Article published online: 2024-02-15

Original Article

Sex Differences in Temporal Sleep Patterns, Social Jetlag, and Attention in High School Adolescents

Fernanda Mayara Crispim Diogo[1] Zoelia Camila Moura Bessa[1] Sabinne Danielle Galina[1] Maria Luiza Cruz de Oliveira[1] Emanuel Linegley Ribeiro da Silva-Júnior[1] Pablo Valdez[2] Carolina Virginia Macêdo de Azevedo[1]

[1] Chronobiology Laboratory, Department of Physiology and Behavior, Postgraduate Program on Psychobiology, Universidade Federal do Rio Grande do Norte, Natal, RN, Brazil
[2] Psychophysiology Laboratory, Faculty of Psychology, University Autonomous of Nuevo León, Monterrey, NL, Mexico

Address for correspondence Fernanda Mayara Crispim Diogo, Chronobiology Laboratory, Department of Physiology and Behavior, Postgraduate Program on Psychobiology, Universidade Federal do Rio Grande do Norte, Natal, RN, Brazil (email: fernanda_mayara@hotmail.com).

Sleep Sci

Abstract

Insufficient sleep and irregular sleep hours are common in adolescents, who experience a delayed sleep phase due to biopsychosocial changes associated with puberty, resulting in later sleep times. However, early morning class hours shorten sleep duration on weekdays. This condition is harmful to cognitive performance, which may be accentuated in girls due to a greater sleep need and less resistance to sleep deprivation. In this study, we evaluated sex differences concerning temporal sleep patterns, social jetlag, and attention in high school adolescents attending morning classes. Students ($n = 146$ - F: 73–16.1 ± 0.8 years; M: 73–16.2 ± 0.9 years) completed a Health and Sleep questionnaire, kept a sleep diary for 10 days, which incorporated a Maldonado Sleepiness Scale, and performed a Continuous Performance Task. On weekends, the girls went to bed earlier and woke up later, spending more time in bed at night and in 24 h on weekdays and weekends, while they also had a greater irregularity in wake-up times ($p < 0.05$). There were no differences between sexes in terms of social jetlag, sleep debt, and sleepiness upon awakening ($p > 0.05$). Regarding attention, the girls had a longer reaction time in phasic alertness ($p < 0.01$) and a tendency to have fewer errors in selective attention ($p = 0.06$). These results persisted when controlled for sleep parameters. Therefore, this suggests that girls have a greater sleep need and less resistance to sleep deprivation, while the differences in attention performance could be due to different strategies, the girls could be making a trade, reducing reaction time in favor of better accuracy, while the boys could be prioritizing a faster response time.

Keywords

- sleep deprivation
- cognition
- adolescent behavior
- social jetlag
- attention

received
January 23, 2023
accepted
August 2, 2023

DOI https://doi.org/10.1055/s-0043-1777831.
ISSN 1984-0659.

Thieme Revinter Publicações Ltda., Rua do Matoso 170, Rio de Janeiro, RJ, CEP 20270-135, Brazil

Introduction

Adolescence is a period of changes in the sleep-wake cycle pattern, characterized by a delay in sleep times, in other words, a tendency toward eveningness.[1–3] These changes are associated with modifications in biological and psychosocial factors that occur on the onset of puberty.[3,4] The decrease in the accumulation rate of homeostatic pressure during wakefulness, allows adolescents to stay awake longer and, consequently, to be exposed to light for a longer time, increasing the phase delay.[3,5] In contrast, several studies have observed that the rate of homeostatic pressure dissipation remains the same throughout adolescence. Therefore, the need for sleep does not change.[3,6]

In addition, the psychosocial context contributes to the phase delay, since there is an increase in bedtime autonomy, socialization, and academic burden.[3] These changes are accompanied by a greater use of electronic media, such as TV, video games, smartphones, and computers,[3,7] which emit light in the blue range, promoting the suppression of melatonin secretion and increasing alertness, causing physiological arousal, with a direct impact on sleep quality and a delay in the circadian system.[8–10]

Therefore, the physiological and psychosocial context of adolescents favors a phase delay, producing a later sleep onset time. The recommended sleep duration for adolescents is between 8 to 10 hours per night; therefore, they tend to wake up later to maintain an optimal sleep duration.[11] However, the early start time of morning classes restricts the wake-up time, shortening the sleep duration.[3,4] On weekends, adolescents compensate for the shorter sleep duration by waking up later, producing a sleep restriction-extension effect, which is associated with irregular sleep hours and sleep debt (time in bed difference between weekdays and weekends).[1,12] Another consequence of irregular sleep hours is the likelihood of developing higher levels of social jetlag, defined as a discrepancy between biological clocks and social schedules, which could cause circadian misalignment.[13]

Sex differences in sleep patterns have been observed in children, adolescents, and adults, with adolescence being the stage in which these differences become more evident.[14,15] With the start of adolescence, women begin to delay sleep times earlier than men, as well as advance their sleep times earlier than men during adulthood. In addition, men tend to prefer later sleep times, while women tend to prefer earlier sleep times. These differences start to disappear in the mid-50s, the average age at which menopause begins.[16,17] This data supports the idea that sex-related differences in sleep patterns may be due to endocrine changes, which are accentuated in adolescence on the onset of puberty,[14,17] and also due to the distinct puberty physiology in both sexes,[14,18] which experience different growth rates, as well as differences in hormone secretion.[19] Other differences between sexes have been found in their circadian rhythms, with women having a shorter circadian period in their body temperature rhythm (women: 24:05 min $\pm$ 12 min - men: 24:11 min $\pm$ 12 min),[20] as well as an earlier phase of the circadian rhythm of melatonin secretion.[21,22]

