Circadian Type and Bed-Timing Regularity in 654 Retired Seniors: Correlations with Subjective Sleep Measures

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Study Objectives: Using telephone interview data from retired seniors to explore how inter-individual differences in circadian type (morningness) and bed-timing regularity might be related to subjective sleep quality and quantity.

Design: MANCOVA with binary measures of morningness, stability of bedtimes, and stability of rise-times as independent variables; sleep measures as dependent variables; age, former shift work, and gender as covariates.

Setting: Telephone interviews using a pseudo-random age-targeted sampling process.

Participants: 654 retired seniors (65 y+, 363M, 291F).

Intervention: none.

Measurements and Results: Independent variables: (1) circadian type (from Composite Scale of Morningness [CSM]), and stability of (2) bedtime and (3) rise-time from the Sleep Timing Questionnaire (STQ). Dependent variables: Pittsburgh Sleep Quality Index (PSQI) score, time in bed, time spent asleep, and sleep efficiency, from Sleep Timing Questionnaire (STQ). Morning-type orientation, stability in bedtimes, and stability in rise-times were all associated with better sleep quality ($P < 0.001$, for all; effect sizes: 0.43, 0.33, and 0.27). Morningness was associated with shorter time in bed ($P < 0.0001$, effect size 0.45) and time spent asleep ($P < 0.005$, effect size 0.26). For bedtime and rise-time stability the direction of effect was similar but mostly weaker.

Conclusions: In retired seniors, a morning-type orientation and regularity in bedtimes and rise-times appear to be correlated with improved subjective sleep quality and with less time spent in bed.

Keywords: Morningness, old, seniors, human, sleep, regularity

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SLEEP AND CIRCADIAN RHYTHMS ARE INEXORABLY LINKED. THE CIRCADIAN TIME AT WHICH SLEEP IS ATTEMPTED IS AN IMPORTANT DETERMINANT OF the duration and quality of the sleep episode. At certain circadian phases, sleep is very difficult to initiate, and other phases very difficult to maintain.[1] In the elderly, slight delays in bedtime (both spontaneously occurring[2] and imposed[3]) have been shown to be associated with less nocturnal sleep being obtained. Also, it has been shown[4] that once awake during the night, seniors find it more difficult to resume sleep than do their younger counterparts, in part because they have extra difficulty in re-initiating sleep near their temperature minimum (Tmin). Indeed, a recent study has shown that when kept awake, seniors are less sleepy than younger adults during the night hours.[5]

During the middle years of life (20 y–59 y), Carrier and colleagues[6] have shown in a cross-sectional study that preferred circadian phase or "circadian type" (as measured by a morningness questionnaire[7]) changes to an earlier timing with increasing age, and that such age-related changes in *morningness* can explain many of the corresponding age-related changes in sleep. Carrier et al.[8] have also shown, using a constant routine protocol, that circadian pacemaker phase per se, is earlier in middle-aged subjects than in young adult ones. Moving to the elderly, sleep disruptions from poor health become increasingly important, but most reviews of the topic of sleep and aging[9-11] agree that age-related changes in sleep may also be a function of age-related changes in circadian rhythms. When compared to younger adults, seniors have higher (i.e., more morning-oriented) morningness scores,[12,13] earlier phasing body temperature and melatonin rhythms,[12] and larger phase angles between DLMO and sleep onset.[14] Thus, at least some of the young versus old differences that have been documented in sleep might be a function of young versus old differences in *circadian type* and *circadian phase*. If that were to be the case, then, even when only seniors (> 65 y) are considered, inter-individual differences in circadian type might also be associated with inter-individual differences in sleep. One of the aims of the present study is to test that hypothesis.

In addition to considering the circadian *phase* of bed timings, one can also consider their *regularity*. Most behavioral treatments for insomnia seek to strengthen circadian rhythmicity by specifying consistency in bedtimes and rise-times.[15] Cross-sectional studies have now revealed that high daily lifestyle regularity (including high regularity in bed timing) is associated with better subjective sleep in college students,[16] in young and middle-aged adults,[17] and in seniors.[18] One can consider the level of regularity versus irregularity, of daily life and of bed timing, to be equivalent to a measure of *circadian amplitude* of behavioral rhythms, in a similar way that morningness can be regarded as a measure of the (preferred) circadian phase of those rhythms. Higher levels of bedtime regularity in seniors may be associated with better sleep either through the action of

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the behavioral rhythms themselves, or through their role as *gatekeepers* to circadian zeitgebers. Those zeitgebers are primarily the photic ones resulting from sleeping in darkness (with eyes closed), but non-photic zeitgebers might also be involved.[19,20] Thus, a high level of regularity in behavioral circadian rhythms can be considered as a way of enhancing circadian zeitgebers for older individuals, keeping their circadian system properly entrained and thereby improving their sleep.

