Published in final edited form as:

Behav Sleep Med. 2016 ; 14(5): 539–549. doi:10.1080/15402002.2015.1048447.

Discrepancies Between Self-Reported Usual Sleep Duration and Objective Measures of Total Sleep Time in Treatment Seeking Overweight and Obese Individuals

Erin O'Brien, PhD, Chantelle Hart, PhD, and Rena R. Wing, PhD

The Miriam Hospital/Alpert Medical School of Brown University

Abstract

Introduction—Given that short sleep duration is associated with increased risk of obesity, there is interest in developing interventions to increase sleep to help with weight control. Few studies have examined the agreement between actigraphy and self-reported usual sleep duration in treatment seeking overweight and obese individuals. We therefore sought to examine the association among individuals enrolling in a weight control program.

Method—63 participants (mean age=45.0 ± 8.9 yrs; mean BMI= 34 ± 4.3) completed the Pittsburgh Sleep Quality Index (PSQI), which asks about total sleep time (TST); they also completed questions on their sleep on weekends and weekdays, which were used to compute a weighted average measure of usual total sleep time. Self-reports were compared to TST estimated from 7 days of actigraphy using Pearson Correlations, raw and absolute discrepancies, and the degree of overlap in participants classified as short sleepers (<6 or <7 hours) via self-report and actigraphy.

Results—Actigraph- estimated TST correlated $r = .31$ with PSQI self-report and $r = .20$ with the weighted average self-reported TST. For approximately one third of the sample, the self-report measures differed by >1 hour from the actigraph estimated TST. Only 20 of the 32 subjects (62.5%) who were classified as short sleepers (<7 hours/night) by actigraphy were similarly classified by self-report and only 2 of the 11 (18 %) based on < 6 hours/night. Poor sleep quality was associated with greater absolute discrepancy between actigraphy and self-reported TST.

Conclusions—In overweight and obese individuals seeking weight control, self-report of usual sleep time and actigraph estimates are only weakly correlated. Future studies should determine whether efforts to modify sleep duration as part of treatments for obesity should target self-reported or actigraph-estimated short sleepers.

A growing body of literature has reported associations between short sleep duration and measures of health and illness, particularly obesity and type 2 diabetes (Bjorvatn et al., 2007; Chaput, Despres, Bouchard, & Tremblay, 2007; Marshall, Glozier, & Grunstein, 2008). This has led to increasing interest in intervening to modify sleep duration as a means of helping with weight control. An important question is how best to identify short sleeping

overweight or obese individuals who might benefit most from an intervention that includes a focus on improving sleep.

Most studies of obesity and sleep duration have relied on self-report to define sleep duration in large part because of the large sample sizes involved in these epidemiological studies (Patel, Malhotra, White, Gottlieb, & Hu, 2006; Gangwich, Malaspina, Boden-Albala, & Heymsfield, 2005; Cappuccio, et al., 2008). Moreover, sleep is often characterized based on the response to a single item (e.g., "On average, how many hours do you sleep each night?"). A number of studies have sought to determine accuracy of self-reported sleep duration. In several of these studies, self-reported sleep duration was compared to polysomnography (PSG) (Baker, Maloney, & Driver, 1999; Manconi et al., 2010; McCall, Turpin, Reboussin, Edinger, & Haponik, 1995; Silva et al., 2007; Tsuchiyama, Nagayama, Kudo, Kojima, & Yamada, 2003). Both under- and over-reporting of sleep duration have been observed, even though the two measures have typically described the same night of sleep. Likewise, a few studies have compared self-report to actigraphy (Girschik, Fritschi, Heyworth, & Waters, 2012; Lauderdale, Knutson, Yan, Liu, & Rathouz, 2008; Van Den Berg JF et al., 2008). Again marked discrepancies have been reported. In several studies, the discrepancy was specifically evaluated by body mass index; Lauderdale et al (2008) reported that the discrepancy between reported and actigraph-assessed sleep was greater in those who had a lower BMI, but Mezick, Wing and McCaffery (2014) found no differences in the discrepancies by BMI. Other variables typically associated with obesity, such as sleep apnea and emotional stress, have been related to the magnitude of the discrepancy between self-report and actigraph estimates of sleep (Vgontzas et al., 2008)

