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Asthma control, social jetlag, and sleep impairment in high school adolescents

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A B S T R A C T

Introduction: Social jetlag is associated with several negative health outcomes, but its impact on asthma control has not been previously investigated. Although impaired sleep is common in asthma, studies on the relationship between sleep quality, social jetlag and asthma control in adolescents are scarce.
Objective: To investigate the relationship between asthma control and sleep quality, sleep-wake pattern and excessive daytime sleepiness in adolescents.
Methods: This was a cross-sectional study of 1457 Brazilian high-school adolescents. Asthma was identified using the International Study of Asthma and Allergies in Childhood questionnaire, and disease control was measured by the Asthma Control Test. Sleep-wake pattern and social jetlag were assessed by the Munich Chrono-Type Questionnaire; sleep quality, by the Pittsburgh Sleep Quality Index; and daytime sleepiness, by the Epworth Sleepiness Scale.
Results: Asthma was present in 250 (17.2%) participants and was classified as uncontrolled in 120 (47.9%). Both uncontrolled and controlled asthma groups, compared with non-asthmatics, had worse sleep quality (81.7% *vs* 77.4% *vs* 56.5%; $p < 0.001$) and excessive daytime sleepiness (EDS: 56.2% *vs* 56.5% *vs* 39.2%; $p < 0.001$). On average, adolescents with uncontrolled asthma, compared to non-asthmatics, showed later sleep onset (mean ± SD: 23:54pm ± 1 h:45min *vs* 23:20pm ± 1 h:27min; $p = 0.002$) and shorter sleep duration (5.7 h ± 1.8 h *vs* 6.3 h ± 1.4 h; $p = 0.002$) on school days. No significant difference in social jetlag was found among the three groups.
Conclusions: Asthma is associated with EDS and poor-quality sleep in adolescents. Social jetlag is common in these subjects and is not related to the presence and control of asthma.

1. Introduction

Asthma is a chronic inflammatory airways disease, characterized by recurrent episodes of variable airflow limitation, associated with wheezing, dyspnea, chest tightness, and cough, which are more pronounced at night [1]. Although it can occur at any age, asthma more frequently affects lower age groups, with even higher prevalence and mortality rates in adolescents than in younger children [2]. The degree of asthma control, which reflects the extent to which disease manifestations can be observed or reduced as a result of treatment, has been described as unsatisfactory in a high proportion of children and adolescents [3].

Accumulating evidence indicates the existence of a reciprocal relationship between asthma and sleep. Nighttime symptoms, found in most asthma patients [4], may result from an increased amplitude in the circadian variation of airway caliber, which reaches its nadir during the night, and is probably related to a well-recognized nocturnal worsening of inflammation and bronchial hyperresponsiveness [5].

Nighttime asthma exacerbations have been associated with short sleep duration, poor sleep quality, and excessive daytime sleepiness, which seem to be more common in patients with inadequate disease control [4,6]. However, even in mild and clinically stable cases, asthma may be accompanied by impaired sleep [7]. Poor sleep quality in asthma can have negative repercussions, not only on the performance of daily living activities and quality of life, but also on lung function and disease progression [4].

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Surprisingly, studies on the relationship between asthma control and sleep in adolescents are very limited.

The word chronotype designates behavioral presentations of the endogenous circadian system that determine the individual preference for sleep and wake times [8]. This preference ranges within a spectrum from markedly morning people, who present an earlier bedtime, mid-sleep, and morning awakening, to evening people, in whom these events occur later in the 24 h period. Those who fall between the ends of this continuum are usually referred to as intermediate types [8]. It is estimated that genetic factors can explain up to 50% of the circadian timing variability in the population [9].

Significant changes in daytime preference have been recognized across the life span [8]. In adolescence, compared to childhood, there is a typically delayed pattern, which increases the vulnerability to sleep problems, and has been attributed to biological as well as psychosocial factors, including slow course of sleep pressure, greater autonomy to decide when to go to bed, participation in social networks, and use of electronic equipment at night [10,11]. The tendency towards eveningness in adolescence usually leads to a delayed sleep time, which is often more pronounced on free days. Conversely, on school days, requirements imposed by school hours that conflict with the preferred wake up time of the adolescent can significantly reduce the number of sleep hours. This phenomenon of reduced sleep on school days and its "compensatory" extension on free days is called social jetlag [10]. Evidence indicates an association between social jetlag and several negative health outcomes, such as increased adiposity, worse cardiorespiratory fitness and excessive daytime sleepiness [12]. Given this context, we hypothesized that social jetlag could also impair asthma control.

The main objective of this study was to investigate the impact of social jetlag on the degree of asthma control in high school adolescents. Additionally, this study aimed to evaluate the relationship between asthma and sleep quality, excessive daytime sleepiness, sleep-wake rhythm characteristics, and chronotype in these subjects.