Regarding the ideal sleep duration, studies have shown a greater sleep need in women.[15,23] Lindberg et al.[24] observed that women had a longer mean total sleep time (425 min $\pm$ 58 min) than men (403 min $\pm$ 50 min). In addition, after a sleep restriction protocol, women have a higher percentage of slow-wave sleep, suggesting a faster sleep pressure build-up and less resistance to sleep deprivation.[25] This characteristic can accentuate the irregularity in sleep times between weekdays and weekends observed in adolescents who study in the morning shift, due to the sleep restriction-extension effect,[1] a condition that is harmful to sleep quality and increases the levels of daytime sleepiness.[1,12]

However, the relationship between sex differences and sleep patterns is still unclear in the literature, because few studies are available and most of those studies are based on adult samples. In some studies, it was observed that women have better objective sleep quality and shorter sleep latency.[23,26] Nevertheless, women report worse subjective sleep quality and more sleep problems than men.[23] There is evidence that these differences start with puberty, with girls having a higher prevalence of insomnia[18,27] and depression.[28] In this context, the use of social media by girls is associated with an increased negative impact on mental health and anxiety symptoms,[29] which can interfere with their sleep health.

Another important point is the impact of sex differences on cognitive performance. Studies have observed sex-related differences in cognitive performance, which indicate that women performed better in tasks that assess episodic memory, verbal and facial recognition, and semantic fluency, while men have an advantage in visuospatial skill tasks.[30–32] As for sleep-related sex differences, women would be more sensitive to attention deficits when deprived of sleep,[33,34] and the cognitive performance of girls could be more affected by social jetlag than that of boys.[35]

Unhealthy sleep negatively affects attention, thus impairing cognitive performance and learning.[36,37] Attention is a basic cognitive process that enables learning and makes it possible to perform everyday tasks that require attention, and it can be defined according to 4 components: 1 - tonic alertness, which is the ability to respond to a stimulus at any time; 2 - phasic alertness, which is the ability to respond to a stimulus after an alert signal; 3 - selective attention gives the individual the ability to respond to a stimulus while ignoring others; and 4 - sustained attention allows sustained focus on a specific stimulus over a period of time.[38–40] Thus, the decline in attentional levels as a result of unhealthy sleep, caused by irregular sleep hours, social jetlag, and insufficient sleep, can be harmful to adolescents in the academic context.[35,41,42]

It is important to assess the differences between sexes concerning sleep patterns and social jetlag in relation to the attention performance at the beginning of morning classes in adolescents on the first years of high school. This would make it possible to observe how sex differences are presented in the sleep patterns and social jetlag of adolescents when responding to the same challenge: the early start time of morning classes, in addition to observing whether these differences are affecting more markedly the attentional performance of girls, and possibly impairing their academic performance. Notably, this study was conducted in a real-life context, which could facilitate the translation of its results to real-world applications and could serve as a basis for new policies concerning the sleep of adolescents considering the different impacts according to sex. Hence, the objective of this study was to evaluate the sex-related differences regarding sleep patterns, social jetlag, and attention in high school adolescents attending morning classes. We hypothesized that girls would suffer more from sleep deprivation on weekdays, leading to compensation on weekends, and this could accentuate irregular sleep hours and social jetlag, negatively affecting the cognitive performance of girls.

Materials and Methods

Participants

The study was developed with the participation of 146 adolescents of both sexes (F: 73–16.1 ± 0.8 years; M: 73–16.2 ± 0.9 years), attending the first years of high school in morning classes starting between 7:00 and 7:30 (07:05 ± 0.17 h) at five private schools and one federal institute in Natal, Rio Grande do Norte, Brazil (Latitude: -5,794.48, Longitude: -35,211; 5° 47′ 42″ South, 35° 12′ 34″, West). The participants and their legal guardians signed an informed consent. Participants were excluded from the sample if they reported any neurological disorder or any type of sleep disorder, such as narcolepsy, insomnia, or sleep apnea, or any use of drugs that could interfere with the performance in the attention assessment task. The research projects that provided the database used in this study were approved by the Research Ethics Committee of Universidade Federal do Rio Grande do Norte (CEP-UFRN/protocols: 1,489,057; 650,621 and 2,628,311).

Procedure

The data collection that fed the database used in this work took place between the years 2014, 2016, and 2019, except for holidays, vacations, and evaluation periods in schools. Data was collected during school hours.

To apply the exclusion criteria, participants completed the Health and Sleep questionnaire, adapted from Mathias et al. (2006), which included questions about general health—such as the use of medications, the presence of sleep and neurological disorders and other diseases—and sleep habits. The questionnaire also contained questions taken from the Brazilian Association of Research Companies (ABEP, in the Portuguese acronym), for the evaluation of socioeconomic status, which was performed following the updated criteria of the year in which the data was collected.[44–46]