The goal of the present study was to examine the association between self-report of usual sleep duration and actigraph-estimated sleep duration in a sample of overweight/obese individuals seeking weight loss treatment. Prior studies have not examined this association in this population. Focusing on individuals who are overweight or obese is important because these individuals would likely be targeted in future weight loss studies that include a sleep component. Moreover, previous studies show that treatment seeking obese individuals differ from the general obese population on a variety of different parameters, including having higher levels of psychopathology and binge eating (Fitzgibbon, Stolley, & Kirschenbaum, 1993), self-stigma (Lillis, Luoma, Levin & Hayes, 2010), and impairment in obesity-specific health related quality of life (Kolotkin, Crosby & Williams, 2002). Thus findings from epidemiological studies of the obese might differ from those seen in treatment-seeking patients. We compare two approaches that are likely to be used to help screen individuals for such interventions: self-report and actigraphy and consider a variety of ways to examine agreement between the measures and the identification of short sleepers.

Methods

Participants

To be eligible for this study, participants were required to be age 25-55, with a BMI between 25 and 50. There was no sleep duration requirement to enter this study and those receiving treatment for sleep apnea were included. , Participants were excluded if they reported being diagnosed with sleep apnea without current or ongoing treatment (e.g., CPAP/Bi-PAP use,

use of mandibular advancement appliance), two or more symptoms of excessive daytime sleepiness (e.g., falling asleep while driving), or use of medications that might affect sleep or weight. Shift workers, those who travel frequently (shifting time zones), and those experiencing hot flashes were also excluded.

Procedures

Participants (N=63) were recruited by advertisements for a research study involving a behavioral weight control intervention. Prior to starting the intervention, all participants completed a battery of self-report questionnaires related to sleep, mood, and health and then wore an actigraph for one week to obtain an objective estimate of sleep duration.

Measures

Self-report measures of sleep duration—The study included several different self-report measures of sleep duration. First, we used The Pittsburgh Sleep Quality Index (PSQI) (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989), which is a reliable, valid, and widely used measure of sleep disturbance. Higher scores indicate poorer sleep, with a cutoff of >5 indicating poor sleep. The PSQI includes several questions about sleep duration over the past month, but does not ask about weekends and weekdays separately. We focus on Question 4 on the PSQI “How many hours of *actual sleep* did you get at night? (This may be different than the number of hours you spend in bed)” to define *PSQI total sleep time (TST)*.

We also asked participants to report “How much total sleep do you get a night?” and queried about weekdays and weekends separately. We utilized a weighted average (averaging 5 weekdays plus 2 weekend days) for a 7-day estimate of *Weighted TST*. Recent data by Lauderdale (2014) suggest that results obtained by asking about weekends and weeknights separately and using a weighted average differ from results obtained by asking about sleep duration in general.

Actigraph measure of sleep—Participants wore actigraphs for one week. Actigraphy was used in the current study in preference to PSG since it is more easily included in larger studies of sleep and obesity and provides an ecologically-valid measure of sleep. Specifically, actigraphy allows participants to sleep in their usual home environment, can be used for longer periods than PSG, and does not appear to change individuals' sleep habits or to have a “first night effect” similar to PSG (Blood, Sack, Percy, & Pen, 1997; Mendels & Hawkins, 1967; Toussaint et al., 1995). Although no previous studies have specifically compared actigraphy and PSG in overweight/obese samples, studies with healthy subjects have demonstrated high correlations (0.9) between actigraphy and PSG measures, particularly for global estimates of sleep duration and time in bed (Blood et al., 1997; Mendels & Hawkins, 1967; Sadeh, Hauri, Kripke, & Lavie, 1995; Toussaint et al., 1995). However, actigraphy is limited in its ability to identify wakefulness and thus systematically over-estimates sleep as measured by PSG (Sadeh, 2011).