Using a cross-sectional telephone survey of 654 retired seniors (both genders, age 65 y+), the aim of the present study was to explore how inter-individual differences in (1) circadian type, and the stability of (2) bedtimes and (3) rise-times, might each be correlated with individual differences in overall subjective sleep quality (as measured by the Pittsburgh Sleep Quality Index [PSQI]),[21] and in measures of self-reported time in bed, time spent asleep, and sleep efficiency (as measured by the Sleep Timing Questionnaire [STQ]).[22] The hypotheses to be tested were H1: Higher levels of *morningness* would be associated with improved levels of reported sleep quality, sleep efficiency, and sleep duration; and H2: Higher levels of a) *Bedtime stability,* and b) *Rise-time stability* would be associated with improved levels of reported sleep quality, sleep efficiency, and sleep duration. Although the theoretic underpinnings to the study posited an effect going from preferred circadian type and/or bed-timing regularity to better sleep, the study's cross-sectional nature precluded testing the causal direction of any association.

METHODS

Parent Study

Data collection for this study was supported by R01 AG 13396 (PI Monk) which comprises a telephone survey of retired workers, some of whom had done shift work. The study is still ongoing. Occasionally, as the study progressed through the current first 3 years of the grant, various shift work exposures (including zero) were favored and/or excluded in order to try to maintain a balance between the 5 shift work exposure bins (0 y, 1-7 y, 8-14 y, 15-20 y, > 20 y). The present analysis is concerned with all subjects who, at the time of writing, had given full complete data from CSM, STQ, and PSQI. This resulted in a group of 654 retired seniors (363M, 291F, age range: 65 y–92 y, mean: 74.7 y [SD 6.0 y]).

Telephone Survey Methodology

The telephone survey lasted 20-30 min and comprised telephone-modified versions of various questionnaires. It was conducted by the Survey Research Program of the University Center for Social and Urban Research (UCSUR), which maintains a highly experienced staff of survey professionals, as well as a pool of experienced interviewers. Commercially available lists of telephone numbers were purchased, which had a high likelihood of having older persons in the household. Zip codes in the Greater Pittsburgh area that were more likely to have retired shift workers—areas where large steel mills and hospitals were located—were over-sampled to increase efficiency. The survey was thus not a true random sample of older people, but subjects were not totally self-selected, as would be the case were the survey to rely upon responses to advertisements, for example.

The survey instrument was programmed into UCSUR's Computer-Assisted Telephone Interviewing (CATI) system. CATI surveys involve programming the survey, with the interviews conducted at personal computers that display the questions in proper order and automatically control question skips and flow. The CATI system additionally has built-in sample management and call scheduling routines to maximize the probability of contacting households. This technology eliminates the need for paper call records and manual data entry, and allows the interviewers to concentrate on conducting high quality interviews. In order to maximize response rates, ≥ 8 calls were made on varying days of the week at different times to maximize the probability of contacting respondents, and attempts were made to convert initial refusals into completed interviews.

The first section of the interview screened the household for retired residents 65 or older, asking if they would then come to the phone. Then, questions regarding former shift work, including length of exposure, were asked. This involved the taking of a detailed work history (including questions about work schedules). This progressed from position to position throughout the subject's entire working life, taking details of work schedule, as well as starting and ending dates (at least to the nearest year). The sleep and circadian questionnaires then followed. We developed telephone versions of the STQ,[22] the PSQI,[21] and the CSM,[23] among other sleep-related and mood-related questionnaires. Because all subjects were retired, no distinction was made between work-days and weekends in the STQ. PSQI questions concerning snoring as reported by a bed-partner (which do not contribute to the overall PSQI score) were not included in the telephone interview. There were also a few simple questions to glean information regarding physical health and demographic information. The interview was anonymous, and has been ruled as exempt (not requiring signed informed consent) by the University of Pittsburgh IRB. The study conformed to the Declaration of Helsinki.

