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Nighttime Variability in Wrist Actigraphy

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Abstract

Wrist actigraphy measures sleep activity and circadian rhythm. This study examined nighttime variability in Actiwatch parameters in a sample of breast cancer survivors (BCSs) to determine a minimum number of nights needed to obtain an accurate picture of objective sleep. A descriptive, quantitative, and repeated measures design was used. Consenting participants wore an actigraph and completed a sleep diary across 7 nights. There were no significant differences in wake after sleep onset (WASO), total sleep time (TST), sleep latency, or sleep disturbances across nights of week (Monday to Sunday) or monitoring nights (1st to 7th). Sleep efficiency was significantly better at Night 6 compared with Night 7. The coefficients of variation (CVs) for WASO ranged from 46% to 86%, TST 23%–34%, sleep latency 154%–246%, sleep efficiency 12%–22%, and sleep disturbances 33%–41%. Although the CVs indicated high variability across women, there was little internight variability in WASO or TST during across 7 nights of sleep. This suggests that in BCSs, Actiwatch data could be collected and evaluated from any single night for an accurate measure of usual sleep.

Keywords

sleep; actigraphy; breast cancer; circadian rhythm; survivors

Wrist actigraphy is a valuable measure of sleep activity and circadian rhythms. The device, which typically looks like a sports watch, is worn on the nondominant wrist for 1 or more nights to measure nighttime sleep (Mini Mitter Co., Inc., 2003). Although not used for diagnosis of clinical sleep disorders, actigraphy is used as a research tool in various patient populations to assess number of sleep disturbances, time spent in bed asleep, and sleep latency (Jean-Louis et al., 1996; Jean-Louis et al., 1997a, 1997b). Researchers evaluating sleep in patients with cancer and cancer survivors have used actigraphy to provide descriptive information about sleep and circadian patterns and to test efficacy of interventions (Ancoli-Israel et al., 2005; Berger, Farr, Kuhn, Fischer, & Agrawal, 2007; Berger et al., 2002; Berger et al., 2003; Epstein & Dirksen, 2007; Miaskowski & Lee, 1999; Roscoe et al., 2002).

Although there are recommendations for using wrist actigraphy to study sleep and circadian rhythms (Littner et al., 2003), these recommendations do not specify the optimal number of

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monitoring nights needed to accurately measure sleep patterns. Some researchers use 6–7 nights (Berger et al., 2002; Epstein & Dirksen, 2007), whereas others use only 2–3 nights (Ancoli-Israel et al., 2005; Berger et al., 2007; Miaskowski & Lee, 1999; Roscoe et al., 2002). It is unclear if nighttime actigraphy data such as wake after sleep onset (WASO), total sleep time (TST), sleep efficiency, sleep latency, and numbers of sleep disturbances are consistent or variable within a week of monitoring. Knowing this information would be useful for making recommendations for a minimum number of nights needed to obtain an accurate picture of nighttime sleep activity. Thus, the purpose of this study was to examine nighttime variability in common actigraphy outcome variables, WASO, TST, sleep efficiency, sleep latency, and number of sleep disturbances in a sample of breast cancer survivors (BCSs) to determine if there is a minimum number of nights needed to obtain an accurate picture of objective sleep.

BACKGROUND

Sleep disturbances in patients with cancer have received recent attention in both descriptive and intervention research studies (Ancoli-Israel et al., 2005; Berger, 1998; Berger et al., 2003; Epstein & Dirksen, 2007; Miaskowski & Lee, 1999; Roscoe et al., 2002; Young-McCaughan et al., 2003). To operationalize objective sleep patterns, researchers often use one of two types of objective sleep monitoring: polysomnography or wrist actigraphy. *Polysomnography* is considered the gold standard for objective sleep measurement. Polysomnography includes at least one overnight stay in a sleep laboratory where electrodes are placed on the face, head, and chest measuring the different phases of sleep (Bowman & Moshenin, 2003). Although home polysomnography devices are currently used, both on-site and home devices are expensive and time consuming that can deter participation by subjects and increase research study costs.

