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Chronotype, bed timing and total sleep time in seniors

Timothy H. Monk and Daniel J. Buysse

Department of Psychiatry, Sleep and Chronobiology Center, University of Pittsburgh School of Medicine, Pittsburgh, PA, USA

Abstract

Many older adults (seniors) experience problems with getting enough sleep. Because of the link between sleep and circadian rhythms, changes in bedtime lead to changes in the amount of sleep obtained. Although primarily determined genetically, chronotype changes with advancing age towards a more morning-type (M-type) orientation. In a 2006 study, we have found a linear relationship, by which the earlier a senior's bedtime, the more sleep she/he will obtain. The aim of this study was to see whether this relationship differs for M-type seniors, as compared to seniors outside the M-type category. Retired seniors ($n = 954$, 535 M, 410F, 65 years+, mean age 74.4 years) taking part in a telephone interview were divided into M-types and Other types (O-types) using the Composite Scale of Morningness (CSM). The relationship between bedtime and Total Sleep Time (TST), and between rise-time and TST, was tested using linear regression separately for M-types and O-types. For each participant, habitual bedtime, rise-time and total Sleep Time (TST) [after removing time spent in unwanted wakefulness] were obtained using a telephone version of the Sleep Timing Questionnaire (STQ). Both chronotype groups showed a significant linear relationship between bedtime and TST ($p < 0.001$); with earlier bedtimes leading to more TST (M-type 5.6 min; O-type 4.4 min per 10 min change [slope difference $p = 0.05$]); and an opposite relationship between rise-time and TST with earlier rise-times leading to less TST (M-type 6.7 min; O-type 4.2 min per 10 min change [slope difference $p = 0.001$]). M-types retired to bed 56 min earlier ($p < 0.001$), awoke 93 min earlier ($p < 0.001$) and obtained 23 min less TST ($p < 0.001$) than O-types. In conclusion, both chronotypes showed TST to be related in a linear way to bedtime and rise-time; the overall shorter TST in M-types was due to them rising 93 min earlier, but only retiring to bed 56 min earlier than O-types; as well as having a steeper rise-time versus TST relationship.

Keywords

Morningness; sleep; bedtime; elderly; circadian

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Correspondence: Timothy H. Monk, Department of Psychiatry, Sleep and Chronobiology Center, University of Pittsburgh School of Medicine, WPIC Room E1123, 3811 O'Hara St, Pittsburgh, PA 15213, USA. Tel: +412 246 6413. Fax: +412 246 5300. monkth@upmc.edu.

DECLARATION OF INTEREST

Dr Monk has no conflicts of interest. Dr Buysse has served as a paid consultant on scientific advisory boards for the following companies: Esai, Merck, Philips Respironics, Purdue Pharma and General Sleep Corporation. Dr Buysse has also spoken at single-sponsored educational meetings for Servier. He has also spoken at a single-sponsored lecture for Astellas. This work was supported by U.S. National Institute on Aging Grants AG-13396 and AG-20677, and by RR-024153. Neither the University of Pittsburgh, nor the funding agencies, necessarily holds the views reported in this article.

INTRODUCTION

The division of human kind into “morning larks” and “night owls” has both an intuitive as well as scientific basis, and chronotype has been an established construct in chronobiology since the earliest years of the discipline (Adan et al., 2012; Halberg, 1973; Horne & Ostberg, 1977). Several questionnaires have been developed to measure chronotype (Cavallera & Giudici, 2008; Horne & Ostberg, 1976; Smith et al., 1989; Torsvall & Akerstedt, 1980) in a variety of different languages (Adan et al., 2012). Chronotype has been well studied in student populations and has been shown to relate to academic performance (Besoluk et al., 2011), self-control (Digdon & Howell, 2008), weight gain (Culnan et al., 2013), caffeine and alcohol use (Taylor et al., 2011), and sensation seeking (Prat & Adan, 2013). There have also been several large-scale studies on adult populations, many of them concerned with sleep, personality or depression (Kitamura et al., 2010; Merikanto et al., 2012; Muro et al., 2009; Roeser et al., 2012). Although thought to be primarily a genetic trait (Klei et al., 2005; Koskenvuo et al., 2007; Vink et al., 2001), it is well established that chronotype is not constant throughout the adult lifespan, but has been found in cross-sectional studies to change towards a morning type orientation with advancing age (Adan et al., 2012; Czeisler et al., 1992; Merikanto et al., 2012; Monk et al., 1991). The biological foundation of this has been confirmed by laboratory studies showing that older adults (seniors) have circadian rhythms which phase at an earlier clock time (usually by 1–2 h) than those of younger adults (Carrier et al., 1999; Czeisler et al., 1992; Monk, 2005; Monk et al., 1995; Prinz et al., 1984). Thus, there are relatively few seniors who are Evening types (E-types). A division of seniors into M-types and Other types (O-types = E-types plus intermediate types) is often more appropriate, therefore, for that age group.

