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SLEEP TIME MONITORING BY ACCELEROMETER IN TWO SUBJECTS FOR 1 YEAR

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The authors conducted sleep time monitoring using an activity-detecting device on a married couple. The subjects were a 39-year-old man and a 36-year-old woman. They were continuously monitored for 1 year or a half-year from 1998 to 1999. Their daily activities were not limited. The male works in an office 5 days a week and stays at home on weekends. The female is a farmer and works in the field when the weather is clear. They usually went to bed at 10–11 p.m. and got up around 6 a.m. the next morning on weekdays. The activity-monitoring device, Actiwatch®, was installed on the wrists of their non-dominant arms. The number of body movements was calculated by the summation of the active electricity number. There was no significant monthly difference in the mean nightly total sleep time (TST) by analysis of variance in either the husband or the wife. When nocturnal and diurnal sleep were combined for the analysis, the mean value in April or May, 1999, was significantly larger than the values in July, August, December or October, although only in the husband. The sleep time for Saturday or Sunday was significantly extended as compared to that of a weekday. Power spectrum analysis showed the TST cycle to predominate on all 7 days in the week in both subjects.

1. INTRODUCTION

In Japan, a sleep time investigation, the "National Time Use Survey", has been carried out by the NHK Broadcasting Culture Research Institute since 1970. A survey on Time Use and Leisure Activities has also been conducted by a self-reporting method by the Management and Coordination Agency since 1976. Both surveys have been made every 5 years. The most precise method of monitoring human sleep has long been the polysomnogram. If the subject cannot tolerate long-term electrode wiring, other physiological methods for monitoring human sleep time should be selected. In this study, an activity-monitoring device called Actiwatch® was used [1].

The activity of the wrist can easily be monitored by the light device and the data quantitatively extracted to judge whether the subject is in the sleep or waking stage. As the device is routinely waterproof, continuous monitoring over weeks can be conducted.

This is a case report describing 1 year of sleep monitoring in two human subjects. Weekly and monthly changes were analyzed.

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2. METHODOLOGY

2.1. SUBJECTS

The first subject, a 39-year-old man, was monitored daily for 1 year from May 21, 1998 to May 20, 1999. Daily activities were not limited. He worked 5 days per week and spent time in his own house on the weekend. He usually went to bed at 10–11 p.m. and got up around 6 a.m. in the morning on weekdays. On weekends, he got up around 7 a.m.

The second subject, a 36-year-old woman, was monitored non-consecutively for 6 months from June 17 to November 30, 1998. Daily activities were not limited. She is a farmer and works in the field whenever the weather is clear. She usually went to bed at 10 p.m. and got up around 6 a.m. the next morning. The subjects were a married couple.

2.2. DEVICE

An activity-monitoring device based on the accelerometer, the Actiwatch® (Mini Mitter Co. Inc., Sunriver), was installed on the wrist of the non-dominant arm. The sampling frequency was 32 Hz and sensitivity 0·05 *g*, counting 1 min as a unit. The number of body movements was calculated by the summation of active electricity counts. If the count was 40 or more, it was judged as awakening. When under 40, the counts of epoch corresponding to 2 min before the target epoch $\times$ 0·04 $+$ the counts of epoch directly adjacent before the target epoch $\times$ 0·2 $+$ the counts of the target epoch $+$ the counts of epoch directly adjacent after the target epoch $\times$ 0·2 $+$ the counts of epoch corresponding to 2 min after the target epoch $\times$ 0·04 exceeds 40, then it was judged as awakening. The validity of this activity-monitoring device in healthy subjects was evaluated. Using this algorithm, the agreement between Actiwatch® and the sleep polygraph was 88·4% on average, based on 24 nights. Pearson's correlation coefficient of total sleep time (TST) between Actiwatch® and the sleep polygraph was 0·848 (Figure 1).