2. Methods

2.1. Participants and study design

This was a cross-sectional study of high school adolescents from public schools in Teresina, Brazil (05°05′21″ S and 42°48′07″ W). Data was collected from August 2016 to November 2018. The city of Teresina has 95 public schools, distributed across four geographical regions, totaling 23,992 high school students. Sample size was calculated applying the formula for cross-sectional studies with a finite population: $n = (Z\alpha^2 * P * Q * N)/(Z\alpha^2 * P * Q) + (N - 1) * E^2$. The following parameters were used: a confidence coefficient of 95% ($Z = 1.96$); a sampling error (E) of 5%; and a population (N) of 23,992 high school adolescents. Assuming a prevalence (P) of asthma symptoms of 19% ($P = 0.19$) [13], a total (n) of 234 participants with asthma was determined.

Ten schools from the four geographic areas of the city of Teresina took part in the study. Schools were sequentially approached, based on number of students enrolled, according to information obtained from the local board of Education. If a preselected school did not agree to participate, the next largest school would be contacted by the investigators, until the desired sample size was achieved.

Student sampling was non-probabilistic and all students present in the selected schools were approached to take part in the study. Male and female adolescents, aged between 14 and 19 years, were included. Adolescents with a previous diagnosis of sleep disorders were not included. Subjects who failed to complete all the research instruments were excluded from that analysis. Initially, one of the investigators (LGFF) gave a detailed explanation of the study methods and objectives. On a second visit, the same investigator handed over the questionnaires and data collection forms, and the participants had 50 min to answer the questions in the classroom. Students who missed school on the day of questionnaire administration were not included in the study.

The study protocol was approved by the Research Ethics Committee (No. 1.765.365). All participants gave their informed assent, and the Free Informed Consent was signed by parents or legal guardians.

2.2. Measures

A purpose-built questionnaire was used to collect sociodemographic data, including age, sex, paid employment, residence, and school year.

Chronotype was assessed by the Brazilian Portuguese version of the Morningness-Eveningness Questionnaire (MEQ) [14] which is based upon the English version of this questionnaire originally published by Horne & Ostberg (1976) and consists of 19 items on sleep habits and activities. A global score ranging from 16 to 86 is obtained by the sum of the items. Individuals are classified as morning type (59–86), intermediate (42–58), and evening type (16–41) [14,15].

The Brazilian Portuguese version of the Munich Chronotype Questionnaire (http://www.bioinfo.mpg.de/wepcronotipo/) was used to assess sleep pattern on school days (weekdays) and free days (weekends). This instrument determines sleep onset, sleep duration and wake-up time. Mid-sleep, the midpoint between sleep onset and wake up, was then calculated using the following formula: mid-sleep = sleep onset + sleep duration/2. Social jetlag, which reflects the discrepancy in the subject's sleep pattern between the weekdays and the weekend, was calculated as the difference between mid-sleep on school days and free days [16,17].

The Brazilian-Portuguese version of the Pittsburgh Sleep Quality Index (PSQI) was used to assess sleep quality [18]. It consists of 19 items that compose seven scoring components, each one related to a specific aspect of sleep: (1) subjective sleep quality; (2) sleep latency; (3) sleep duration; (4) habitual sleep efficiency; (5) sleep disorders; (6) use of sleep medications; and (7) daytime dysfunction. The global score is obtained from the sum of the scores of the seven domains and could range from 0 to 20 points, with higher total scores indicating worse sleep quality. An overall global score higher than 5 is considered indicative of poor sleep quality [16]. The reliability and validity of the version of the PSQI used in this study was previously assessed in Brazilian adolescents. The questionnaire showed "high internal consistency and moderate reliability" [19].

Daytime sleepiness was assessed by the Epworth Sleepiness Scale (ESS), which was previously translated and validated for use in Brazilian subjects [20]. It is a self-administered tool that measures the probability of falling asleep in eight daily life situations, quantified as zero (no chance), 1 (small chance), 2 (moderate chance) or 3 (high chance). The final score ranges from zero to 24 and scores higher than 10 points is considered indicative of excessive daytime sleepiness (EDS) [20].

The presence of asthma was assessed by the asthma component of the International Study of Asthma and Allergies in Childhood (ISAAC) written questionnaire. The ISAAC is recognized as an important initiative designed to compare the prevalence of asthma and allergic diseases in children and adolescents in different regions of the world, using uniform criteria. Originally developed in English, the asthma component of the ISAAC written questionnaire has been previously translated and validated for use in Brazil [21]. It consists of eight questions: four about asthma symptoms, three about asthma severity, and one about previous medical diagnosis. A global score is calculated from the sum of specific values for each answer. In this interpretation of the ISAAC asthma module, the final score ranged from 0 to 14 points. Participants with scores equal to or greater than 6 were classified as asthmatics [21].