For the assessment of the temporal sleep patterns of the sample, the participants recorded their sleep parameters (bedtime and wake-up times, awakening method, nap duration and frequency) using a sleep diary for 10 days, as well as sleepiness upon awakening using the Sleepiness Scale illustrated with faces by Maldonado,[47] adapted by Belísio.[48] The sleep recording began on a Friday, including one weekend, followed by a week of classes and another weekend. During the recording period, students performed a Continuous Performance Task (CPT), which assesses attention components as proposed by Valdez.[40] This task was performed by the participants through a computer that presented a random sequence of single-digit numbers on a monitor screen, which then recorded their responses coming from a keyboard. The participants were instructed to respond using the ‘1’, ‘2’, and ‘3’ keys on the numeric keypad on the keyboard, using the index, middle and ring fingers to press each key respectively, and according to the following guidelines: press the ‘1’ key when any number from 0 to 8 appears on the screen; press the ‘2’ key when the number 9 appears; and press the ‘3’ key when a number 4 appears after a number 9. Responses to the ‘1’ key were taken as tonic alertness, responses to the ‘2’ key were taken as selective attention, responses to the ‘3’ key were taken as phasic alertness, and the performance changes from the beginning to the end of the task were taken as sustained attention. Each participant performed this task from Tuesday to Friday, from 7:30 am until 9: am. Participants were asked about their food consumption prior to each task to control for substances that could interfere with the task performance.

Statistical Analysis

Participants of both sexes were selected, matching their socioeconomic status and age, resulting in an equal sample number for the female and male groups.

Then, the following variables were calculated:

1. Bedtime and wake-up time irregularity: standard deviation of the bedtime and wake-up times during the week;
2. Sleep debt: the difference between the average time in bed on weekends and weekdays;
3. Time in bed during a 24-hour period: nocturnal time in bed plus the duration of naps on the corresponding day;
4. Chronotype: first, the mid-sleep phase of free days (MSF) (midpoint between the beginning and end of sleep) was calculated. When participants compensated for insufficient sleep on free days (sleeping more on free days than on school days), a mid-sleep phase correction was made to remove the homeostatic compensation from the chronotype score. For this correction, the average time in bed for the entire week is calculated and half of the oversleep is subtracted from the MSF.[49] Thus, the corrected mid-sleep phase during free days (MSFsc) is the chronotype score (MSFsc = MSF - (SDf - SDw)/2).
5. Social jetlag: social jetlag was calculated by subtracting the MSF from the mid-sleep phase during school days (MSW) (social jetlag = MSF – MSW).[49]

For the attention components, the CPT analysis used the following variables: 1 - general reaction time, general percentage of correct and incorrect responses and, omissions; 2 - reaction time of correct responses, percentage of correct and incorrect responses, and omissions of tonic alertness, selective attention and phasic alertness; and 3 - the general stability (an indicator of sustained attention), calculated from the standard deviation of the reaction time of the correct responses throughout the task.

Finally, a multivariance analysis of covariance (MANCOVA) was used to assess the relationship among sex, temporal sleep patterns, sleepiness upon awakening, bedtime and wake-up time irregularity, social jetlag, sleep debt, and attention: 1–sex as a fixed factor and chronotype as a covariate, and bedtime, wake-up time, time in bed at night and during 24 h, sleepiness upon awakening, bedtime and wake-up time irregularities, sleep debt, and social jetlag as dependent variables; 2 - sex as a fixed factor and the following variable as covariates: chronotype, bedtime, wake-up time, time in bed at night and in 24 h, sleepiness upon awakening, bedtime and wake-up time irregularities, sleep debt and social jetlag, and attention components as a dependent variable.

An additional analysis was performed to assess the participants' awakening method (alarm clock, by someone, and spontaneously) and the frequency of naps, using a Chi-square test considering sex of the participant and day of the week (weekdays and weekends). A level of significance of 5% was considered for all tests used in this study. In addition, the considered effect sizes were small (η^2p: 0.01–0.06); moderate (η^2p: 0.06–0.14), and large ($\geq \eta^2$p: 0.14).[50]

Results

Sex and Temporal Sleep Patterns

The multivariate analysis showed that there was an effect of sex of the participant ($p < 0.01$) and of chronotype ($p < 0.001$) on sleep times, sleepiness upon awakening, bedtime and wake-up time irregularity, sleep debt, and social jetlag (►**Table 1**).

In the univariate analysis (►**Table 1**), after adjusting for the chronotype effect, there was an effect of sex of the participant on bedtime and wake-up time on weekends,

Table 1 Multivariate and univariate analysis of the model using sex as a fixed factor and chronotype as a covariate for the analysis of temporal patterns of sleep and sleepiness upon awakening during weekdays and weekend in addition to social jetlag and sleep debt.