Participants wore a Basic Motion Logger Actigraph (Ambulatory Monitoring Inc) on their non-dominant wrist during the day and at night for one week, and were required to have at least 5 complete nights, including at least 1 weekend night. Standard procedures were

employed to determine actigraph estimates of sleep (Acebo & LeBourgeois, 2006; Sadeh & Acebo, 2002). Consistent with Sadeh and colleagues (1994), the actigraph was initialized for 1-minute epochs in zero-crossing mode. Participants completed sleep diaries to ensure that there were no aberrations affecting the sleep period (e.g., medication use) and to help establish sleep and wake estimates from actigraphy. Any discrepancies between the self-report diary data and the actigraphy were queried with participants. Any remaining questions regarding accurate establishment of sleep onset and offset were resolved in consensus meetings. Data were analyzed to estimate sleep/wake using the Action-W software (AMI, Ardsley, NY, USA) and validated algorithms (Sadeh, Sharkey, & Carskadon, 1994). We focused on the *Actigraph Total Sleep Time (TST)*, which is defined as minutes of scored sleep during the sleep period (i.e., sleep period minus any minutes scored as wake during the period). This measure has been used in several prior studies of the discrepancy between self-report and actigraphy (Girschik et al., 2012; Lauderdale et al., 2008; Van Den Berg JF et al., 2008).

Other measures—Participants reported demographic information, including age, gender, race, employment status, and marital status and completed The *Perceived Stress Scale* (PSS)(Cohen, Kamarck, & Mermelstein, 1983) which is a 4-item measure that examined perceived stress, the Berlin Questionnaire (Netzer, Stoohs, Netzer, Clark, & Strohl, 1999) which classifies individuals' risk of having sleep apnea as "high" or "low," and the Center for Epidemiological Studies—Depression Scale (CES-D)(Radloff, 1977). The CES-D is a widely used, standardized measure of depression which consists of 20 items. Total scores range from 0-60 with higher scores indicating increased depressive symptoms. Body mass index (BMI; kg/m²) was calculated based on participant's measured height and weight. Participants were weighed in their clothes, without shoes, using a calibrated digital scale (Tanita BWB 800). Weight was measured to the nearest 0.1 kg. Height was measured to the nearest centimeter using a calibrated, wall-mounted stadiometer.

Statistical Analyses

Descriptive statistics were conducted to describe the sample. Raw and absolute discrepancies (with and without consideration of the direction of the discrepancy) between measures of sleep were calculated. Pearson correlations were used to examine associations between subjective and objective measures of sleep duration and paired t-tests were used to compare the absolute discrepancies between various measures. Since several criteria have been used to categorize "short-sleepers" (Gangwisch, Malaspina, Boden-Albala, & Heymsfield, 2005; Taheri, Lin, Austin, Young, & Mignot, 2004), we examined the accuracy of categorizing short sleepers by two different criteria, using less than 6 or less than 7 hours. Linear regression analyses were conducted to determine the degree to which demographic, sleep, or health factors predicted raw and absolute discrepancies between subjective and objective measures of TST.

Results

Demographic and Sleep Characteristics of Participants

Participants (N=63) averaged 45.0 ± 8.9 years of age (range 25-55), and had a BMI of 33.9 ± 4.3 (25.8-42.5). Eighty one percent were females; 83% were White, 8% were African American and 9% were of other race/ethnicities. Means and standard deviations for other baseline and for the actigraph and self-report sleep measures are presented in Table 1. TST from the actigraph averaged $6.85 \pm .86$ hours (Interquartile range (IQR) 6.54- 7.4) , compared to 6.67 ± 1.0 hours from the PSQI (IQR 6.0-, 7.0) and 6.87 ± 1.03 hours by the weighted average self-report (IQR 6.14- 7.28).