Subjects

All subjects were required to be 65 y or older, to have not done any shift work in the past 12 months, and to be now retired (i.e., not working for pay for more than 10 h per week outside the home). Both men and women were eligible, and race was not a factor in subject recruitment. All subjects were required to speak and understand English. Shift work and day work were both defined very specifically with regard to working times and hours worked per month. Only jobs requiring ≥ 35 h/week of work outside the home were included in the definitions of shift work and day-work. Military service was not included. Shift work was defined as non-overtime scheduled work outside the home overlapping the midnight to 6 am window (i.e., night work) on either a fixed or rotating basis (details of which were taken). The present study included only those 654 subjects (363M, 291F) with complete answers to the STQ, PSQI, and CSM, as well as a full detailed work history. There were 351 retired shift workers (215M, 136F) and 303 retired day workers (148M, 155F). The retired shift workers had a median shift work exposure of 12.2 years. Overall, the 654 subjects had full-time work experience totaling a median of 35.3 years, and were a median of 12.5 years into their retirement.

Data Analysis

Excel files containing the telephone interview responses from the CATI system were prepared by personnel at UCSUR, and then sent to Dr. Monk's laboratory for analysis with any personal identifying information replaced by a code number. The present study focuses only on responses to the STQ, PSQI, and CSM questions (as well as demographics).

There were two stages to the statistical analysis. First, descriptive statistics were generated for data presentation, with Cohen's d effect sizes calculated and reported. Second, a MANCOVA was applied to each dependent variable, assessing the effect of each independent variable when age, gender, and former shift work status, were extracted as covariates (see below).

Independent Variables

Total CSM score was used to indicate circadian type (morningness). CSM scores comprise a whole number between 13 and 55, with higher numbers representing a more morning-type orientation. Scores ≤ 22 indicate an evening type; scores ≥ 44 a morning type. There were 2 measures of bedtime regularity: (1) stability of bedtime (SB); and (2) stability of rise-time (SR), each as measured by the STQ. The STQ asked how stable (i.e., similar each night) the subject's bedtimes, and rise-times were from night to night in 2 separate questions. Each question yielded a number between 1 and 11, corresponding to the magnitude of variability in timing (1 = 0-15 min, 2 = 16-30 min, etc.), with higher numbers representing greater variability. For CSM, a binary split was made between Morning-type (M-type) and all other types (O-type), defining M-types as CSM ≥ 44 (see below). Binary splits were also made for SB and SR, with stability defined as scoring 1 (0-15 min) on the given measure (see below).

Covariates

Age (< 75 y versus ≥ 75 y), gender, and former shift worker versus former day worker (as defined above) were used as covariates in the statistical analysis.

Dependent Variables

All dependent variables involved subjectively reported sleep. Sleep quality was assessed using the PSQI total score, which comprises a whole number between 0 and 21, with lower numbers representing better sleep; a score > 5 is considered a criterion for sleep problems.[21] *Time in bed* was calculated as the number of minutes between habitual bedtime and habitual rise-time. The STQ[22] asks questions regarding how much sleep is lost in trying to fall asleep (sleep latency – SL) and in unwanted wakefulness thereafter (wake after sleep onset – WASO). *Time spent asleep* was then calculated as *time in bed* – (SL + WASO). *Sleep efficiency* was then calculated as 100**time spent asleep*/*time in bed*.

RESULTS

Descriptive Statistics of Variables

Mean, standard deviation, median, and interquartile range for each variable are given in Table 1. In terms of circadian type, as previous studies[12,13] would suggest, these older (≥ 65 y) subjects had a pronounced tendency towards morningness, and 43% met the criterion (CSM score ≥ 44) for being a Morning-type (M-type). Thus, a binary split between M-types and all Others (O-types) was made to categorize subjects by circadian type. In terms of stability of bedtime (SB), and stability of rise-time (SR), 49% of subjects had a score of 1 (0-15 min) in bedtime stability, 57% had a score of 1 in rise-time stability. Thus, for both bedtime and rise-time (separately) a binary split was made between stable (≤ 15 min) and variable (> 15 min) subjects.

