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INFLUENCE OF CHRONOTYPE, SEASON, AND SEX OF SUBJECT ON SLEEP BEHAVIOR OF YOUNG ADULTS

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The aim of this study was to investigate whether sex, season, and/or chronotype influence the sleep behavior of university students. Detailed data were collected on activity/rest patterns by wrist actigraphy combined with diaries. Thirty-four medical students (19 female and 15 male) were monitored by Actiwatch® actometers for 15 consecutive days in May and again in November. The data of a modified Horne and Östberg chronotype questionnaire, which were collected from 1573 female and 1124 male medical school students surveyed in the spring and autumn over an eight-year period, were evaluated. Actiwatch® sleep analysis software was used to process the activity data with statistical analyses performed with ANOVA. We found no significant sex-specific differences in sleep efficiency, sleep onset latency, or actual sleep-time duration. However, we did find a difference in sleep efficiency between morning and evening types, with morning types having a higher sleep efficiency (87.9%, SD = 1.3) than evening types (84.3%, SD = 0.87%; $p = 0.007$). Seasonal differences were also detected: the actual sleep-time duration in autumn was significantly longer (mean 6.9 h, SD = 0.13 h) than in spring (6.6 h, SD = 0.1 h; $p = 0.013$). Evaluation of the chronotype questionnaire data showed that individuals with no special preference for morningness or eveningness (i.e., so-called intermediates) were most common. The distribution of chronotypes was related to the sex of subject. Men displayed eveningness significantly more often than women (28.9% males vs. 20.8% females; $p < 0.001$), while females exhibited greater morningness (20.3% females vs.15.6% males; $p < 0.001$). Sex influences chronotype distribution, but not actual sleep time-duration, sleep onset latency, or sleep efficiency. The latter, however, differed among chronotypes, while actual sleep-time duration was affected by season. (Author correspondence: hanna.lehnkering@charite.de or renate.siegmund@charite.de)

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INTRODUCTION

Activity-rest rhythms show great variation among individuals. Some people prefer morning activity and find it easy to awaken early, while others experience a peak of activity in the evening and stay up late. The observation of different human chronotypes dates back to Marsh (1906), who noted that his subjects judged their efficiency over the course of the day differently, and therefore concluded that there are day and night people. In 1976, Horne and Östberg developed the Morningness-Eveningness (MEQ) questionnaire to categorize the chronotypes of people into five groups: extreme and moderate morning types (M-types), intermediate ("neither") types (I-types), and moderate and extreme evening types (E-types). This questionnaire is widely used world-wide and is accepted as the easiest method to determine a person's individual preference. Several studies (Baehr et al., 2000; Bailey & Heitkemper, 2001 Duffy et al., 2001) showed that MEQ designation correlates well with "physiological" chronotype, which means the endogenous circadian rhythmicity of morning types peaks earlier than evening types (e.g., earlier peak of body temperature and earlier phase of melatonin circadian rhythms).

The findings of studies pertaining to the influence of sex on chronotype distribution are not always consistent, even though it is presumed to exert an influence. Most studies report higher MEQ scores (tendency towards morningness) in females than males (Adan & Natale, 2002; Achari & Pati, 2007; Baehr et al., 2000). Indeed, Roenneberg et al. (2003), who developed a new chronotype questionnaire, found a more pronounced tendency towards morningness in German and Swiss women than in men. However, no large-scale study seems to have been conducted with the MEQ in Germany to investigate this relation.

Timetables in German society are very strict, and people are compelled to adjust their "natural" time patterns to them. Several studies have investigated the influence of chronotype on sleep parameters in adults, such as sleep duration and timing (Medeiros et al., 2001; Park et al., 1998; Roenneberg et al., 2003). The results, however, are inconsistent. Both Park and Roenneberg reported a shorter sleep duration in evening than in morning types on weekdays and the reverse on the weekend. Medeiros et al. (2001), however, found that chronotype exerted no effect on sleep duration. All studies agree that evening, as opposed to morning, types display more irregular sleeping patterns.