Associations between Self-Report and Objective Data

While the means were consistent, the correlations between actigraph TST and self-reported usual sleep were low ($r=.31$, $p=0.01$ for correlation with PSQI and $r=.20$, $p=0.11$ for correlation with weighted average TST). Moreover, the average absolute discrepancy between actigraphy and the two self-report measures was over 50 minutes and approximately one-third of participants had a discrepancy of greater than 1 hour (Table 2). Correspondence between the actigraph and the PSQI measures of total sleep time (TST) is shown in Figure 1. As expected, when participants were asked about their typical night sleep duration they used only hour and half hour increments (6, 6.5, 7 etc). Participants who reported 6 hours TST on the PSQI (Question #4) had actigraph estimated TST between 4.8 and 8.5 hours per night, and those who reported PSQI TST of 7 hours per night had actigraph TSTs of 5.1 to 8.1 hours per night. The Bland-Altman plot of these same data (Figure 2) shows little association between the sleep time averaged across actigraphy and PSQI and the magnitude or the direction of the discrepancy between these two measures.

Accuracy of Classification of Short Sleepers

Using actigraph TST, 32 participants (51%) were considered short sleepers (<7 hours), and using either of the self-reported TST measures, 33 participants were classified as short sleepers. However, only 20 participants were classified as short-sleepers by both actigraphy and self-report. Thus, only 62% of the individuals who would be classified as short-sleepers by self-report were estimated to be short sleepers by actigraphy. Similarly, when the <6 hour criterion was used, 11 were classified as short sleepers by actigraphy, but only 2 of these individuals were similarly classified by self-report.

What health/demographic/sleep factors affect the discrepancy between subjective and objective measures of sleep?

We also examined demographic, health, and sleep variables that might be related to the raw or absolute discrepancy between subjective and objective sleep measures. The only variable that had significant correlations was the PSQI total score. Those who had higher PSQI total scores, indicating poorer sleep quality, were more likely to underestimate their total sleep time ($r=.50$, $p<.001$) and made larger absolute errors ($r=.44$, $p<.001$). The correlations remained similar when sleep duration was removed from the PSQI total score. None of the

other variables we considered, including gender, age, race, BMI, PSS, CESD, or Berlin risk were significantly related to the discrepancies.

Discussion

There is increasing interest in the association between sleep duration and obesity. Epidemiological studies, which typically use self-reported usual sleep, report both cross-sectional and prospective associations between short sleep duration and risk of obesity or weight gain (Cappuccio et al., 2008). Laboratory studies suggest mechanisms through which short sleep might influence body weight, including changes in leptin and ghrelin and increases in food intake, although not all studies confirm these findings (Schmid et al., 2009; Spiegel, Tasali, Penev, & Van Cauter, 2004). Given the prevalence of obesity and the difficulty of producing long-term weight loss, these findings are leading to a call for interventions to modify sleep as a means of treating obesity.

The present study confirms a number of prior studies showing a marked discrepancy between self-report of usual sleep duration and actigraphy (including Lauderdale et al, 2008; Van Den Berg, et al., 2008; Girschik, et al., 2012) and specifically extends these findings to individuals seeking weight loss treatment. On average participants in the present study had total sleep times of 6.7-6.9 hours based on either of the two self-report measures or actigraphy, but individuals reporting 6 hours of sleep might be sleeping anywhere between 4.8 and 8.6 hours per night as assessed by actigraphy. Both under- and over-estimation of sleep were common and the average absolute discrepancy between self-report of usual sleep and actigraphy was almost a full hour (51-54 minutes). Only 62% of individuals classified as short sleepers (< 7 hours) by actigraphy were considered short sleepers by self-report if the <7 hour criterion was used and only 18% if the <6 hour criterion was used.

Given the extent of the discrepancy in our study, and the fact that large discrepancies have been reported previously, it is of concern that many epidemiological studies are still using a single questionnaire item that asks participants about their usual sleep duration. We note several recent studies showing associations between sleep duration and health consequences, including obesity and mortality, that use the single item of usual sleep duration (Ford, 2014; Jean-Louis et al., 2014; Patterson et al., 2014; Xiao, Keadle, Hollenbeck, & Matthews, 2014). An important contribution of this study is to highlight the marked discrepancy and hopefully encourage use of several different measures of sleep duration in future studies.