An alternative method of sleep measurement used in research settings is wrist actigraphy. *Wrist actigraphy* is a sensitive objective measure of sleep in both cancer and healthy populations (Ancoli-Israel et al., 2003; de Souza et al., 2003; Kushida et al., 2001; Means, Edinger, & Husain, 2002; Wilson, Watson, & Currie, 1998). Studies have shown concordance between actigraphy and polysomnography on certain sleep parameters such as TST and sleep efficiency (de Souza et al., 2003; Kushida et al., 2001). Actigraphy measures movements in the nondominant wrist and provides information about WASO, TST, sleep efficiency, sleep latency, and number of sleep disturbances. This method of measurement is typically less expensive and can be used over longer time. However, it is unclear how many nights are optimal to accurately measure nighttime activity.

One study of noncancer subjects was found that examined variability of actigraphy findings over 6 nights. Researchers evaluated actigraphy data for internight variability in a sample of 99 men and women aged 50–98 years. No first night effect was found among the subjects suggesting no adaptation to wearing the actigraph device is warranted. In addition, no significant differences were found in activity level and movement over 6 nights of recordings for all subjects (van Hilten et al., 1993), suggesting that patterns of nighttime sleep activity were similar among the 6 nights of recording. Coefficients of variation (CVs) results were varied depending on the sleep parameter with higher values suggesting higher variability. There was a significant difference for mean immobility periods in females suggesting greater variability of sleep findings in women. However, this study was limited to older men and women without cancer who were retired. This could account for the lack of variability in nighttime sleep patterns. In addition, all subjects were started at the same time and day of the week so the night of monitoring was confounded with the day of the week. The current study analyzed variability for both day (Monday to Sunday) and night of recording (Night 1, Night 2, etc.) to determine variability.

CONCEPTUAL FRAMEWORK

The two-process model of sleep regulation was the conceptual framework for this study. The framework highlights the physiological mechanisms that drive sleep and wake (Achermann, 2004; Borbély, 1982; Borbély & Achermann, 1999, 2005; Dijk, Beersma, Daan, Bloem, & Van den Hoofdakker, 1987). Visually, the model is a wave-like structure that shows the relationship between two independent physiological processes of sleep: (a) homeostatic process (Process S) increases during wake (drives the need for sleep) and decreases during sleep (decreases the need for sleep), and (b) the circadian process (Process C) determines alterations of high and low sleep propensity that are independent of prior sleep–waking (the timing to sleep and wakefulness), which determines the onset and end of sleep (Borbély, 1982). Process C is directed by a clock-like mechanism that is not related to prior levels of sleep or the wake-like Process S. Process S and Process C act independently to predict the timing and duration of sleep, structure of sleep, and changes in daytime wakefulness (Borbély & Achermann, 2005; Daan, Beersma, & Borbély, 1984). Changes in these processes can account for night-to-night variability in actigraphy measures of sleep.

Description, Administration, and Scoring of Instrument

The actigraph is worn on the nondominant wrist for 1 or more nights. The device can measure 1 in. × 1 in. × 0.25 in. and weighs 0.75 oz (Mini Mitter Co. Inc., 2003). The device contains an accelerometer that is able to sense any daytime or nighttime motion with a minimal force greater than 0.01 g (Mini Mitter Co. Inc., 2003). The sensor integrates the speed and degree of motion, which produces an electrical current that varies in magnitude. Studies show a high correlation between wrist actigraphy and polysomnography in the assessment of TST and number of nighttime awakenings in healthy individuals, with correlations of .95 for sensitivity, .36 for specificity, and .80 for accuracy (Kushida et al., 2001). These correlations have been replicated in various other validation studies (Ancoli-Israel et al., 2003; de Souza et al., 2003).