Factors other than chronotype might also influence sleep-wake patterns. The circadian pacemaker (SCN) controls the sleep-wake cycle and is synchronized by environmental light stimuli conveyed from the retina to the SCN via the retinohypothalmic nueral tract (Perreau-Lenz et al., 2004). Light is regarded as one of the most important zeitgebers. This leads to the assumption that season may play a role in influencing the sleep-wake cycle of human beings. Laboratory studies suggest the sleep duration of humans is shorter in summer/spring than in winter/autumn (Wehr, 1991; Wirz-Justice et al., 1984); although Kohsaka et al. (1992) were unable to substantiate this.

Inconsistent findings have been reported regarding the influence of sex on sleep, with most studies reporting a longer sleep duration in women (Ohayon et al., 2004; Roenneberg et al., 2003; Wirz-Justice et al., 1984). However, some other studies indicate this difference is age-dependent and seen only after the age of 35–40 yrs (Reyner et al., 1995; Williams et al., 1974).

This article sought to verify the results concerning differences in sleep behavior according to chronotype and sex, in addition to season, using actigraphy, which shows good validity and reliability when compared to polysomnography in healthy adults (Ancoli-Israel et al., 2003). Ancoli-Israel et al. mentions that actigraphy provides good representation of the actual sleep and mid-sleep times but is less accurate in determining sleep onset latency and sleep efficiency. Kushida et al. (2001) found no significant difference in sleep time and sleep efficiency measured by actigraphy combined with diary reports compared to polysomnography (PSG). The present study's subjects wore actometers with event-buttons, which were used to mark their bed and rising times. Additionally, they kept a diary to record the exact time of going to bed. This made it easier to accurately define the right clock time to use to calculate sleep onset latency. The calculation of sleep efficiency depends on the determination of sleep onset latency, though minor variations from the "real" value of these parameters cannot be fully excluded.

METHODS

Subjects and Experimental Procedure

The study protocol and procedures complied with the guidelines of the Declaration of Helsinki as required by the journal (Touitou et al., 2006).

Over a period of 8 yrs, all first year medical students who took part in the chronobiology section of the biology course at the Charité—Universitätsmedizin (Berlin) were asked to complete the Horne and Östberg questionnaire. We collected data from 2697 (1573 female and 1124 male) students, both in spring and autumn. Of these, we chose 34 students—19 females (7 E-types, 7 M-types, 5 I-types) and 15 males (5 E-types, 5 M-types, 5 I-types)—19–31 yrs of age to record their activity-rest rhythms for 15 consecutive days in May and again in November by wrist actigarphy and, in addition, a standardized diary. Furthermore, 20 other subjects (i.e., nursing and paramedic and nursing science students [MP/PP]; 18 females and 2 males; 6 E, 5 M, and 9 I-types) from the Charité—Universitätsmedizin Berlin were recruited to participate in an additional actigraphy study. Their activity-rest behavior was recorded for 15 consecutive days in November. These students also kept a diary and completed the MEQ. All subjects were in good physiological and psychological health, as assessed by interview, and had no sleep complaints. None of the participating students had part-time jobs. Other exclusion criteria were small children living in the same household. Because the students were in the same year of their studies, they had the same university timetables with lectures generally starting at 08 : 15 h in both the spring and autumn school terms. Because morning lectures were not compulsory, however, the students could follow their preferred individual timetables. Ohayon et al. (2004) reported in a meta-analysis that studies that kept habitual sleep patterns produced a larger effect size than those with an imposed schedule for lights on/off. They also described that inclusion or exclusion of drugs or alcohol had no influence on effect size. Therefore, we did not restrict the bedtime or alcohol consumption of our subjects.