This study is also significant because it raises an important issue for researchers and therapists who are interested in trying to intervene on sleep duration to help ameliorate obesity. Should self-reported sleep duration or objectively measured sleep duration be used to identify those for whom increasing sleep may be most advantageous? The epidemiological literature has established an association between obesity and self-reported sleep. Given that, our interventions might best be directed at those who report short sleep, regardless of what their objective sleep assessments may indicate. If self-reported short sleepers are targeted, the interventions to modify sleep duration may need to address psychological issues, such as stress and depression since self-reported short sleep has been

shown to be associated with these psychological variables (e.g. Vgontzas, et al, 2008; Lauderdale, 2008).

The present study is also important because it extends prior research by focusing specifically on overweight and obese, middle-aged, participants who were seeking to enter a weight loss program and includes a full week of actigraphy. Our results however are similar to other studies that also compared self-report to actigraphy. Lauderdale(Lauderdale et al., 2008) examined the discrepancy between actigraphy and self-report sleep duration on the PSQI in a larger sample of participants, but the individuals in that study were younger and less overweight than in the present study and not seeking treatment. Lauderdale et al reported a correlation of .47 between the objective and subjective measure of sleep duration and noted that self-report overestimated actual sleep. In the present study, the correlation between actigraphy and PSQI was lower ($r=.31$) and both under- and over-reporting occurred almost equally. Although the Lauderdale study did not indicate the percent of participants who would be correctly or incorrectly classified as short sleepers based on self-report, we found that the prevalence of short-sleepers defined as < 7 hours was 51-54% by actigraphy or self-report, but only 32% of subjects were classified as short-sleepers by both approaches. Similarly the prevalence of short-sleepers defined as < 6 hours by actigraphy or self-report ranged from 8-17%, but only 3.2% were classified as short sleepers (<6 hours) by both approaches. Van Den Berg (Van Den Berg JF et al., 2008) studied 969 older adults (age 57-97) and compared 6 nights of actigraphy with a sleep diary kept during the same period. Thirty four percent of the participants had a discrepancy of greater than 1 hour between the two measures, which was quite similar to what we observed.

There are a variety of possible explanations for the observed discrepancy between the self-report of usual sleep duration and actigraphy, including the fact that actigraphy measured sleep over a specific 7 day period, whereas self-report asked about general sleep habits. Assessing sleep duration via a sleep diary might provide a stronger association with actigraphy than asking about usual sleep. We could not examine this in our study because we used the diaries to assist us in interpreting the actigraph data, and thus the two measures were confounded. Sleep diaries have not been used in most of the epidemiological studies that have demonstrated associations between short sleep and obesity risk. However, we recommend that they be incorporated in future studies. Examining the association between actigraphy and both a self-report measure of usual sleep and a sleep diary may provide a better understanding of why discrepancies exist between self-report and actigraphy. Another explanation, which we examined, was that the wording of the sleep question might influence the discrepancy. However, we found little difference between the PSQI measure of sleep duration which asked about the past 30 days, with no distinction between weekends and weekdays, and the weighted self-report measure which asked about total sleep time on weekdays and weekends and weighted these to determine weekly averages. Actigraphy provides an estimate of sleep, not a direct measure, and has its own limitations, including the fact that it may not capture periods of night-time wakening (Sadeh, 2011).

We also examined participant characteristics that might be related to the discrepancy between self-report and actigraph estimated TST. We observed that participants with poor sleep quality were more likely to underestimate their sleep duration compared to objectively-