The data from the actigraph is generally downloaded using computerized software that quantifies outcome variables such as WASO, TST, sleep efficiency, sleep latency, and number of sleep disturbances. Researchers can input the data from a diary that captures time to bed and time awake into the computer software to ensure accuracy of results. Results are generated by the software providing output for the listed outcome variables. Results should be verified for missing data (subject taking off the watch or malfunction in watch) by evaluating the visual graphs produced by the software. Data can be exported into various graphs or spreadsheets for further analysis. Because of the multiple comparisons involved in the analysis, common variables were focused on in this study: percentage of WASO, TST, percentage of time in bed spent asleep (sleep efficiency), time it takes to fall asleep (sleep latency), and number of sleep disturbances.

METHODS

Design and Setting

The study was a descriptive, quantitative, and repeated measure across 7 nights of sleep recordings. Two settings were used to identify the sample: a southeastern National Cancer Institute-designated cancer center and a midwestern National Cancer Institute-designated cancer center.

Sample

The sample consisted of 55 BCSs who were a mean age of 54 years (*SD* = 9), White (80%), employed at least part-time (75%), postmenopausal (93%), with a mean of 16 years (*SD* =

2.4) education, and at least one concurrent medical problem (64%). Women were generally Stage 1–2 at diagnosis (69%) and taking endocrine therapy (51%).

Women were recruited for the sample if they (a) were at least 21 years old; (b) had a history of breast cancer; (c) had finished primary cancer treatment such as surgery, chemotherapy, or radiation; (d) had no active breast cancer; (e) had no history of other cancer; (f) were willing and able to provide informed consent and health information authorization; and (g) were willing to wear the actigraphy device for 7 nights.

Procedures

The study was approved by the cancer center scientific review committees and institutional review boards at each study site. Subjects were recruited by physician referral and an institutional review board-approved recruitment database. Eligible and interested women were contacted in person in the cancer clinics or by telephone and screened for eligibility by a trained research assistant. Eligible women provided informed consent and Health Information Portability and Accountability Act authorization. Once consent was received, subjects were scheduled for a research visit. The scheduled visit days and times were not the same for all participants. The setting used for data collection was the participants' homes, a private clinic area, or an agreed location outside the home that was within 60 miles of the university. A trained research assistant met the participant and provided verbal instruction regarding the written diary and care of the actigraph. The assistant then placed the actigraph on the nondominant wrist. Participants wore the actigraph at home for 8 days to provide 7 nights of actigraphy data. After 8 days of recording, the actigraph was picked up in person by a research assistant or mailed by the study participant to the study team in a prepaid envelope. Women were compensated for their participation in the study.

Measures

To calculate WASO, TST, sleep efficiency, sleep latency, and number of sleep disturbances, sleep was measured using the Actiwatch-64 (Mini Mitter Co. Inc., Bend, OR). The device looks like a black sport watch worn on the nondominant wrist for eight continuous 24-hour periods. The watch is water resistant and can be worn when bathing. The device uses an accelerometer to measure motion (further description of the device is referenced in preceding section). A 7-night self-reported sleep diary was completed by participants to facilitate data analysis. The diary measured time to bed (lights out), time out of bed (feet on the floor), and naps. The data from the actigraph was downloaded onto a secure, computerized server using the Actiwatch-64 (v. 5.0) software (Mini Mitter Co. Inc., Bend, OR) and analyzed using the times listed in the subjective diary to guide visualization of the sleep times. Once all the time to bed, time out of bed, and nap times were entered into the program, the Actiwatch software provided automated scoring of WASO, TST, sleep efficiency, sleep latency, and number of sleep disturbances. The output was analyzed and verified by a research assistant to ensure accuracy.