The amount of sleep an individual will obtain is largely dependent upon the circadian phase at which sleep is attempted (Borbély, 1982; Czeisler et al., 1980; Zee & Manthena, 2007). This is true both for young and middle-aged adults as well as for seniors (Vitiello, 1997). In a 2006 study (Monk et al., 2006), we examined diary data from 182 seniors yielding 896 subject-nights to show that the earlier a senior went to bed, the greater amount of actual sleep they would report obtaining. Thus, on average, each advance of 10 min in bedtime (to an earlier time) was associated with 7.2 more minutes of actual Total Sleep Time (TST) being obtained (after removing time spent in unwanted wakefulness), as reported in a sleep diary. This finding from *spontaneous* bedtime variation (both within- and between subjects) was confirmed by an experiment in which the sleep of seniors was changed by *manipulating* the bedtime in a situation of time isolation and ad-lib sleep (Monk et al., 2009). In that study, moving the bedtime earlier by 2 h led to 23 more minutes of polysomnographically recorded sleep being obtained, while moving it later by 2 h resulted in a 26-min reduction.

While younger adult M-types appear to show better sleep than E-types (Merikanto et al., 2012; Roeser et al., 2012; Soehner et al., 2007), in retired seniors, the reverse may be true. In an older adult sample (Monk et al., 2011), we have shown (in a subset of the present study of retired seniors – see below) that when Total Sleep Time (TST = time spent in bed minus time in unwanted wakefulness) was assessed using the Sleep Timing Questionnaire (STQ) (Monk et al., 2003), there was an apparent paradox in that M-types reported

significantly *less* actual sleep being obtained than was obtained by O-types. Thus, although seniors who retire to bed earlier report *more* sleep than those with later bedtimes, seniors who are M-types appeared to report *less* sleep than seniors who are O-types, even though they go to bed significantly *earlier* than O-types. The present study aimed to further explore the relationship between bedtime and TST in a large sample of retired seniors (65 years+), separating them into M-types and O-types. It sought to test the following hypotheses: (1) That M-types (like O-types) would show a linear relationship between bedtime and TST, and rise-time and TST; (2) That the slope of these relationships would be different in magnitude (and perhaps direction) between M-types and O-types and (3) That M-types would have shorter TST than O-types.

METHOD

A more detailed description of data collection methods has been published elsewhere (Monk et al., 2012, 2013). To summarize, a telephone survey of >1100 community resident retired seniors was undertaken, which included (among other components) a telephone version of the Sleep Timing Questionnaire (STQ) (Monk et al., 2003). The STQ is a questionnaire designed to obtain similar information as that which is obtained from a week-long sleep diary, but in a one-time retrospective questionnaire. It yields estimates of habitual bedtime, rise-time, sleep latency and minutes of wakefulness after sleep onset. Thus, from it one can glean a measure of actual TST (habitual time in bed minus [sleep latency plus wake after sleep onset]). Also given in the interview was a telephone version of the Composite Scale of Morningness [CSM] (Smith et al., 1989). The CSM yields a single numerical score between 13 and 55, with higher numbers representing a more morning-type chronotype. We followed the recommendations of the creators of the CSM in defining M-types as those scoring 44 and above (Smith et al., 1989). Those scoring <44 (intermediate-types and evening types) were combined into a group which we refer to here as Other-type (O-type). Fortuitously, M-type and O-type groups were of approximately equal size.