Measurements

All subjects completed the MEQ to determine chronotype. The questionnaire consists of 19 questions concerning the preferred timing of activity or sleep and physical/mental state after waking. We used a German translation of the MEQ (Östberg, 1976). Subjects with a test score of: 16–30 were rated as extreme evening types, 31–41 as evening types, 42–58 as intermediate types, 59–69 as morning types, and 70–86 as extreme morning types, respectively.

Detailed data on the activity-rest rhythm of participants were collected using Actiwatch® actometers (CNT, Cambridge, UK). An internal acceleration sensor recorded movements and compiled them over 1 min intervals. The sums were saved on a microchip inside the actometer and sent to a computer for visualization as activity-rest plots (actograms). Each participant wore one actometer on the non-dominant hand (all were right-handed). The subjects were also required to keep a diary record of their bed and rest times.

Data Analysis and Statistical Procedure

Nights with missing time segments due to removal of the actometer were not included in the calculation of sleep parameters. Using the actograms, we calculated several sleep-specific parameters. Actual sleep-time duration, sleep efficiency (ratio of immobile time/sleep duration = relative rest), sleep onset latency, and mid-sleep (mean clock time between the start and end of sleep) were determined using Actiwatch® Sleep Analysis Software and Microsoft® Excel. A detailed description of the algorithm used to distinguish between sleep and wakefulness can be found in Lehnkering et al. (2006). The significance of the distribution of the chronotypes by sex of subject was evaluated by the chi^2 test. The Wilcoxon test was used to compare sleep time between weekdays and weekend days, while all other statistical calculations were performed using ANOVA. The threshold value for significance was set to $\alpha = 0.05$.

RESULTS

Evaluation of the Horne and Östberg Questionnaire data of the 2697 students showed that individuals with no special preference for morningness or eveningness (i.e., so-called intermediates) were most common. The distribution of the various chronotypes was related to the sex of subjects. As shown in Figure 1A, men displayed eveningness significantly more often than women (28.9% males vs. 20.8% females, $p < 0.001$), while females exhibited greater morningness (15.6% males vs. 20.3% females, $p < 0.001$). Overall, females showed a significantly higher MEQ score than males ($p < 0.001$).

Analysis of the actograms from the 34 medical students showed the mean actual sleep time duration was 6 : 43 h (SD = 1 : 23 h). The mean sleep latency was 8 min (SD = 14 min), and the mean sleep efficiency was 85.7% (SD = 5.9%). We did not find significant sex-specific differences in these sleep parameters ($p = 0.84$ for actual sleep-time duration, $p = 0.34$ for sleep efficiency, $p = 0.38$ for sleep latency). Furthermore, to exclude the influence of potentially different sleep behavior during weekends on our calculations, we compared the parameters of weekday (Tuesday and Wednesday nights) and weekend (Friday and Saturday night) sleep. No significant differences were found ($p = 0.416$ for actual sleep-time duration, $p = 0.589$ for sleep efficiency, $p = 0.7$ for sleep latency). An intergroup comparison between morning and evening types also did not show significant differences for the investigated sleep parameters between weekday and weekend nights ($p = 0.227$ for actual sleep-time duration, $p = 0.160$ for sleep efficiency, $p = 0.719$ for sleep latency).

Mid-sleep, which marks the midpoint between the commencement and end of sleep, was found to be around 04 : 00–04 : 30 h for the medical students. As expected, it was significantly earlier in morning (mean of entire test period 04 : 08 h, SD = 00 : 48 h) than evening types (mean of entire test period 04 : 59 h, SD = 00 : 50 h; $p = 0.006$). It was also found to shift to a later time of the night during weekends