Data Analysis

The sample included BCSs who completed 1 week of wrist actigraphy and had data for all nights of recording. This included 7 nights of continuous recordings on the wrist actigraphy. To determine sample characteristics, frequencies and descriptive statistics were computed using SPSS 15.0 (SPSS Inc., Chicago, IL). Internight variability in WASO, TST, sleep efficiency, sleep latency, and number of sleep disturbances was examined across nights of the week (Monday to Sunday) and monitoring nights (first to seventh) separately. One-way repeated measures analyses of variance (RM-ANOVA) were performed. Values were significant at $p < .05$. To further analyze intrasubject variability of nighttime readings, the CV was calculated (CV = standard deviation/mean × 100) for each night of WASO, TST,

sleep efficiency, sleep latency, and number of sleep disturbances. This calculation provides a percentage where a higher number suggest higher variability (Wikipedia, 2008).

RESULTS

Variability in Nighttime Sleep

WASO, TST, sleep efficiency, sleep latency, and number of sleep disturbances results showed most of the sample slept less than 6 hours (*SD* = 1.7), with 15% of sleep time spent awake. The mean sleep efficiency was 78% (*SD* = 13.8), mean sleep latency was 67 minutes (*SD* = 0.50), and mean number of sleep disturbances was 24.1 (*SD* = 9.5). For nighttime variability among WASO, TST, sleep efficiency, sleep latency, and number of sleep disturbances findings, RM-ANOVA results showed no significant differences in WASO ($F = 0.76$, $p = .50$), TST ($F = 2.27$, $p = .06$), sleep efficiency ($F = 1.75$, $p = .15$), sleep latency ($F = 1.29$, $p = .27$), and number of sleep disturbances ($F = 0.72$, $p = .61$) for nights of week (Monday to Sunday) using the Greenhouse–Geisser correction (Field, 2005; Table 1). For monitoring nights (first to seventh), RM-ANOVA results showed no significant differences in WASO ($F = 0.55$, $p = .61$), TST ($F = 2.26$, $p = .06$), sleep latency ($F = 1.13$, $p = .34$), and number of sleep disturbances ($F = 0.77$, $p = .57$) using the same correction method (Table 2). However, sleep efficiency was significantly better at Night 6 compared with Night 7 ($F = 2.48$, $p = .04$).

Overall, this suggests that there was little variability in WASO, TST, sleep efficiency, sleep latency, and number of sleep disturbances during across 7 nights of sleep in BCSs. The CVs for WASO ranged from 46% to 86%, TST 23%–34%, sleep latency 154%–246%, sleep efficiency 12%–22%, and sleep disturbances 33%–41% (Table 3). The highest percentage of variation was noted for sleep latency over all nights of recording.

DISCUSSION

Results suggest there is little internight variability in actigraphy recordings for WASO, TST, sleep efficiency, and sleep disturbances for BCSs. It is unclear why there were significant differences in sleep efficiency between Nights 6 and 7. This could be attributed to the small sample size in the study. It is also interesting that the TST was near significant for both nights of week and monitoring nights, suggesting some variability in the hours of sleep obtained throughout the recording. The TST is constantly low throughout the week and less than what is generally recommended.

Overall, findings suggest that to obtain an accurate measurement of WASO, TST, sleep efficiency, sleep latency, and sleep disturbances using the actigraphy, information could be collected and evaluated from any night. However, the CV, which provides the distribution of responses around the mean, showed large values (values close or more than 100%) for 3 nights of WASO and all nights of sleep latency suggesting greater within subject means for those variables. This might suggest that the precision of the actigraphy findings for the measurement of WASO and sleep latency was low. This again could be attributed to the small sample size.

There were several limitations of this study. First, the small sample size could have contributed to the lack of significant findings. In addition, findings are only applicable to BCSs. Second, there was only one research assistant generating the actigraph scoring for all files, introducing possible error in data interpretation.

In summary, sleep actigraphy is an important and valuable tool used to measure sleep in patients with cancer. Because sleep disturbances are so prevalent in breast cancer survivors,

accurate measurement of objective sleep variables is essential. Depending on the primary sleep variable of interest, findings suggest that fewer days could provide useful data regarding sleep. Although the number of recording nights can vary based on the research hypotheses, the benefits of reducing monitoring time include less participant burden and increased use of study resources. Future investigation of actigraphy sleep variables such as sleep–wake rhythms in various cancer populations is warranted to generate more specific actigraphy guidelines that include number of days needed for accurate measurement of those variables.