Analysis	Factor	Pillai trace	Dependent variable	df	Adjusted means (std. error)	F	p	η^2p
Multivariate effects	Chronotype (covariate)	1.000		13.123		465,256.195	< **0.001**	1.000
	Sex	0.207		13.123		2.463	< **0.01**	0.207
Univariate effects	Sex		Bedtime (weekdays)	1.135	**F:** 22 h 56 min (6.04) **M:** 23 h 10 min (6.04)	2.504	0.11	0.018
			Bedtime (weekend)	1.135	**F:** 23 h 53 min (3.14) **M:** 00 h 06 min (3.14)	7.740	< **0.01**	0.054
			Wake up time (weekdays)	1.135	**F:** 06 h 01 min(4.27) **M:** 05 h 54 min (4.27)	1.130	0.29	0.008
			Wake up time (weekend)	1.135	**F:** 08 h 56 min (7.87) **M:** 08 h 35 min (7.87)	3.743	< **0.05**	0.027
			Time in bed (weekdays)	1.135	**F:** 07 h 05 min (6.31) **M:** 06 h 44 min (6.31)	5.505	< **0.05**	0.039
			Time in bed (weekend)	1.135	**F:** 09 h 05 min (9.31) **M:** 08 h 31 min (9.31)	6.590	< **0.01**	0.047
			Time in bed 24 h (weekdays)	1.135	**F:** 07 h 31 min (6.43) **M:** 07 h (6.43)	11.564	< **0.001**	0.079
			Time in bed 24 h (weekend)	1.135	**F:** 09 h 25 min (9.07) **M:** 08 h 42 min (9.07)	11.029	< **0.001**	0.076
			Sleepiness upon awakening (weekdays)	1.135	**F:** 4.74 (0.21) **M:** 4.75 (0.21)	0.003	0.95	0.000
			Sleepiness upon awakening (weekend)	1.135	**F:** 3.49 (0.17) **M:** 3.80 (0.17)	0.906	0.34	0.007
			Bedtime irregularity	1.135	**F:** 01 h 11 min (3.19) **M:** 01 h 13 min (3.19)	0.206	0.65	0.002
			Wake up time irregularity	1.135	**F:** 01 h 55 min (4.24) **M:** 01 h 40 min (4.24)	5.213	< **0.05**	0.037
			Sleep debt	1.135	**F:** 01 h 59 min (10.20) **M:** 01 h 46 min (10.20)	0.778	0.38	0.006
			Social jetlag	1.135	**F:** 01 h 58 min (4.88) **M:** 01 h 49 min (4.88)	1.866	0.17	0.014

Abbreviations: df, degree of freedom, F, female; M, male.

Table 2 Awakening methods proportions and nap frequency during weekdays and weekends between sexes (F: female; M: male).

Variable	F (%)	M (%)	p^a	p^b	p^c	p^d
Awakening methods (weekdays)						
Alarm clock	53.94	52.11	0.57	< **0.001**	< **0.001**	< **0.001**
By someone	32.70	35.92				
Spontaneously	13.37	11.97				
Awakening methods (weekend)						
Alarm clock	20.36	14.59	< **0.01**			
By someone	25.36	18.15				
Spontaneously	54.29	67.26				
Nap frequency						
Weekdays	30.70	20.62	< **0.001**	< **0.001**	< **0.001**	< **0.05**
Weekend	19.78	13.98	*0.06*			

Abbreviations: F, female; M, male.
p^a: value of significance of the comparison between sex.
p^b: value of significance between weekdays and weekends irrespective of sex.
p^c: value of significance between girls' weekdays and weekends proportions
p^d: value of significance between boys' weekdays and weekends proportions.

with girls going to bed earlier ($p < 0.01$) and waking up later ($p < 0.05$). Also, girls spent more time in bed at night on weekdays ($p < 0.05$) and weekends ($p < 0.01$) in relation to boys, a finding that was also observed in time in bed during 24 h on weekdays ($p < 0.0\ 1$) and weekends ($p < 0.001$). Additionally, girls showed a greater irregularity in wake-up times ($p < 0.05$) when compared with boys. There were no differences between the sexes in the other variables of sleep patterns and social jetlag (see ►**Table 1**).

For the awakening method of the participants (►**Table 2**), during weekdays, both boys ($X^2 = 235.07$; $p < 0.001$) and girls ($X^2 = 144.23$; $p < 0.001$) were mostly woken up by an alarm clock or by someone, while on weekends there was an increase in spontaneous awakenings, irrespective of sex ($X^2 = 372.93$; $p < 0.001$). In a comparison by sex, on weekends, girls had the highest proportions of waking up by an alarm clock and by someone, while boys had the highest proportion of waking up spontaneously ($X^2 = 9.90$; $p < 0.01$). No differences were found during weekdays ($X^2 = 1.09$; $p = 0.57$).

Regarding nap frequency, most participants did not nap on weekdays and weekends (►**Table 2**). However, nap frequency was higher during weekdays when compared with weekends, irrespective of sex ($X^2 = 14.94$; $p < 0.001$). Analyzing for each sex, boys ($X^2 = 5.01$; $p < 0.05$) and girls ($X^2 = 10.24$; $p < 0.001$) had a higher nap frequency on weekdays. Between both sexes, girls had the highest nap frequency ($X^2 = 14.136$; $p < 0.001$). This difference on weekends tended to reach statistical significance (weekdays: $X^2 = 11.08$; $p < 0.001$ - weekends: $X^2 = 3.34$; $p = 0.06$).

Sex and Attention

The multivariate analysis showed that there was no effect of sex ($p = 0.12$) and sleep-related variables (chronotype: $p = 0.94$, bedtime, wake-up time, time in bed at night and in 24 h, sleepiness upon awakening, bedtime and wake-up time irregularities, sleep debt, and social jetlag) on the attention components (►**Table 3**).

In the univariate analysis (►**Table 3** - Fig. 1), when controlling for the sleep-related variables (chronotype, bedtime, wake-up time, time in bed at night and in 24 h, sleepiness upon awakening, bedtime and wake-up time irregularities, sleep debt and social jetlag), it was observed that girls have a longer general reaction time ($p < 0.05$) and a longer phasic alertness reaction time ($p < 0.01$) than boys. Besides, they showed a tendency to have a lower proportion of incorrect responses for selective attention ($p = 0.06$) when compared with boys. There were no differences in the other variables of the components of attention (see ►**Table 3** and Fig. 1).

