J. (2008). Clinical guideline for the evaluation and management of chronic insomnia in adults. *Journal of Clinical Sleep Medicine*, *4*, 487–504.

Semler, N. C., & Harvey, A. G. (2006). Daytime functioning in primary insomnia: Does attentional focus contribute to real or perceived impairment? *Behavioural Sleep Medicine*, *4*, 85–103.

Sharpley, A. (1996). Impact of daytime sleepiness underrated. *Lancet*, *338*, 71.

Sharpley, A., Clements, A., Hawton, K., & Sharpe, M. (1997). Do patients with 'pure' chronic fatigue syndrome (neurasthenia) have abnormal sleep? *Psychosomatic Medicine*, *59*, 592–596.

Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R., & Jacobs, G. A. (1983). *Manual for the State-Trait Anxiety Inventory (Form Y)*. Palo Alto, CA: Consulting Psychologists Press.

Stone, K. C., Taylor, D. J., McCrae, C. S., Kalsekar, A., & Lichstein, K. L. (2008). Nonrestorative sleep. *Sleep Medicine Reviews*, *12*, 275–288.

Ware, J. E., Snow, K. K., Kosinski, M., & Gandek, B. (2000). *SF-36 health survey: Manual and interpretation guide*. Lincoln, RI: Quality Metric Incorporated.

Watson, N. F., Jacobsen, C., Goldberg, J., Kapur, V., & Buchwald, D. (2004). Subjective and objective sleepiness in monozygotic twins discordant for chronic fatigue syndrome. *Sleep*, *27*, 973–977.

Watson N. F., Kapur, V., Arguelles, L. M., Goldberg, J., Schmidt, D. F., Armitage, R., & Buchwald, D. (2003). Comparison of subjective and objective measures of insomnia in monozygotic twins discordant for chronic fatigue syndrome. *Sleep*, *26*, 324–328.

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