For the dependent variables, the distribution of PSQI scores showed a median score of 5 which is the accepted criterion value (a score > 5 indicates sleep problems according to the standard PSQI definition).[21] Thus, about half the sample had sleep problems, and about half did not. The distribution of PSQI scores was approximately Gaussian, but with a positive skew. The standard deviation was 3.5 units. The distribution of the STQ sleep variables was approximately normal for time in bed and time spent asleep, with means of 8.25 h and 7.50 h, respectively, and showed the expected skew for sleep efficiency, with a mean at 90.8%. Importantly, for both time in bed and time spent asleep, the standard deviations were > 1 h, indicating that there was variance to be explained within the dependent sleep variables. On average, bedtimes were at 23:14, (SD 70 min), rise-times at 07:29 (SD 80 min). As one would expect, on average, M-types were earlier than O-types in bedtimes (difference = 51 min, P < 0.0001), and also in rise-times (difference = 83 min, P < 0.0001).

Circadian Type (Morningness)

As compared to O-types, on average, M-types reported better subjective sleep quality (4.5 vs. 6.0; $F_{1,649}$ = 29.59; P < 0.0001; effect size = 0.43), and slightly higher sleep efficiency (92% vs. 90%; $F_{1,649}$ = 4.95; P < 0.05; effect size = 0.18), but shorter time in bed (477 min vs. 509 min; $F_{1,649}$ = 30.80; P < 0.0001; effect size = 0.45) and time spent asleep (439 min vs. 458 min; $F_{1,649}$ = 10.08; P < 0.005; effect size = 0.26).

Bedtime stability

As compared to variable bedtime (VB) subjects, stable bedtime (SB) subjects reported *better* subjective sleep quality (4.8 vs, 6.0; $F_{1,649}$ = 18.47; P < 0.0001; effect size = 0.33) and slightly higher sleep efficiency (92% vs 90%; $F_{1,649}$ = 3.63; P = 0.06; effect size = 0.15). However, time in bed was *lower* (490 min

Table 1—Descriptive statistics (n = 654)

Variable	Mean	SD	Median	Interquartile range
CSM (morningness)	41.3	6.6	42.0	9
Bedtime stability (arbitrary units)	1.86	1.32	2.00	1
Rise-time stability (arbitrary units)	1.71	1.22	1.00	1
PSQI (total score)	5.4	3.5	5.0	4
TIB (min)	495 (8.25 h)	73.4	495 (8.25 h)	90
TSA (min)	450 (7.50 h)	79.9	457 (7.62 h)	95
Sleep efficiency (%)	90.8	9.5	93.9	8.47
Habitual bedtime	23:14	69.9 min	23:00	90 min
Habitual rise-time	07:29	80.0 min	07:30	90 min

vs. 501 min; $F_{1,649} = 3.93$; $P < 0.05$; effect size = 0.16) and *time spent asleep* was about even (449 min vs. 451 min; $F < 1$).

Rise-Time Stability

As compared to VR subjects, SR subjects reported *better* subjective sleep quality (5.0 vs. 5.9; $F_{1,649} = 12.03$; $P < 0.001$; effect size = 0.27) and higher sleep efficiency (92% vs. 90%; $F_{1,649} = 7.29$; $P < 0.01$; effect size = 0.21), but shorter time in bed (489 min vs. 504 min; $F_{1,649} = 7.62$; $P < 0.01$; effect size = 0.22). However, time spent asleep showed very little difference between VR and SR subjects (448 min vs. 453 min; $F < 1$).

Covariates

Age appeared to have no effect ($P > 0.30$). With regard to gender, men had lower PSQI scores (4.8 vs. 6.1; $P < 0.0001$), and slightly higher sleep efficiency scores (91.8% vs. 89.7%; $P < 0.005$) than women. Former shift workers had higher PSQI scores (5.6 vs. 5.1; $P < 0.05$) and slightly lower sleep efficiency scores (90.2% vs. 91.5%; $P < 0.05$) than former day workers.