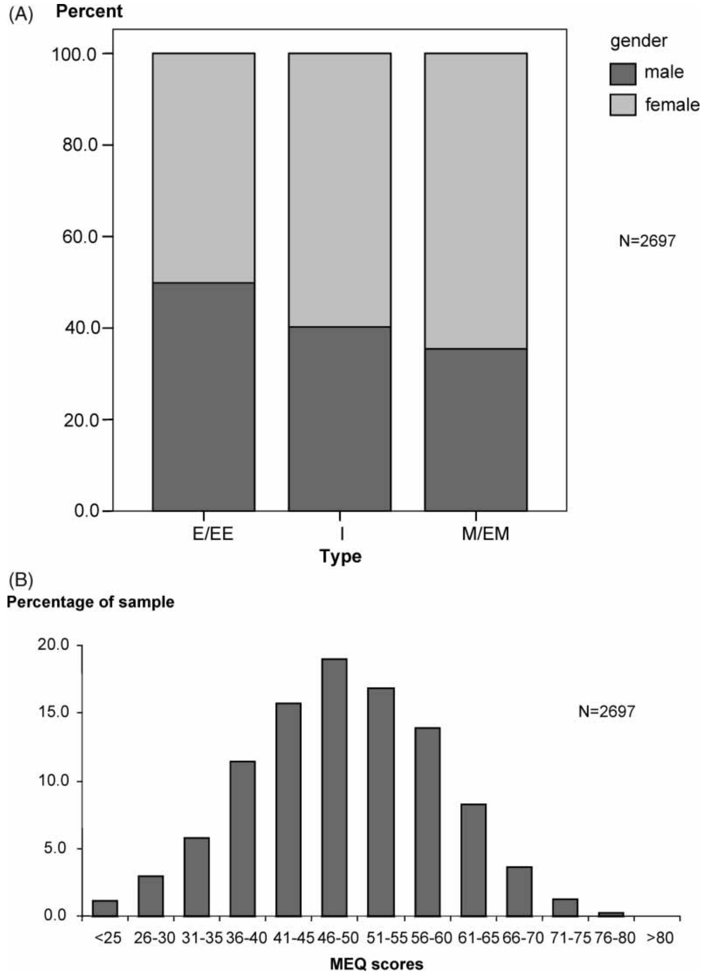

FIGURE 1 (A) Distribution of chronotypes according to sex of subjects (n = 2697). The influence of sex is statistically significant. (B) Frequency distribution of subjects according to MEQ scores. Abbreviations: EM = extreme morningness, M = morningness, I = intermediate type, E = eveningness, and EE = extreme eveningness.

($p < 0.001$) as illustrated in Figure 2. Figure 3 presents an excerpt of an actogram of one male medical student; it provides a good representation of how sleep duration is unaffected on the weekend, while the timing of sleep shifts to a much later period.

Figure 4A shows that the sleep efficiency differed between morning and evening types ($p = 0.007$ in the spring and $p = 0.039$ autumn), that is, that it is better for morning (87.9%, SD = 1.3%) than evening types (84.3%, SD = 0.87%). In winter, the day of measurement significantly influenced sleep efficiency ($p = 0.032$). This was especially the case for