Discussion

This work evaluates the sex differences in relation to temporal sleep patterns, social jetlag, time in bed at night and in 24h, sleep debt, and attention in high school adolescents attending morning classes. It is important to emphasize that this study evaluated the relationship between these variables in high school students in a real-life context, providing an ecological analysis of the sleep patterns in adolescents. We observed that, compared with boys, girls presented a longer time in bed at night and during 24 h, a greater wake-up time irregularity, while also showing a longer reaction time in general and in phasic alertness, and a tendency to have a lower proportion of incorrect responses in selective attention.

When applying a multivariate analysis, sex and chronotype affected the variables of temporal sleep patterns and social jetlag, showing that sex and chronotype influence the sleep patterns of adolescents, as seen in other studies.[18,35]

For the univariate analysis, when controlling for the effect of chronotype, girls went to bed earlier and woke up later on

Table 3 Multivariate and univariate analysis of the statistical model using sex as a fixed factor and chronotype as a covariate for the analysis of the components of attention.

Analysis	Factor	Pillai trace	Dependent variable	df	Adjusted means (std. error)	F	*p*	η^2p
Multivariate effects	Chronotype (covariate)	0.112		14.109		0.986	0.47	0.11
	Sex	0.164		14.109		1.522	0.12	0.16
Univariate effects	Sex		General reaction time (ms)	1.122	**F:** 382.11 (9.15) **M:** 354.35 (9.68)	4.340	< **0.05**	0.034
			General correct responses (%)	1.122	**F:** 88.64 (0.91) **M:** 86.72 (0.96)	2.115	0.15	0.017
			General wrong responses (%)	1.122	**F:** 6.77 (0.46) **M:** 7.95 (0.49)	3.117	*0.08*	0.025
			General omissions (%)	1.122	**F:** 2.69 (0.39) **M:** 2.69 (0.41)	0.000	0.99	0.000
			Tonic alertness's reaction time (ms)	1.122	**F:** 397.59 (10.29) **M:** 376,67 (10.88)	1.950	0.17	0.016
			Tonic alertness's correct responses (%)	1.122	**F:** 93.35 (0.74) **M:** 92.14 (0.78)	1.276	0.26	0.010
			Tonic alertness's wrong responses (%)	1.122	**F:** 2.28 (0.23) **M:** 2.59 (0.25)	0.833	0.36	0.007
			Tonic alertness's omissions (%)	1.122	**F:** 2.87 (0.42) **M:** 2.78 (0.44)	0.022	0.88	0.000
			Selective attention's reaction time (ms)	1.122	**F:** 467.82 (12.91) **M:** 440.91 (13.66)	2.049	0.15	0.017
			Selective attention's correct responses (%)	1.122	**F:** 77.09 (1.79) **M:** 72.71 (1.89)	2.827	*0.09*	0.023
			Selective attention's wrong responses (%)	1.122	**F:** 17.46 (1.43) **M:** 21.33 (1.51)	3.470	*0.06*	0.028
			Selective attention's omissions (%)	1.122	**F:** 2.20 (0.39) **M:** 2.66 (0.42)	0.656	0.42	0.005
			Phasic alertness's reaction time (ms)	1.122	**F:** 383.85 (12.35) **M:** 339.45 (13.06)	6.100	< **0.01**	0.048
			Phasic alertness's correct responses (%)	1.122	**F:** 78.75 (1.59) **M:** 76.85 (1.68)	0.683	0.41	0.006
			Phasic alertness's wrong responses (%)	1,122	**F:** 16.80 (1.33) **M:** 18.74 (1.40)	1.005	0.32	0.008
			Phasic alertness's omissions (%)	1.122	**F:** 2.36 (0.38) **M:** 2.11 (0.40)	0.206	0.65	0.002
			General stability (SD of reaction time of correct responses)	1.122	**F:** 160.20 (4.37) **M:** 150.97 (4.62)	2.107	0.15	0.017

Abbreviations: df, degree of freedom, F, female; M, male; SD, standard deviation.

weekends with a longer time in bed at night and during 24 h during weekdays and weekends, which is indicative of a greater sleep need. Several studies show evidence of a greater sleep need by girls, represented by a longer sleep duration or time in bed.[15,23,26,35,51] This result is corroborated by the higher frequency of naps in girls, confirmed by the longer time in bed during 24 h, which is the sum of naps durations and nocturnal time in bed. The greater sleep need could be leading girls to compensate for insufficient sleep through napping, as well as longer times in bed on weekends, when they are free from fixed morning class schedules. In addition, girls had a lower proportion of spontaneous awakenings on weekends, despite spending more time in bed, which indicates that they were more sleep deprived than boys. On the other hand, spontaneous awakening can be caused by other factors such as anxiety and notification alerts by smartphones. However, evidence shows that girls spend more time on smartphones and social media than boys, which leads girls to have an increased negative impact on mental health.[29] This is further evidence that the fewer spontaneous awakening by girls were caused by insufficient sleep on weekdays. Nevertheless, there was no difference between sexes regarding sleepiness on awakening, this may be due to the sleepiness scale used, which may not have detected the differences. Likewise, there were no differences regarding irregularities in bedtimes and sleep debt. The absence of differences in these indexes may be due to sleep compensation through naps during the week, which could be mitigating the sleep deprivation in girls, reducing the sleepiness on awakening, and preventing an even greater extension of sleep on weekends, which would result in a greater difference in the rates of irregularity and sleep debt between the sexes. On the other hand, girls showed greater irregularity in wake-up times, which reinforces the greater change in the wake-up time of girls on weekends.