Subjects were required to be 65 years or older, to have not done any shift work in the past 12 months, and to be now retired. Both men and women were studied. Because the major hypotheses of the study related to night shift work, retired shift workers were oversampled, eventually representing ~65% of the sample. Prior to the present analysis, we thus compared Retired Shift Workers (RSW) with retired Day Workers (RDW) to ensure that RSW and RDW did not differ in the relation between bedtime and TST (they did not). The present analysis removed subjects who did not answer every question of the CSM; or who either reported a habitual bedtime after 04:00, or reported a habitual TST of <4 h. This left a sample of 945 (535 M, 410F, mean age 74.4 years, SD 6.1 years). The M-type group ($n = 475$) was 59.8% male and had a mean age of 74.2 years (range: = 65–94 years); the O-type group ($n = 470$) was 53.4% male and had a mean age of 74.6 years (range: 65–92 years). The study conformed to all international ethical standards (Portaluppi et al., 2010).

Scattergrams of bedtime (x axis) versus TST (y axis) were first plotted separately for M-type and O-type groups. Pearson correlations and best-fitting regression lines were then calculated. The slopes of these lines were then used to test the hypothesis that the regression lines would have a negative slope, indicating that the earlier the bedtime, the greater would

be the reported TST. Also tested was the hypothesis that chronotype differences would appear in the strength and perhaps direction of the bedtime – TST relationship. In a parallel analysis, the relationship between *rise-time* and TST was also explored, again separately for the two chronotype groups. Then, differences between M-types and O-types in sleep timing and duration were calculated and significance tested by the *t*-test. This tested the hypotheses that M-types would go to bed and get up in the morning earlier and report less TST than O-types.

RESULTS

When scattergrams were plotted of bedtime versus TST (Figure 1, upper panels), significant negative correlations (of similar value) emerged for both M-types and O-types (M-Types: $r = -0.451, p < 0.001$; O-Types: $r = -0.399, p < 0.001$). Thus, for both chronotypes, the earlier the bedtime the longer was the TST. Consideration of the slopes of the best-fitting regression lines (Figure 1, upper panels) indicated that the slope for M-types was steeper than that of O-types [M-types: 5.6 min longer TST per 10 min advance; O-types: 4.4 min longer TST per 10 min advance; (slope difference $Z = 1.62, p = 0.05$)] (Paternoster et al., 1998). When scattergrams were plotted of *rise-time* versus TST (Figure 1, lower panels), significant positive correlations (of similar value) emerged for both M-types and O-types (M-Types: $r = 0.544, p < 0.001$; O-Types: $r = 0.414, p < 0.001$). Thus, for both chronotype groups, the earlier the rise-time the *shorter* was the TST. Consideration of the slopes of the best-fitting regression lines (Figure 1, lower panels) indicated that the slope for M-types was steeper than that of O-types: M-types: 6.7 min versus 4.3 min shorter TST, per 10 min advance; (slope difference $Z = 3.78, p = 0.001$) (Paternoster et al., 1998).

Inspection of habitual bedtimes and rise-times revealed that on an average, M-types went to bed 56 min earlier (22:43 versus 23:39, $t = 12.99, p < 0.001$), and awoke 93 min earlier (06:44 versus = 08:17, $t = 20.39, p < 0.001$) than did O-types. In agreement with our earlier analysis of a subset (~69%) of these data (Monk et al., 2011), M-types reported 23 min shorter TST than did O-types (443 versus 466 min, $t = 4.56, p < 0.001$).