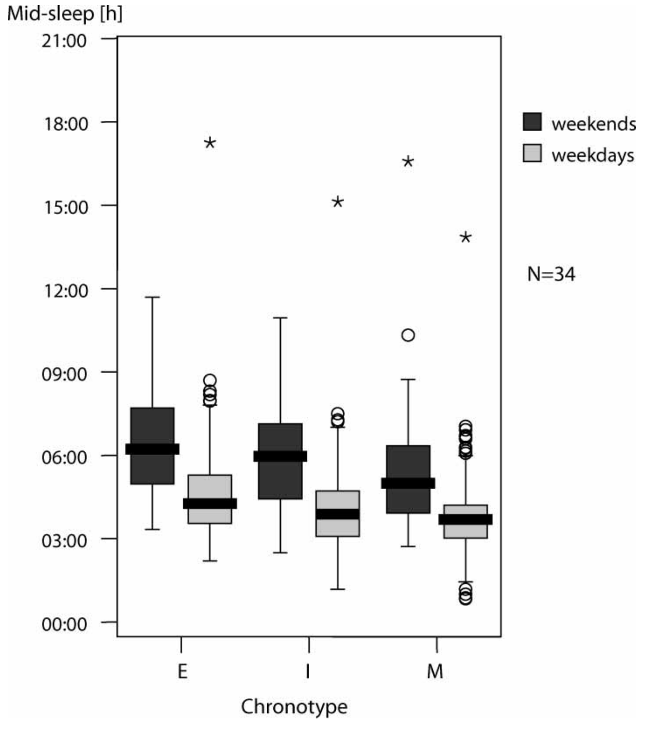

FIGURE 2 The boxplots show the mid-sleep time for weekday and weekend sleep by chronotype as calculated from wrist actigraphic data. The weekday-weekend difference is statistically significant, as is the difference between morning and evening types. The bold black lines through the boxes denote the median; the length of each box is the interquartile range (lower edge marks the 25th percentile, the upper edge the 75th percentile); bars outside the boxes mark the minimum and maximum of inner limits. Circles and asterisks mark outliers.

evening types, who showed higher sleep efficiency in the night from Saturday to Sunday compared to other nights. For this night, sleep efficiency was equally good for the morning and evening types (see Figure 4B). Actual sleep-time duration and sleep latency did not differ among the chronotypes ($p = 0.15$ and $p = 0.681$, respectively).

No seasonal differences in sleep parameters were detected, except for actual sleep-time duration. Actual sleep time duration was longer in autumn (mean 6.9 h, SD = 0.13 h) than in spring (6.6 h, SD = 0.10 h; $p = 0.013$; see Figure 5).

A comparison of medical and MP/PP students revealed no significant difference in any of the sleep parameters examined ($p = 0.747$ for actual sleep-time duration, $p = 0.73$ for sleep efficiency, $p = 0.58$ for sleep latency). The MP/PP students, like the medical students, showed a higher sleep efficiency in morning than evening types, although this difference was not quite statistically significant ($p = 0.051$).

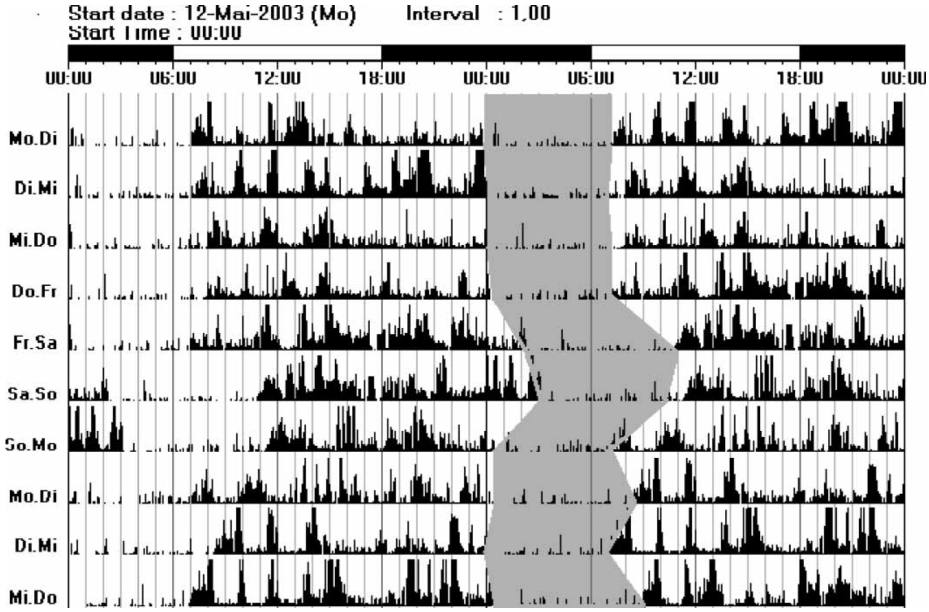

FIGURE 3 Original actogram of a male student. The data are double-plotted, with successive days plotted both next to and beneath each other. X-axis: clock time in hours; Y-axis: days of measurement. Activity is shown as black bars. Time between falling asleep and getting up is marked in grey. Abbreviations for weekdays are given in German; Mo = Monday, Di = Tuesday, Mi = Wednesday, Do = Thursday, Fr = Friday, Sa = Saturday, So = Sunday.