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TABLE 1

Intranight Variability Across Night of the Week

Variable	*n*	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	F^a	*p*
WASO										
M(*SEM*)	55	14.53 (1.21)	16.12 (1.74)	13.65 (0.80)	16.09 (1.78)	14.18 (0.88)	14.95 (0.96)	15.26 (1.01)	0.76	.50
TST										
M(*SEM*)	55	5.45 (0.31)	6.07 (0.21)	5.89 (0.24)	6.22 (0.23)	6.29 (0.19)	5.91 (0.20)	6.33 (0.24)	2.27	.06
Sleep latency[b]										
M(*SEM*)	55	0.31 (0.10)	0.23 (0.05)	0.17 (0.03)	0.18 (0.05)	0.35 (0.08)	0.18 (0.04)	0.34 (0.8)	1.75	.15
Sleep efficiency[c]										
M(*SEM*)	55	79.89 (1.74)	75.92 (2.17)	78.54 (1.37)	77.70 (1.96)	77.09 (1.74)	78.73 (1.86)	76.14 (2.13)	1.29	.27
Sleep disturbances										
M(*SEM*)	55	24.58 (1.22)	24.29 (3.31)	24.88 (1.28)	25.24 (1.63)	22.62 (1.16)	25.22 (1.35)	24.12 (1.34)	0.72	.61

Note. WASO = wake after sleep onset. TST = total sleep time.

[a]Greenhouse–Geiser correction for nonsphericity.

[b]Represents minutes of sleep latency.

[c]Represents percentage of sleep efficiency.

TABLE 2

Intranight Variability Across Monitoring Night

Variable	*n*	Night 1	Night 2	Night 3	Night 4	Night 5	Night 6	Night 7	F^a	*p*
WASO										
M(*SEM*)	55	13.65 (1.02)	15.76 (1.71)	15.43 (1.78)	15.84 (1.73)	15.53 (1.14)	14.58 (1.02)	15.63 (0.97)	0.55	.61
TST										
M(*SEM*)	55	5.62 (0.26)	6.06 (0.24)	6.09 (0.27)	6.56 (0.24)	5.95 (0.18)	6.14 (0.20)	5.73 (0.23)	2.26	.06
Sleep latency[a]										
M(*SEM*)	55	0.14 (0.03)	0.30 (0.07)	0.22 (0.05)	0.28 (0.07)	0.28 (0.09)	0.22 (0.05)	0.32 (0.08)	1.13	.34
Sleep efficiency[b]										
M(*SEM*)	55	79.90 (1.88)	77.01 (1.98)	76.61 (2.20)	78.16 (1.67)	79.81 (1.30)	79.81 (1.29)	74.22 (2.23)	2.48	.04*
Sleep disturbances										
M(*SEM*)	55	23.90 (1.39)	24.54 (1.40)	23.48 (1.31)	25.26 (1.29)	24.58 (1.17)	25.88 (1.50)	23.30 (1.26)	0.77	.57

Note. ASO = wake after sleep onset.

[a]Greenhouse–Geiser correction for nonsphericity.

[b]Represents minutes of sleep latency.

[c]Represents percentage of sleep efficiency.

*$p < .05$.

TABLE 3

Coefficient of Variation (%)

Variable	Night 1	Night 2	Night 3	Night 4	Night 5	Night 6	Night 7
WASO	55.46	80.64	85.55	81.00	54.67	51.78	45.94
TST	33.99	29.54	32.51	26.83	22.86	24.59	29.84
Sleep latency	178.57	173.33	154.55	192.86	246.42	154.09	181.25
Sleep efficiency	17.38	19.03	21.29	15.86	15.40	11.99	22.23
Sleep disturbances	41.13	40.46	39.40	35.99	33.52	41.00	38.15

Note. WASO = wake after sleep onset. TST = total sleep time.