DISCUSSION

As noted in the Introduction, being cross-sectional, we cannot ascribe the causal directionality of effect using the results of the present study. In terms of subjective sleep quality as measured by the PSQI, all hypotheses were, though, strongly supported by the data. A morning-type orientation, stability in bedtimes, and stability in rise-times were all associated with better sleep ($P < 0.001$, for all 3) with effect sizes of 0.43, 0.33, and 0.27, (respectively). Thus, both early phasing and more regular behavioral circadian rhythms were associated with better self-rated sleep quality, although stability in rise-times showed a slightly smaller effect.

With regard to circadian type, the present findings suggest that earlier preferred circadian phasing was associated with better sleep quality. Thus, within reason, it may, perhaps, be appropriate to advise seniors to go to bed earlier than they did in their younger years (while recognizing that their nocturnal sleep is likely to be shorter than that of the young).[24] Importantly, the present subjects were not only seniors (> 65 y), but also *retired* seniors. Thus, there were no work-related demands upon their time. In younger adult years, to live more in tune with one's circadian characteristics might warrant *later* bedtimes. However, in younger adult years, work and school schedules often provide a constraint on rise-times, and an equivalent relationship (if present) might be masked by those constraints.

With regard to bedtime and rise-time regularity, the finding that more regular bedtimes and rise-times are related to improved perceived sleep quality is in line with other studies linking higher levels of daily lifestyle regularity (e.g., as measured by the Social Rhythm Metric)[25] to better sleep quality in college students,[16] in young and middle-aged adults,[17] and in seniors.[18] Since regularity in bedtimes and rise-times constitute a major component of other aspects such as meal timings and social contacts,[25] the present results can be considered as a validation of the more general daily lifestyle regularity findings. Moreover, since contemporary definitions of insomnia now rely in large part upon how the sleep is *perceived* by the insomnia patient,[26] this finding may also be important in validating the advice regarding sleep timing regularity that is given in many behavioral treatments of insomnia. Thus, almost all behavioral treatments prescribe regularity in rise-times, and many prescribe regularity in bedtimes (within the constraint of only going to bed when sleepy).[27] The present results suggest that in seniors, at least, regularity in sleep timing can be associated with better perceived sleep quality, with the association being stronger in bedtimes than in rise-times. Again, it is worth noting that the present subjects were all retired, and thus without constraints on rise-times arising directly from work or school schedules.

Moving to measures of time in bed, time spent asleep, and sleep efficiency from the STQ,[22] the picture becomes more complicated. Here, although several effects were statistically significant, the only variable combination showing a moderate effect size was that of circadian type on time in bed. Thus, M-types showed about 30 min shorter time in bed than O-types, with an effect size of 0.45 ($P < 0.0001$). The sleep efficiency of M-types was also slightly higher, but with a very modest effect size (0.18, $P < 0.05$). For stable bedtime (SB), the direction of effect was the same (shorter time in bed than VB), but again the difference was small (about 12 min) and the effect size was weak (0.16, $P = 0.05$). For stable rise-time (SR), the effect was in the same direction (shorter time in bed compared to VR), and slightly stronger in effect size (0.22, $P < 0.01$). SR subjects also showed a better sleep efficiency than VR subjects with a weak effect size (0.21, $P < 0.01$). This suggests that the circadian type and bed-timing regularity attributes that were associated with *better* quality of sleep ratings were also associated with the individual having to spend *less* time in bed. Arguably, this buttresses the use of mild sleep restriction in the behavioral treatment of insomnia.[28] In terms of time spent asleep, M-types reported an average of 20 fewer minutes of sleep than O-types, with an effect size of 0.26 ($P < 0.005$). For the bedtime and rise-time stability variables, there appeared to be little or no difference between SB and VB (effect sizes = 0.03, n.s.), or between SR and VR (effect size = 0.05, n.s.) in time spent asleep. Thus, it would seem that good perceived sleep quality in these seniors was not necessarily related to obtaining more actual sleep.

CONCLUSION

A morning-type orientation and regularity in bedtimes and rise-times is associated with better sleep quality in retired seniors, although less time is spent in bed. These effects appear not to be based upon differences in the actual amount of sleep obtained.

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This was not an industry supported study. Dr. Buysse has consulted for Actelion, Arena, Cephalon, Eli Lilly, GlaxoSmith-Kline, Merck, Neurocrine, Pfizer, Respironics, Sanofi-Aventis, Sepracor, Servier, Somnus Therapeutics, Stress Eraser, Takeda, and Transcept; has received research support from Sepracor;

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