DISCUSSION

Both M-types and O-types showed a significant linear relationship between bedtime and TST. This confirmed the 2006 and 2009 results which had concluded that the earlier a senior went to bed, the more actual sleep she or he would obtain. The TST value, it should be remembered, excluded the time in bed which was spent *awake*, which was not insignificant (~50 min) in this older adult sample. The 2006 study (Monk et al., 2006) differed from the present one in a number of important ways. It used an entirely separate sample of seniors, did not require the subject to be retired and measured TST using a 2-week diary, (Monk et al., 1994) rather than the one-time retrospective questionnaire STQ (Monk et al., 2003). The retirement issue may be important in having “freed up” the participant to make their own bed timing decisions without regard to employment. Importantly, the 2006 study also included both within-subject and between-subject variability in bedtime as the independent variable. Thus, it is not surprising that the slopes of the fitted regression lines linking

bedtime with TST did in fact slightly differ [7.2/10 min (2006 study) versus 5.6/10 min (Current M-types) and 4.4/10 min (Current O-types)].

When the *rise-time* versus TST relationship was considered, significant linear relationships were still found, but this time, of course, in the opposite direction. Thus, the earlier a senior arose from bed, the *less* TST the senior reported. Again, the effect was there for both chronotypes, with a steeper slope for the M-types than for the O-types. Further research is needed to determine *why* this difference in slope occurred. One possible explanation is that M-types are more influenced by endogenous chronobiological processes, essentially having a stronger circadian amplitude. Another is simply that the O-type group was more heterogeneous, including both evening and intermediate chronotypes, thus diluting the effect.

In terms of sleep timing, although M-types went to bed an average of 56 min earlier than O-types, their risetime averaged 93 min earlier. Thus, there was a greater chronotype effect in the morning than in the evening. This is in line with our 2007 study (Monk & Kupfer, 2007) of the effects of age on various components of chronotype as measured using the Horne–Ostberg Questionnaire (Horne & Ostberg, 1976). We identified three major components to chronotype: Factor 1: *Circadian phase/Morning functioning*; Factor 2: *Evening sleepiness* and Factor 3: *Morning sleepiness/Inability to sleep late*. In two separate analyses, one using age as a continuous variable (20–60 years), the other comparing older adult (65–93 years) and younger adult (19–38 years) groups, we found that *Evening sleepiness* was the factor showing the weakest age effect, while *Morning sleepiness/Inability to sleep late* was the one showing the strongest age effect. This imbalance in chronotype effect may have contributed to TST differences between the two chronotype groups. As compared to O-types, on average, the M-types lost ~37 min more of time in bed from their earlier morning rise-time than they gained by their earlier evening bedtime. Thus, although the relationship between bedtime and TST that was reported in the 2006 paper occurred for both chronotypes, superimposed upon that effect was an imbalance between bedtime and rise-time in chronotype effects.

The shorter TST seen here in M-type seniors is the converse of the M-type superiority in sleep seen in younger adults, who have *better* sleep than E-types (Merikanto et al., 2012; Roeser et al., 2012; Soehner et al., 2007). However, the two effects may perhaps stem from similar underlying reasons. In young adults, E-types go to bed later and get less sleep. In older adults, M-types get up earlier and get less sleep. One might speculate that there is a commonality in that social obligations truncate sleep in each case. For young adults, school or work prevents them from sleeping as *late* as they would like. For older adults, social obligations may prevent them from starting their sleep as *early* as they would like. In both cases, social routines and conventions may be taking precedence over behaviors that might otherwise occur because of simple chronobiology, with sleep duration suffering as a consequence. The practical implications of this are that M-type seniors should perhaps avoid late evening TV viewing and social commitments. It is possible that the relatively fixed sleep timing for M-type seniors leads to less flexibility than is evidenced in O-type seniors. For O-type seniors, later bedtimes can more easily be accompanied by correspondingly later rise-times, thus preserving sleep duration.

CONCLUSION

Both M-type and O-type groups showed TST to be related in a linear way to bedtime and rise-time. For both bedtime and rise-time, M-types showed a significantly steeper regression line slope than O-types. M-types arose 93 min earlier, but only retired to bed 56 min earlier than O-types and thus obtained less sleep than them.

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FIGURE 1.

Scattergrams of the bedtime – TST relationship (upper panels), and the rise-time TST relationship (lower panels), with the best-fitting regression line, plotted separately for M-types ($n = 475$) [left panels] and O-types ($n = 470$) [right panels]. In order to facilitate comparison of regression line slopes, the same x axis (12 h) and y axis (600 min) scales are used for all panels.