DISCUSSION

The results of our study are consistent with the findings of Adan and Natale (2002) and other recent studies showing that morningness is more common in women than men. The later investigators found that females tended to score significantly more toward morningness than males in a sample of 2,135 Spanish and Italian university students. We confirm that this is true of German students as well. However, Park et al. (1998) found no such tendency in Japanese workers. Gaina et al. (2006) found, in a study of Japanese junior high school children, that females tended to express eveningness more often than males. It is noteworthy that Paine et al. (2006) did not find a sex influence on chronotype when they took into consideration age and work schedule. This might be an interesting aspect; the present subjects were all about the same age and had a similar university schedule.

Study results concerning sleep parameters are inconsistent. In a meta-analysis of 47 studies using either PSG or actigraphy, Ohayon et al. (2004) described a decrease of total sleep time and sleep efficiency and increase in sleep latency with age. Jean-Louis et al. (2000) reported longer sleep duration for women than men over 40 yrs of age. Most studies investigating

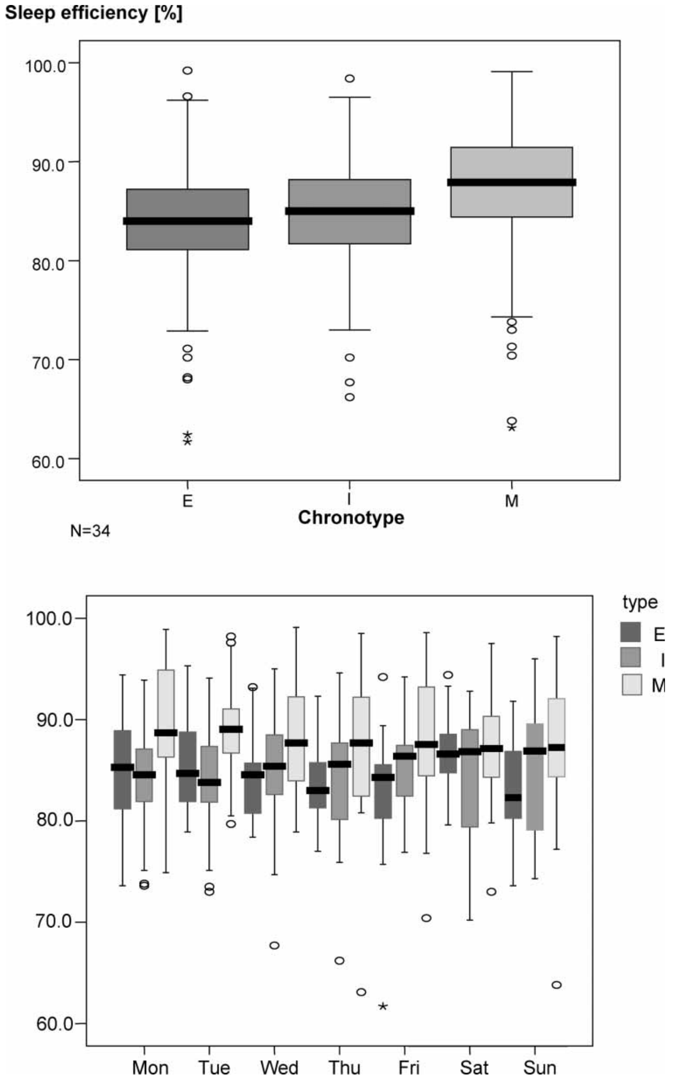

FIGURE 4 The boxplots denote sleep efficiency (% time in bed spent asleep) (A) for the different chronotypes calculated from actigraphic data, and (B) as a percentage for the different chronotypes calculated from actigraphic data only of the winter test period. E: $n = 12$, I: $n = 10$, M: $n = 12$. Sleep efficiency is significantly higher for morning types and influenced by day of measurement ($p = 0.032$). The bold black lines through the boxes show the median; the length of each box is the interquartile range (lower edge marks 25th percentile, the upper edge 75th percentile); bars outside the boxes mark the minimum and maximum of inner limits. Circles and asterisks mark outliers.