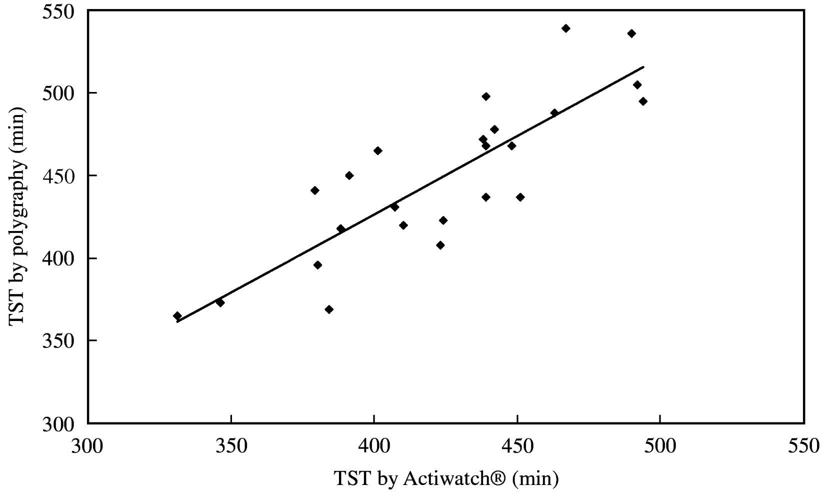

Figure 1. Relationship between total sleep times by Actiwatch® and polygraphy. $y = 0{\cdot}95x + 48{\cdot}6$, $n = 24$, $r = 0{\cdot}848$, $p < 0{\cdot}01$.

2.3. STATISTICAL ANALYSIS

Monthly and weekly trends were checked by multiple comparison using the Tukey method. Power spectrum analysis was done to check the TST cycle. SPSS 10·0J for Windows was used for the analysis.

3. RESULTS

Trend graphs of nocturnal TST for the husband and wife are shown in Figures 2 and 3 respectively. There was no significant difference in the mean value of TST at night for each month by analysis of variance in either the husband or the wife. If daily sleep time was compiled in TST for the analysis, the value in April or in May, 1999, was extended

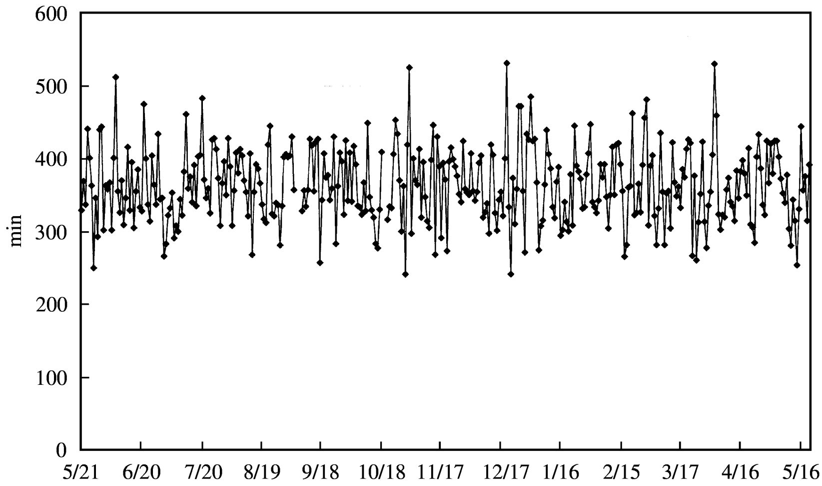

Figure 2. Change in total nocturnal sleep time of husband.

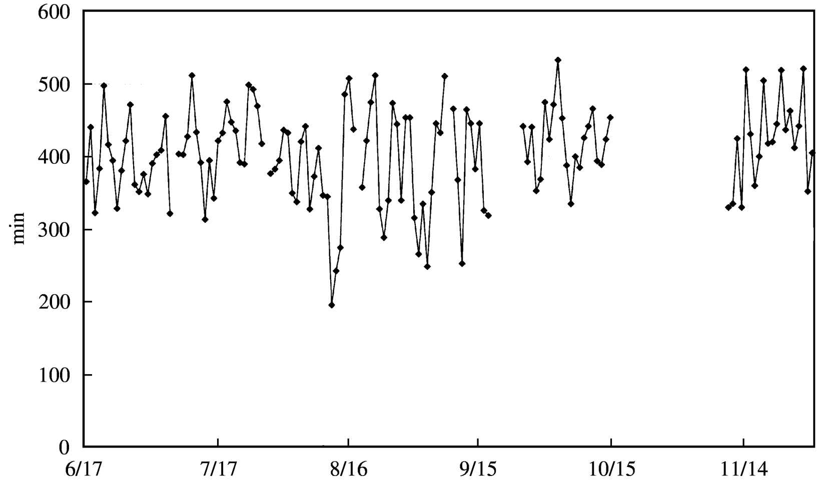

Figure 3. Change in total nocturnal sleep time of wife.