However, the differences between the sleep patterns of girls and boys were not enough to lead to sex differences in social jetlag. In the literature, the findings about sex differences in social jetlag in adolescents are mixed: Díaz-Morales & Escribano[35] observed that girls have higher social jetlag, while Mathew et al.[52] did not observe any differences. These mixed results emphasize the need for further research on the presence of differences between sexes in social jetlag and if girls could be more affected. Additionally, the average social jetlag in this study (girls: 1 h 58 min; boys: 1 h 49 min) is relatively similar to other studies, which showed more than 2 h of social jetlag.[35,52,53] On the other hand, a Brazilian study showed an average of 1 h of social jetlag in adolescents;[53] this difference can be explained because that study used a corrected social jetlag formula (MSFsc- MSW), while our results were obtained using the original formula (MSF - MSW).[49]

A multivariate analysis showed no effect of sex, chronotype, bedtime, wake-up time, time in bed at night and during 24 h, sleepiness upon awakening, bedtime and wake-up time irregularities, sleep debt, and social jetlag on attention. However, after controlling for the effects of chronotype and other sleep-related variables in the univariate analysis, girls showed a longer general reaction time, which indicates a reduction in tonic alertness, and a longer phasic alertness reaction time, indicating a reduction in phasic alertness. A reduction in tonic and phasic alertness manifested as longer reaction times could be due to sleep deprivation or sleep reduction, as has been previously observed.[55] These components of attention are related to the prefrontal cortex,[36] which is affected negatively by sleep deprivation.[56] Therefore, the task performance could be affected by the time in bed on weekdays, as the task was performed in the morning. The participants of the present study had less than 8 hours of sleep per night, below the 8 to 10 hours recommended by the National Sleep Foundation for adolescents[11]; as a consequence, we can deduce that these adolescents are sleep deprived during weekdays, which would impair their attentional performance. However, the sleep-related variables did not show an effect on the components of attention. Nevertheless, girls had a longer time in bed on weekdays and showed a tendency to have a lower proportion of incorrect responses on selective attention, indicating better performance. Thus, the sex differences in sleep may not be the cause of the sex differences in attention performance. Sex differences in cognitive tasks have been observed in other studies and could be due to a difference in response strategy to obtain an optimal result.[57–59] Blatter et al.[60] suggested that girls would trade worse reaction times in favor of better response accuracy and boys would prefer to optimize their response times, which also occurs when sleep-deprived.[33,60] Another explanation for the lack of sleep's effect on attention may be related to the absence of an objective measurement of sleep quality, which is a strong predictor of cognitive performance in students.[56]

This study's results must be interpreted in the context of various limitations. First, the lack of objective measures. Second, the menstrual cycle of girls was not accounted for as a control for sleep variables, which undergo phase-dependent changes in the menstrual cycle, such as increased arousals during sleep and worse sleep quality.[18] In addition, attention undergoes changes, which are characterized by fluctuations in attentional levels throughout the menstrual cycle.[33] Third, objective sleep quality was not assessed; therefore, we could not evaluate its effect on attention performance. Thus, future studies should analyze the subjective and objective sleep quality in both sexes and relate them to chronotype, social jetlag, sleep hour irregularity, sleep debt, sleepiness upon awakening, and attention as well as assessing sleepiness before performing cognition tasks. This would allow the evaluation of the effects of sleep quality and sleepiness on cognitive performance, which is described in the literature a a strong predictor of attention.[56]

In summary, the results corroborate previous studies that observed that sex differences in sleep patterns are present in adolescence.[14,18] This suggests that girls have a greater sleep need than boys, inferred from the longer time spent in bed both during weekdays and weekends, in addition to a higher frequency of naps during weekdays, and earlier bedtimes with later wake-up times on weekends. In addition, the longest time in bed within 24 hours indicates that girls compensate for insufficient sleep through napping. These results indicate greater compensation for insufficient sleep during school days, which may be related to lower resistance to sleep deprivation. As a result, girls suffer greater sleep restriction-extension effects, leading to greater irregularity in wake-up time.

Finally, we suggest that school is a temporal challenge for adolescents of both sexes, in which the early morning start time shortens sleep duration on school days, which can promote chronic sleep deprivation, a condition that can be harmful to the academic performance and health of these young people. However, this temporal challenge appears to be greater for girls, demonstrated by their greater amount of sleep on weekends. Thus, sleep hygiene awareness measures should be promoted in schools for both adolescents and parents, considering sex as an important factor in the implementation of socioeducational measures, to emphasize the importance of sleep for a better quality of life, academic and social performance. At the same time, public policies must be implemented regarding the adaptation of school hours to better meet the physiological needs of adolescents, adhering to a later school schedule or a schedule that considers the student's chronotype.

Funding

This work was supported by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES – Grant #001), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), and Universidade Federal do Rio Grande do Norte.

Conflict of Intertests

The authors have no conflict of interests to declare.

Acknowledgments

We would like to thank the school's teaching teams for their collaboration and support, and especially the students who agreed to participate in this research. We would also like to thank Dr. SP and Dr. JS for their valuable suggestions. This work was supported by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES – Grant #001), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and Universidade Federal do Rio Grande do Norte.