young adults have found no sex differences (Klei et al., 2005; Monk et al., 2000; Mongrain et al., 2005; Park et al., 2001), whereas Tsai and Li (2004) described a longer sleep latency for females. They investigated 237 university students from all academic fields using sleep logs. No sex differences were found in the present study's more homogeneous subject group,

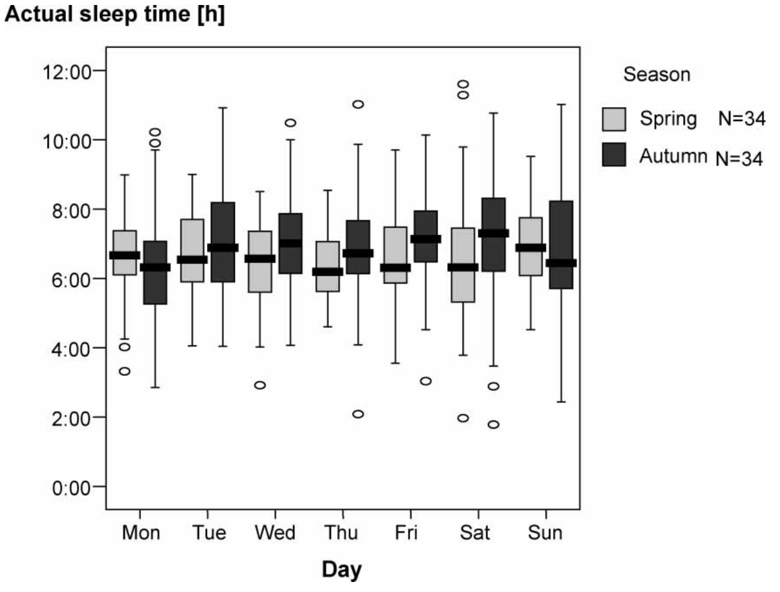

FIGURE 5 The boxplots denote actual sleep time in hours separately for spring and autumn measurements. The overall difference between the spring and autumn measurements is significant. The bold black lines through the boxes show the median; the length of each box is the interquartile range (lower edge marks 25th percentile, the upper edge 75th percentile); bars outside the boxes mark the minimum and maximum of inner limits. Circles and asterisks mark outliers.

which consisted of medical students who adhered to the same university timetable. In a three-night PSG study of young adults, Goel et al. (2005) found that female subjects had longer sleep times, shorter sleep latencies, and better sleep efficiencies than males. Subjects in this study had a given bedtime from 24 : 00 h (lights off) and wake-up time at 08 : 00 h (lights on). Under these conditions, where subjects have no outside pressure to get up earlier than after 8 h of sleep, young women seem to have a better sleep quality than men. It is known, however, that women consistently report a poorer sleep quality than men (Park et al., 1998; Tsai & Li, 2004). Could this be because when females and males have the same conditions, such as the same university timetables, the females sleep patterns "reduce" to the standard that is normal for males? Further research is needed to develop a better understanding of sleep problems. The present results suggest that under similar environmental conditions, females and males of the same age and ethnic background show similar sleep behavior.

The later (delayed) mid-sleep time in E-types than in M-types is consistent with the results of the MEQ. However, the literature is inconsistent regarding sleep parameter differences in sleep according to chronotype. Roenneberg et al. (2003) reported shorter sleep duration in E- than M-types on weekdays, while the opposite was true during the weekend. That study included a very non-homogeneous group of subjects.