TABLE 1

Total nocturnal and diurnal sleep times of husband and wife for each month of the year

Month	n	Husband	H_Night	n	Wife	W_Night
1998						
5	11	428·8(72·04)	364·8(63·09)			
6	30	431·6(66·95)	363·7(49·78)	14	458·9(67·73)	393·1(51·03)
7	31	416·7(66·41)†‡	360·2(51·39)	29	485·2(61·11)	412·3(49·17)
8	31	421·5(63·83)†‡	362·2(44·59)	30	472·1(114·37)	385·0(79·85)
9	27	442·0(70·43)	374·3(46·03)	22	469·7(128·75)	387·0(75·53)
10	29	424·0(76·17)†	355·0(52·84)	15	437·3(47·51)	424·7(47·37)
11	30	443·8(65·64)	370·3(55·38)	20	492·5(75·26)	422·5(61·86)
12	31	412·2(66·69)†‡	365·5(62·04)			
1999						
1	31	437·0(72·58)	365·2(53·36)			
2	28	435·2(61·61)	366·0(52·05)			
3	31	450·8(78·94)	350·9(51·12)			
4	30	484·2(79·96)	364·9(53·37)			
5	20	495·9(65·95)	359·6(51·11)			

Note: There was a significant difference in the mean value of total sleep time for the husband by analysis of variance. A multiple comparison was made by the Tukey method.

†Significantly lower than the single underlined value.

‡Significantly lower than the double underlined value.

TABLE 2

Total nocturnal and diurnal sleep times of the husband and wife for each day of the week

Week	n	Husband	H_Night	n	Wife	W_Night
Sunday	51	525·1(53·83)	419·5(45·69)†‡	19	511·9(85·40)	440·4(50·11)
Monday	50	423·0(61·12)†‡	364·3(39·73)†	19	444·6(73·30)†	392·3(60·92)
Tuesday	51	400·8(50·15)†‡	336·8(42·37)†‡	14	431·3(61·95)†	366·6(50·68)†‡
Wednesday	52	413·7(57·83)†‡	343·9(40·77)†‡	20	450·7(65·11)†	383·0(65·99)†‡
Thursday	53	425·5(59·42)†‡	351·3(42·37)†‡	20	453·3(75·67)†	385·8(65·16)†
Friday	52	403·4(62·89)†‡	342·1(49·17)†‡	19	457·8(53·78)†	395·8(67·37)
Saturday	51	484·6(63·28)	385·8(49·71)	19	548·2(138·95)	447·2(55·01)

Note: There was a significant difference in the mean value of total sleep time by analysis of variance. A multiple comparison was made by the Tukey method. The dotted line was significantly lower than the mean value for Monday.

† Significantly lower than the single underlined value.

‡ Significantly lower than the double underlined value.

significantly as compared to those in July, August, December or October, although only in the husband (Table 1).

The sleep time on Saturday and Sunday was extended significantly as compared to that on weekdays (Table 2). The longest TST was observed on Sunday in the husband and on Saturday in the wife.

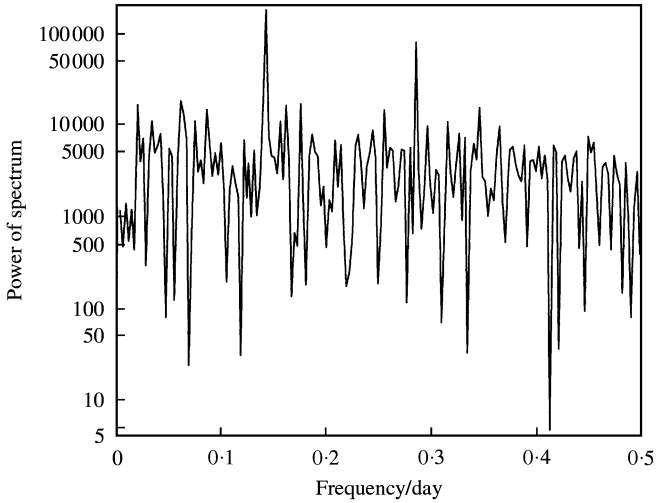

Figure 4. Periodgram of total sleep time in husband.