References

1 Andrade MM, Benedito-Silva AA, Domenice S, Arnhold IJ, Menna-Barreto L. Sleep characteristics of adolescents: a longitudinal study. J Adolesc Health 1993;14(05):401–406

2 Carskadon MA, Vieira C, Acebo C. Association between Puberty and Delayed Phase Preference [Internet]. Sleep 1993;16;

3 Crowley SJ, Wolfson AR, Tarokh L, Carskadon MA. An update on adolescent sleep: New evidence informing the perfect storm model. J Adolesc 2018;67:55–65

4 Carskadon MA. Sleep in Adolescents: The Perfect Storm. Vol. 58,. Pediatric Clinics of North America.: Elsevier; 2011. p. 637–47

5 Taylor DJ, Jenni OG, Acebo C, Carskadon MA. Sleep tendency during extended wakefulness: insights into adolescent sleep regulation and behavior. J Sleep Res 2005;14(03):239–244

6 Jenni OG, Carskadon MA. Normal Human Sleep at Different Ages: Infants to Adolescents Key Concepts. SRS Basics Sleep Guid. 2005;(January):11–19

7 Hale L, Kirschen GW, LeBourgeois MK, et al. Youth Screen Media Habits and Sleep: Sleep-Friendly Screen Behavior Recommendations for Clinicians, Educators, and Parents. Child Adolesc Psychiatr Clin N Am 2018;27(02):229–245

8 Figueiro MG, Lesniak NZ, Rea MS. Implications of controlled short-wavelength light exposure for sleep in older adults. BMC Res Notes 2011;4:334

9 Higuchi S, Motohashi Y, Liu Y, Ahara M, Kaneko Y. Effects of VDT tasks with a bright display at night on melatonin, core temperature, heart rate, and sleepiness. J Appl Physiol 2003;94(05):1773–1776

10 van der Lely S, Frey S, Garbazza C, et al. Blue blocker glasses as a countermeasure for alerting effects of evening light-emitting diode screen exposure in male teenagers. J Adolesc Health 2015;56(01):113–119

11 Hirshkowitz M, Whiton K, Albert SM, et al. National Sleep Foundation's sleep time duration recommendations: methodology and results summary. Sleep Health 2015;1(01):40–43

12 Valdez P, Ramírez C, García A. Delaying and extending sleep during weekends: sleep recovery or circadian effect? Chronobiol Int 1996;13(03):191–198

13 Wittmann M, Dinich J, Merrow M, Roenneberg T. Social jetlag: Misalignment of biological and social time. In: Chronobiology International. 2006. p. 497–509

14 Knutson KL. Sex differences in the association between sleep and body mass index in adolescents. J Pediatr 2005;147(06):830–834

15 Tonetti L, Fabbri M, Natale V. Sex difference in sleep-time preference and sleep need: a cross-sectional survey among Italian pre-adolescents, adolescents, and adults. Chronobiol Int 2008;25(05):745–759

16 Duarte LL, Menna-Barreto L, Miguel MAL, et al. Chronotype ontogeny related to gender. Braz J Med Biol Res 2014;47(04):316–320

17 Roenneberg T, Kuehnle T, Pramstaller PP, et al. A marker for the end of adolescence. Vol. 14,. Current Biology. Cell Press;; 2004

18 Mong JA, Cusmano DM. Sex differences in sleep: Impact of biological sex and sex steroids. Vol. 371, Philosophical Transactions of the Royal Society B: Biological Sciences. Royal Society of London;; 2016. p. 20150110

19 Cameron N, Bogin B. Human Growth and Development. Human Growth and Development. Elsevier Inc.; 2012

20 Duffy JF, Cain SW, Chang AM, et al. Sex difference in the near-24-hour intrinsic period of the human circadian timing system. Proc Natl Acad Sci U S A 2011;108(Suppl 3, Suppl 3)15602–15608

21 Wever RA. Sex differences in human circadian rhythms: intrinsic periods and sleep fractions. Experientia 1984;40(11):1226–1234

22 Cain SW, Dennison CF, Zeitzer JM, et al. Sex differences in phase angle of entrainment and melatonin amplitude in humans. J Biol Rhythms 2010;25(04):288–296

23 Baker FC, Yűksel D, de Zambotti M. Sex Differences in Sleep. In: Current Clinical Neurology. Humana Press Inc.; 2020. p. 55–64

24 Lindberg E, Janson C, Gislason T, Björnsson E, Hetta J, Boman G. Sleep disturbances in a young adult population: can gender differences be explained by differences in psychological status? Sleep 1997;20(06):381–387

25 Armitage R, Hoffmann RF. Sleep EEG, depression and gender. Vol. 5, Sleep Medicine Reviews. W.B. Saunders Ltd; 2001. p. 237–46

26 Goel N, Kim H, Lao RP. Gender differences in polysomnographic sleep in young healthy sleepers. Chronobiol Int 2005;22(05):905–915

27 Zhang B, Wing YK. Sex differences in insomnia: a meta-analysis. Sleep 2006;29(01):85–93

28 Salk RH, Hyde JS, Abramson LY. Gender differences in depression in representative national samples: Meta-analyses of diagnoses and symptoms. Psychol Bull 2017;143(08):783–822

29 Twenge JM, Martin GN. Gender differences in associations between digital media use and psychological well-being: Evidence from three large datasets. J Adolesc 2020;79:91–102

30 de Frias CM, Nilsson LG, Herlitz A. Sex differences in cognition are stable over a 10-year period in adulthood and old age. Neuropsychol Dev Cogn B Aging Neuropsychol Cogn 2006;13(3-4):574–587

31 Halpern DF, LaMay ML. The Smarter Sex: A Critical Review of Sex Differences in Intelligence. Educ Psychol Rev 2000;12(02):229–246