Nothing is known about their timetable of work or other activities. Medeiros et al. (2001), who included only medical students with the same university timetable in their study, found no effect of chronotype on sleep duration. In a recent study done with the prescribed sleep duration of 8 h under laboratory conditions, Mongrain et al. (2006) also reported no chronotype differences in total sleep time, sleep efficiency, and sleep duration. Gaina et al. (2006), in a study of Japanese junior high school students, found morning types were more satisfied with their sleep than evening types. The present results support the fact that there is no difference between morning and evening types in actual sleep time. However, a higher sleep efficiency was found in M- than E-types. This is consistent with the findings put forward in a review by Ferrara and De Gennaro (2001). The inconsistent results of the above cited studies could be due to the specific nature of the study conditions. In this study, subjects had to follow the university timetable, which is a more preferred timetable for M-types. This might have lead to lower values of sleep efficiency by E-types, because they would be required to advance their circadian phase during weekdays, which is more difficult to achieve biologically than is a delay (Valdez et al., 2003). The data, however, were assembled using wrist actigraphy, which is less reliable than PSG in determining sleep efficiency. Hence, PSG studies are recommended to further investigate the difference in sleep efficiency between the different chronotypes.

A number of studies found an extension of sleep-time duration on weekend nights, especially in E-types (Monk et al., 2000; Roenneberg et al., 2003; Tsai & Li, 2004). Monk, however, found the weekend time in bed increased by only 27 min. Lima et al. (2002) described that students who had morning classes extended their sleep duration on weekend nights by 1 h, while the sleep duration of students who had late schedules remained the same. No differences were found in any of this study's investigated sleep parameters between weekday and weekend sleeps. The present subjects had early classes, but they were not compulsory; therefore, they could have slept in not only on some weekend but also on some weekday mornings. This could explain why no difference was found in actual sleep time duration between weekday and weekend nights. The finding that sleep phases delay on weekend nights is, however, consistent with previously reported findings (Roenneberg et al., 2003; Valdez et al., 2003).

Aschoff (1969) described a correlation between the duration of sunshine on a given day and the duration of activity in day-active bird species. It is also known that under laboratory conditions, total sleep time in human beings increases during exposure to long (14 h) compared to short nights (8 h) (Wehr, 1991; Wehr et al., 1993). Telephone interviews of 989 people in Switzerland revealed sleep duration to be longer in winter than summer (Wirz-Justice et al., 1991). Under conditions of temporal isolation, where subjects can choose their sleep time, more sleep occurs in autumn and winter than in spring and summer (Wirtz-Justice et al., 1984). These results can be confirmed under natural environmental conditions; the sleep length of these young adult student subjects increased in autumn compared to spring.

The subjects of our study had a very short actual sleep-time duration of only 6 : 43 h. The standard deviation of 1 : 23 h, however, is rather high, indicating that on some nights the students slept longer seemingly because of an accumulated sleep debt. This short sleep time in medical students is, however, consistent with the finding of 6 : 52 h (SD = 1 : 33 h) reported by Medeiros et al. (2001). The average sleep duration of a young adult is 7–8 h, according to Ferrara and Gennaro (2001). They state that such short sleep duration can negatively impact performance. Oginska and Pokorski (2006) found that among female adolescents and university students in particular, females show a greater need for sleep than males, even though their average sleep length did not differ. In this regard, the students declared they suffer from excessive drowsiness during the daytime. The performance of students worsens as a function of the amount of decrease in sleep length and the irregularity of the sleep-wake cycle (Medeiros et al., 2001), both of which are seen in the students. Regrettably, no data were collected on academic performance. It is, however, useful to conduct further research in this field to ensure that students perform at their best.

This study investigated differences in the activity/rest rhythm by sex of subject using the MEQ questionnaire and wrist actigraphy in a very homogenous group of students. No differences in sleep behavior were found. However, it was found that the distribution of chronotypes varied by sex. Little difference was determined in sleep according to season of year; sleep duration was shorter in spring than autumn, although further sleep studies should be conducted on this aspect.

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