measured TST. These findings are consistent with previous studies that have consistently shown greater discrepancies between self-reported TST and either PSG or actigraph measures of sleep in those with poorer sleep quality, insomnia, sleep apnea, or depression (Blackwell, Ancoli-Israel, Redline, & Stone, 2011; Manconi et al., 2010; McCall et al., 1995; Means, Edinger, Glenn, & Fins, 2003; Van Den Berg JF et al., 2008). We did not find an association with BMI, confirming a recent study by Mezick et al (2014), but perhaps influenced also by the fact that all participants in this study were overweight or obese. We also did not find a correlation with those at high risk for sleep apnea based on the overall Berlin questionnaire. This study has several strengths but also some limitations. Strengths include the use of two different self-report measures, the use of sleep diaries and consensus meetings to ensure appropriate scoring of the actigraph data, and the use of several different approaches to examine the discrepancy between the measures. However, the number of subjects studied was relatively small and primarily non-Hispanic white and female. The study did not include an objective assessment of sleep apnea, a prevalent problem within the obese that has been shown to be associated with the magnitude of discrepancy between self-report and actigraph estimated TST (Lauderdale, et al, 2008). The study also did not control for menstrual cycle or pre/post-menopausal status, variables that could potentially influence sleep quality (Baker & Driver, 2007), however women experiencing hot-flashes were excluded. While gender was not found to be a significant moderator in any of the analyses, the generalizability of these findings to males may also be limited. Questions assessing self-reported TST were intended to prompt participants to reflect on how much actual sleep they obtained per night on average, excluding nighttime wakefulness. However, consistent with existing epidemiological studies, the present study did not specifically ask participants to estimate wake time after sleep onset (WASO). Also, while actigraphy typically allows for examination of sleep across a longer period of time in the individual's usual sleep environment, it must be considered as a proxy measure of sleep and cannot diagnose sleep apnea or other occult sleep disorders.

In summary, the present findings confirm prior studies showing that self-reported sleep duration is only weakly associated with actigraph-estimated sleep and extends this finding to a sample of overweight/obese adults seeking treatment for their obesity. Given this discrepancy, an important question raised by this study is who should be targeted for interventions focused on increasing sleep in order to help with obesity: those who have short sleep defined by self-report or those who have short-sleep measured by actigraphy? Further research is needed to determine the relationship of BMI and health problems with both self-report and objective sleep duration to help answer this question.

Acknowledgments

Funding

This project was supported by NIH Grant # CA150387

References

Baker FC, Driver HS. Circadian rhythms, sleep, and the menstrual cycle. [Review]. *Sleep Med.* 2007; 8(6):613–622. doi: 10.1016/j.sleep.2006.09.011. [PubMed: 17383933]