32 Herlitz A, Yonker JE. Sex differences in episodic memory: the influence of intelligence. J Clin Exp Neuropsychol 2002;24(01):107–114

33 Vidafar P, Gooley JJ, Burns AC, et al. Increased vulnerability to attentional failure during acute sleep deprivation in women depends on menstrual phase. Sleep 2018;41(08):1–9

34 Santhi N, Lazar AS, McCabe PJ, Lo JC, Groeger JA, Dijk DJ. Sex differences in the circadian regulation of sleep and waking cognition in humans. Proc Natl Acad Sci U S A 2016;113(19):E2730–E2739

35 Díaz-Morales JF, Escribano C. Social jetlag, academic achievement and cognitive performance: Understanding gender/sex differences. Chronobiol Int 2015;32(06):822–831

36 Goel N. Neurobehavioral Effects and Biomarkers of Sleep Loss in Healthy Adults. Curr Neurol Neurosci Rep 2017;17(11):89

37 Goel N, Rao H, Durmer JS, Dinges DF. Neurocognitive consequences of sleep deprivation. Semin Neurol 2009;29(04):320–339

38 Cohen RA, O'Donnell BF. Models and Mechanisms of Attention. In SpringerBoston, MA1993. p. 177–86

39 Posner MI, Rafal RD. Cognitive theories of attention and the rehabilitation of attentional deficits. Neuropsychol Rehabil 1987;x:182–201

40 Valdez P, Ramírez C, García A, Talamantes J, Armijo P, Borrani J. Circadian rhythms in components of attention. In: Biological Rhythm Research. 2005

41 Forest G, Gaudreault P, Michaud F, Green-Demers I. Gender differences in the interference of sleep difficulties and daytime sleepiness on school and social activities in adolescents. Sleep Med 2022;100:79–84

42 Haraszti RÁ, Ella K, Gyöngyösi N, Roenneberg T, Káldi K. Social jetlag negatively correlates with academic performance in undergraduates. Chronobiol Int 2014;31(05):603–612

43 Mathias A, Mendonça M, Andrade M. Incentivo hábitos de sono adequados: um desafio para educadores. Núcleo Ensino da Unesp. 2006:1–14

44 ABEP - Associação Brasileira de Empresas de Pesquisa. Critério de Classificação Econômica Brasil. 2014

45 ABEP - Associação Brasileira de Empresas de Pesquisa. Critério de Classificação Econômica Brasil. 2015

46 ABEP - Associação Brasileira de Empresas de Pesquisa. Critério de Classificação Econômica Brasil. 2019

47 Maldonado CC, Bentley AJ, Mitchell D. A pictorial sleepiness scale based on cartoon faces. Sleep 2004;27(03):541–548

48 Belísio AS. Padrões temporais de sono, sonolência diurna e os componentes da atenção em crianças que estudam nos turnos da manhã e da tarde na educação infantil. Universdade Federal do Rio Grande do Norte;; 2014

49 Roenneberg T, Pilz LK, Zerbini G, Winnebeck EC. Chronotype and social jetlag: A (self-) critical review. Vol. 8, Biology. MDPI AG; 2019

50 Cohen J. Statistical Power Analysis for the Behavioral Sciences. 2nd ed. New York:: Lawrence Erlbaum Associates; 1988:567 p.

51 Franco P, Putois B, Guyon A, et al. Sleep during development: Sex and gender differences. Vol. 51, Sleep Medicine Reviews. W.B. Saunders Ltd; 2020

52 Mathew GM, Hale L, Chang AM. Sex Moderates Relationships Among School Night Sleep Duration, Social Jetlag, and Depressive Symptoms in Adolescents. J Biol Rhythms 2019;34(02):205–217

53 Haynie DL, Lewin D, Luk JW, et al. Beyond Sleep Duration: Bidirectional Associations Among Chronotype, Social Jetlag, and Drinking Behaviors in a Longitudinal Sample of US High School Students. Sleep 2018;41(02):zsx202

54 Carvalho-Mendes RP, Dunster GP, de la Iglesia HO, Menna-Barreto L. Afternoon School Start Times Are Associated with a Lack of Both Social Jetlag and Sleep Deprivation in Adolescents. J Biol Rhythms 2020;35(04):377–390

55 Doran SM, Van Dongen HP, Dinges DF. Sustained attention performance during sleep deprivation: evidence of state instability. Arch Ital Biol 2001;139(03):253–267

56 Dewald JF, Meijer AM, Oort FJ, Kerkhof GA, Bögels SM. The influence of sleep quality, sleep duration and sleepiness on school performance in children and adolescents: A meta-analytic review. Sleep Med Rev 2010;14(03):179–189

57 Adam JJ, Paas FGWC, Buekers MJ, Wuyts IJ, Spijkers WAC, Wallmeyer P. Gender differences in choice reaction time: evidence for differential strategies. Ergonomics 1999;42(02):327–335

58 Kuula L, Pesonen AK, Martikainen S, et al. Poor sleep and neurocognitive function in early adolescence. Sleep Med 2015;16(10): 1207–1212

59 Medeiros LS, Santos FH, Almeida AP, et al. Sex differences in the cognitive performance in adults: role of impaired sleep. Sleep Sci 2022;15(01):17–25

60 Blatter K, Graw P, Münch M, Knoblauch V, Wirz-Justice A, Cajochen C. Gender and age differences in psychomotor vigilance performance under differential sleep pressure conditions. Behav Brain Res 2006;168(02):312–317