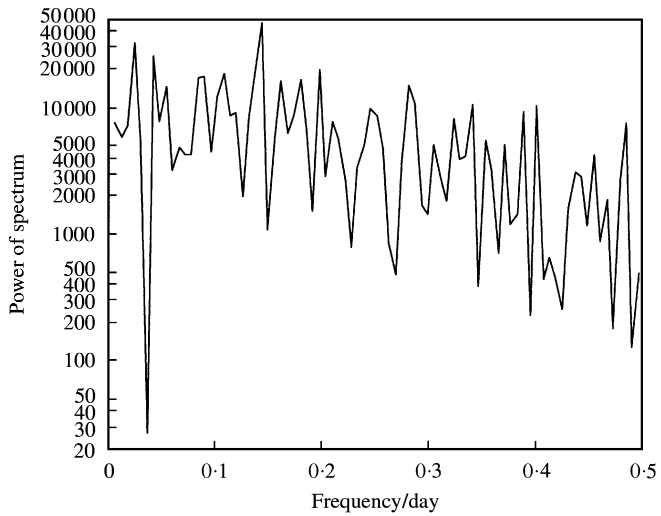

Figure 5. Periodgram of total sleep time in wife.

Nocturnal TST of the husband changed every 7 days according to power spectrum analysis (Figure 4). The wife's nocturnal TST also changed every 7 days (Figure 5). When diurnal sleep was added, the result was the same in both husband and wife.

In addition, the relationship between TST and the menstrual cycle was analyzed. There was no significant TST change in relation to the menstrual cycle, although TST was 423 min during nights when menstruation occurred and 395 min on average other nights.

4. DISCUSSION

The first subject spent his working time doing deskwork and his sleep pattern became bi-phasic in a week. Nocturnal and diurnal sleep times were extended in the last 2 months, partly because of habituation to the body movement monitoring. As nocturnal sleep time did not change significantly in the last 2 months, diurnal sleep became longer. In general, the seasonal change in diurnal and nocturnal (24 h) sleep time is small [2]. The authors focus on only 1 year in this report, and seasonal changes cannot be clearly detected. In addition, the sleep pattern in the female showed no monthly change.

Most studies of seasonal effects on sleep have relied on self-reports rather than actual physiological sleep laboratory measures. Several studies have found using a sleep questionnaire survey that people generally sleep longer in the fall and winter than in the spring and summer. For example, the mean sleep time of more than 100 children was longer in winter than in summer [3]. Kleitman and Kleitman [4] interviewed a group of citizens of Tromsö, a Norwegian town situated to the north of the Arctic Circle, and found that their reported sleep lengths were about an hour less in summer (7·5 h) than in winter (8·5 h). Kleitman explained that the shorter sleep time in summer was attributable not to earlier rising times but rather to later bed times. A questionnaire survey of 249 Austrian medical students found that they slept about a half-hour less in summer than in winter (7·3 versus 7·8 h) [5]. This difference was the result not of seasonal changes in the time they went to bed but rather of earlier rising times during the summer months. A similar reduction in average nocturnal sleep duration from winter to summer was also reported for a large group of American college students [2].

In contrast, a group of children showed no such seasonal variations in sleep duration [6]. Weitzman *et al.* found no seasonal effects on sleep duration in northern Norway using sleep polygraphy, and sleep lengths differed by only 15 min between summer and winter [7]. In contrast, Kohsaka *et al.* reported that the TST difference between summer and winter could not be detected with the sleep polygraph but that stage 4 decreased and rapid eye movement (REM) sleep increased significantly in winter [8]. There was no clear monthly TST change in our report, and TST did not reflect a seasonal change.