- Baker FC, Maloney S, Driver HS. A comparison of subjective estimates of sleep with objective polysomnographic data in healthy men and women. *J Psychosom Res.* 1999; 47(4):335–341. [PubMed: 10616227]
- Bjorvatn B, Sagen IM, Oyane N, Waage S, Fetveit A, Pallesen S, Ursin R. The association between sleep duration, body mass index and metabolic measures in the Hordaland Health Study. *J Sleep Res.* 2007; 16(1):66–76. [PubMed: 17309765]
- Blackwell T, Ancoli-Israel S, Redline S, Stone KL. Factors that may influence the classification of sleep-wake by wrist actigraphy: the MrOS Sleep Study. [Comparative Study Research Support, N.I.H., Extramural]. *J Clin Sleep Med.* 2011; 7(4):357–367. doi: 10.5664/JCSM.1190. [PubMed: 21897772]
- Blood ML, Sack RL, Percy DC, Pen JC. A comparison of sleep detection by wrist actigraphy, behavioral response, and polysomnography. *Sleep.* 1997; 20(6):388–395. [PubMed: 9302721]
- Buysse DJ, Reynolds CF 3rd, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res.* 1989; 28(2):193–213. [PubMed: 2748771]
- Cappuccio FP, Taggart FM, Kandala NB, Currie A, Peile E, Stranges S, Miller MA. Meta-analysis of short sleep duration and obesity in children and adults. *Sleep.* 2008; 31(5):619–626. [PubMed: 18517032]
- Chaput JP, Despres JP, Bouchard C, Tremblay A. Short sleep duration is associated with reduced leptin levels and increased adiposity: Results from the Quebec family study. *Obesity (Silver Spring).* 2007; 15(1):253–261. [PubMed: 17228054]
- Cohen S, Kamarck T, Mermelstein R. A global measure of perceived stress. *J Health Soc Behav.* 1983; 24(4):385–396. [PubMed: 6668417]
- Ford ES. Habitual Sleep Duration and Predicted 10-Year Cardiovascular Risk Using the Pooled Cohort Risk Equations Among US Adults. *J Am Heart Assoc.* 2014; 3(6) doi: 10.1161/JAHA.114.001454.
- Gangwisch JE, Malaspina D, Boden-Albala B, Heymsfield SB. Inadequate sleep as a risk factor for obesity: analyses of the NHANES I. *Sleep.* 2005; 28(10):1289–1296. [PubMed: 16295214]
- Girschik J, Fritsch L, Heyworth J, Waters F. Validation of self-reported sleep against actigraphy. *J Epidemiol.* 2012; 22(5):462–468. [PubMed: 22850546]
- Jean-Louis G, Williams NJ, Sarpong D, Pandey A, Youngstedt S, Zizi F, Ogedegbe G. Associations between inadequate sleep and obesity in the US adult population: analysis of the national health interview survey (1977-2009). [Research Support, N.I.H., Extramural]. *BMC Public Health.* 2014; 14:290. doi: 10.1186/1471-2458-14-290. [PubMed: 24678583]
- Lauderdale DS, Knutson KL, Yan LL, Liu K, Rathouz PJ. Self-reported and measured sleep duration: how similar are they? *Epidemiology.* 2008; 19(6):838–845. [PubMed: 18854708]
- Manconi M, Ferri R, Sagrada C, Punjabi NM, Tettamanzi E, Zucconi M, Ferini-Strambi L. Measuring the error in sleep estimation in normal subjects and in patients with insomnia. *J Sleep Res.* 2010; 19(3):478–486. [PubMed: 20149068]
- Marshall NS, Glozier N, Grunstein RR. Is sleep duration related to obesity? A critical review of the epidemiological evidence. *Sleep Med Rev.* 2008; 12(4):289–298. [PubMed: 18485764]
- McCall WV, Turpin E, Reboussin D, Edinger JD, Haponik EF. Subjective estimates of sleep differ from polysomnographic measurements in obstructive sleep apnea patients. *Sleep.* 1995; 18(8): 646–650. [PubMed: 8560130]
- Means MK, Edinger JD, Glenn DM, Fins AI. Accuracy of sleep perceptions among insomnia sufferers and normal sleepers. [Research Support, U.S. Gov't, Non-P.H.S.]. *Sleep Med.* 2003; 4(4):285–296. [PubMed: 14592301]
- Mendels J, Hawkins DR. Sleep laboratory adaptation in normal subjects and depressed patients (“first night effect”). *Electroencephalogr Clin Neurophysiol.* 1967; 22(6):556–558. [PubMed: 4164969]
- Netzer NC, Stoohs RA, Netzer CM, Clark K, Strohl KP. Using the Berlin Questionnaire to identify patients at risk for the sleep apnea syndrome. *Ann Intern Med.* 1999; 131(7):485–491. [PubMed: 10507956]
- Patterson RE, Emond JA, Natarajan L, Wesseling-Perry K, Kolonel LN, Jardack P, Arab L. Short sleep duration is associated with higher energy intake and expenditure among African-American and

- non-Hispanic white adults. [Research Support, N.I.H., Extramural]. *J Nutr.* 2014; 144(4):461–466. doi: 10.3945/jn.113.186890. [PubMed: 24523490]
- Radloff LS. The CES-D scale: A self-report depression scale for research in the general population. *Applied Psychological Measurement.* 1977; 1:385–401.
- Sadeh A, Hauri PJ, Kripke DF, Lavie P. The role of actigraphy in the evaluation of sleep disorders. *Sleep.* 1995; 18(4):288–302. [PubMed: 7618029]
- Sadeh A, Sharkey KM, Carskadon MA. Activity-based sleep-wake identification: an empirical test of methodological issues. *Sleep.* 1994; 17(3):201–207. [PubMed: 7939118]
- Schmid SM, Hallschmid M, Jauch-Chara K, Wilms B, Benedict C, Lehnert H, Schultes B. Short-term sleep loss decreases physical activity under free-living conditions but does not increase food intake under time-deprived laboratory conditions in healthy men. [Research Support, Non-U.S. Gov't]. *Am J Clin Nutr.* 2009; 90(6):1476–1482. doi: 10.3945/ajcn.2009.27984. [PubMed: 19846546]
- Silva GE, Goodwin JL, Sherrill DL, Arnold JL, Bootzin RR, Smith T, Quan SF. Relationship between reported and measured sleep times: the sleep heart health study (SHHS). *J Clin Sleep Med.* 2007; 3(6):622–630. [PubMed: 17993045]
- Spiegel K, Tasali E, Penev P, Van Cauter E. Brief communication: Sleep curtailment in healthy young men is associated with decreased leptin levels, elevated ghrelin levels, and increased hunger and appetite. *Ann Intern Med.* 2004; 141(11):846–850. [PubMed: 15583226]
- Taheri S, Lin L, Austin D, Young T, Mignot E. Short sleep duration is associated with reduced leptin, elevated ghrelin, and increased body mass index. *PLoS Med.* 2004; 1(3):e62. [PubMed: 15602591]
- Toussaint M, Luthringer R, Schaltenbrand N, Carelli G, Lainey E, Jacqmin A, Macher J. First-night effect in normal subjects and psychiatric inpatients. *Sleep.* 1995; 18(6):463–469. [PubMed: 7481418]
- Tsuchiyama K, Nagayama H, Kudo K, Kojima K, Yamada K. Discrepancy between subjective and objective sleep in patients with depression. *Psychiatry Clin Neurosci.* 2003; 57(3):259–264. [PubMed: 12753564]
- Van Den Berg JF, Van Rooij FJ, Vos H, Tulen JH, Hofman A, Miedema HM, Tiemeier H. Disagreement between subjective and actigraphic measures of sleep duration in a population-based study of elderly persons. *J Sleep Res.* 2008; 17:295–302. [PubMed: 18321246]
- Xiao Q, Keadle SK, Hollenbeck AR, Matthews CE. Sleep Duration and Total and Cause-Specific Mortality in a Large US Cohort: Interrelationships With Physical Activity, Sedentary Behavior, and Body Mass Index. *Am J Epidemiol.* 2014; 180(10):997–1006. doi: 10.1093/aje/kwu222. [PubMed: 25281691]

Figure 1.
Correspondence between actigraph and self-report total sleep time

Figure 2.
Bland Altman plot of Actigraphy and PSQI self-reported total sleep time

Table 1

Subject Characteristics (N=63)

	Mean	SD	Interquartile range (IQR)
Gender (% female)	81.0%		
Race/Ethnicity (% White)^I	84.1%		
Age	44.95	8.87	37,53
BMI	33.96	4.33	30.6,37.03
Weight (kg)	91.9	14.8	79.5,102.8
Total PSQI score	6.03	3.04	4,8
Perceived Stress Scale	5.13	2.71	3,7
Berlin Questionnaire (% high risk)	44.4%		
Category 1 “snoring” (% Positive)	42.9%		
Category 2 “fatigue/sleepiness” (% Positive)	23.8%		
Category 3 “hypertension/BMI” (% Positive)	77.8%		
CES-D	10.37	7.32	3,14
Actigraph Total sleep time	6.85	0.86	6.54,7.4
PSQI Total sleep time	6.67	1.00	6.0,7.0
Weighted average Total sleep time	6.87	1.04	6.14,7.28

^I
N=62

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Table 2
Discrepancies between subjective and objective measures of Total Sleep Time (TST)

Variables compared	Correlation	Raw Discrepancy (minutes)		Absolute Discrepancy (minutes)		% w/discrepancy ± 60 min
		M (SD)	IQR	M (SD)	IQR	
Actigraphy TST vs. PSQI TST	.31	11 (66)	-30, +50	51 (43)	16,69	35%
Actigraphy TST vs. Weighted average TST	.20	-1 (73)	-44, +43	54 (48)	21,66	32%

Table 3

Number and percent of total sample with short sleep by different criteria

Total Sleep Time	Actigraphy	PSQI	Weighted Average	Short by Both	
				Actig and PSQI	Actig and Weighted Avg
< 7 hours	32 (51%)	33 (52%)	34 (54%)	20 (32%)	20 (32%)
< 6 hours	11 (17.5)	5 (7.9%)	10 (15.2%)	2 (3.2%)	2 (3.2%)