REM sleep seasonality is not yet clearly recognizable. Askenasy and Goldstein made 615 polysomnographic recordings in male patients of sleep clinics and found REM sleep time with an acrophase during December–January and a nadir during July–September (single cosinor analysis: mesor $= 49{\cdot}7 \pm 0{\cdot}9$, amplitude $= 5{\cdot}9 \pm 1{\cdot}2$, $p < 0{\cdot}001$) [9]. Both REM sleep time and REM sleep percentage were higher and REM sleep latency shorter during winter and spring than during summer and fall. These data were controlled for age, apnea-hypopnea index and clinical diagnosis type. This was explained mainly by the external temperature. In contrast, Herer and Lavie did not find seasonality in REM sleep based on the results of 706 non-selected male sleep apnea patients. They showed a stability of REM time with a maximum difference between seasons of 7·0 min [10].

Binkley *et al.* made 1-year monitoring of reported sleep information, such as wake-up and to-sleep times, in four subjects [11]. The months with the latest wake-up and latest to-sleep times were concentrated around the winter solstice, and the months with the earliest wake-up and earliest to-sleep times were clustered around the fall equinox. Throughout the year, wake-up times were close to the time of sunrise, but to-sleep times were several hours past sunset. Furthermore, weekend delays in wake-up time (0·8–1·6 h), weekend delays in to-sleep time (0·1–0·5 h), and shorter weekend awake time (0·8–1·3 h) were observed. In our report, to-sleep time was later from December to March, although there were no significant differences in the mean value of to-sleep time between months ($p = 0{\cdot}10$ by analysis of variance).

Binkley surveyed the wrist activity of a woman with respect to her menstrual cycle [12]. He reported that a strong cyclic change was recognized in the average value of motions calculated every 5 min by compiling diurnal and nocturnal data and that there was a dip during ovulation. The authors calculated activity during sleep and found no differences in the mean value of activity during sleep during menstrual periods.

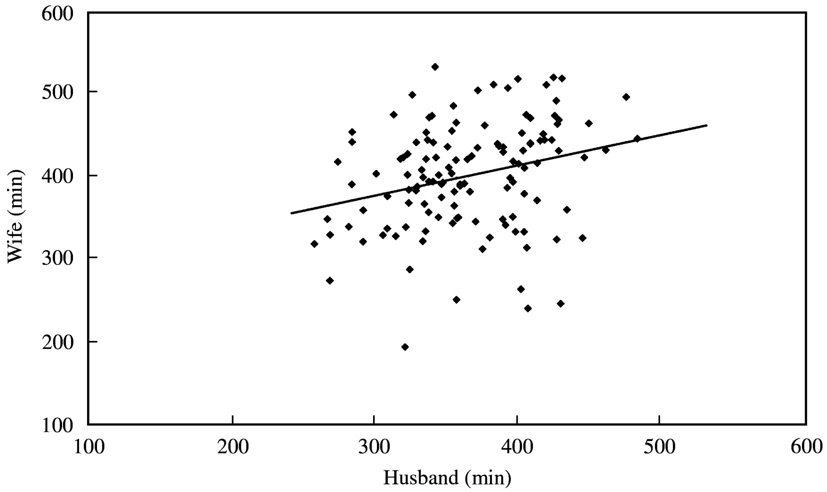

Figure 6. Association between total nocturnal sleep times of husband and wife. $y = 0{\cdot}37x + 265{\cdot}0$, $n = 127$, $r = 0{\cdot}277$, $p < 0{\cdot}01$.

Ishizuka *et al.* assessed the effect of the menstrual cycle on the subjective evaluation of sleep [13]. They calculated the auto-correlation coefficient and found that sleepiness was 0·56 for a 7-day cycle, which was significant. Other subjective aspects of sleep, such as sleep initiation (latency) and sleep maintenance (no-fragmentation), showed no significant cyclical change according to menstruation.

A significant spouse correlation was found in sleep quality changes during both winter and summer [14]. This may indicate an environmental factor in the development of the seasonal patterns of sleep. The association of sleep between husband and wife in this report was checked by TST using data from 127 nights. A weak but significant association was recognized (Figure 6, $r = 0{\cdot}277$, $p < 0{\cdot}01$). Herein, a weekly cycle was clearly observed in both the husband and the wife, which is consistent with the results of two large surveys in Japan [15, 16]. As our sample size is limited, additional data must be compiled and evaluated.

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