Asthma control was assessed by a previously translated and validated version of the Asthma Control Test (ACT), which self-evaluates the presence of signs, symptoms, and use of asthma relief medications in the previous four weeks. The total score, obtained from the sum of these items, can range from 5 to 25 points and corresponds to three degrees of control: total control or clinical remission of asthma symptoms (25); adequate control (20–24); and uncontrolled asthma (<20 points) [22]. For analysis purposes, asthmatic adolescents in the present study were classified into 2 groups: (i) well-controlled asthma, including those with complete or adequate disease control (20–25 points); and (ii) uncontrolled asthma (<20 points).

2.3. Statistical analysis

Data were described as mean and standard deviation (SD) for quantitative variables, and frequencies for qualitative variables. The Pearson's Chi-Square Test was used to compare qualitative variables. The Kolmogorov-Smirnov test was used for inferential analysis to verify the normality of quantitative data. The Kruskal-Wallis test was used to compare adolescents with controlled and uncontrolled asthma, and without asthma. Spearman's test was used to assess correlation between variables of interest. Multivariate binary logistic regression with the forced entry method was performed to assess the potential association between adolescent characteristics and the presence of asthma. For this analysis, the presence of asthma was considered as an outcome (ISAAC ≥6) and sex, chronotype, daytime sleepiness and sleep quality were chosen as independent variables. The absence of multicollinearity of the predictors was verified, when all the factorial predictors of variation were close to 1. Finally, the Odds Ratio (OR) and confidence interval (CI) of the independent variables were specified. Statistical analysis was performed using IBM® SPSS software version 22.0. The level of statistical significance was established at $p < 0.05$.

3. Results

A total of 1457 teenagers (females = 54.2%; mean age ± SD = 16.1 ± 1.1 years) took part in the study. Overall, 12% were classified as morning type, 68% as intermediate, and 20% as evening type. Poor sleep quality (PSQI >5) was observed in 60.1% of the participants (mean PSQI score ± SD = 6.38 ± 2.72) and excessive daytime sleepiness (ESS>10) in 42% (mean ESS score ± SD = 9.78 ± 4.48).

Asthma was identified in 250 (17.2%) participants. In these subjects, medical diagnosis of asthma was reported by 56.4%; wheezing attacks in the previous 12 months, by 83.6%, sleep disturbed by wheezing in the previous year, by 55.2%, and nocturnal cough, by 73.2%. The global ISAAC score was 8.8 ± 2.1. Uncontrolled asthma was found in 47.9% of the affected individuals and adequate or complete control in 52.1%. Mean ACT score was 17.8 ± 7.1.

For analyses purposes, participants were classified into 3 groups: uncontrolled asthma, controlled asthma, and non asthma. The uncontrolled asthma group presented a higher percentage of female subjects (75.2%; $X^2 = 22.73$, $p < 0.001$) compared to the controlled asthma and non asthma groups. No differences were found among the three groups concerning work activity, school shift (morning vs full day shift), and chronotype (Table 1).

Participants from uncontrolled and controlled asthma groups had a higher percentage of poor sleep quality (PSQI >5) than students without asthma (81.7% *vs* 77.4% *vs* 56.5%; $X^2 = 41.12$; $p < 0.001$). Sleep quality assessed by the global PSQI score was better in participants without asthma (6.1 ± 2.6) than in those with controlled (7.5 ± 2.7; $p < 0.001$) and uncontrolled asthma (8.3 ± 3.0; $p < 0.001$), as shown in Table 1. As for the PSQI domains of sleep latency, sleep disorders, and daytime dysfunction, there was a significant difference between adolescents without asthma and uncontrolled and controlled asthma ($p < 0.001$). In the domains of subjective quality of sleep and use of sleeping medication, there was a difference between uncontrolled asthma and non-asthma groups ($p < 0.001$), as shown in Fig. 1.

The frequency of adolescents with EDS (ESS >10) was higher in uncontrolled and controlled asthma groups compared to non-asthma group (respectively, 56.2% *vs* 56.5% *vs* 39.2%; $X^2 = 22.65$; $p < 0.001$). Similarly, the ESS score was on average higher in adolescents with uncontrolled (11.9 ± 5.0) and controlled disease (11.7 ± 4.6) than in participants without asthma (9.4 ± 4.3; $p < 0.001$), as described in Table 1.

Adolescents with controlled and uncontrolled asthma had a higher frequency of short sleep duration (<6 h) than adolescents without asthma, both on school days (47.8% *vs* 35.6%; $X^2 = 12.28$; $p < 0.001$) and free days (13.5% *vs* 8.9%; $X^2 = 4.95$; $p = 0.026$).

On school days, students with uncontrolled asthma, compared to non-asthmatics, had a later sleep onset (respectively, 11:54 p.m. ± 1 h:45min *vs* 11:20 p.m. ± 1 h:27min; $p = 0.002$) and mid-sleep (2 h:47min ± 00:57 min *vs* 2 h:30min ± 00:51 min; $p = 0.006$) (Table 2). On free days, sleep onset was later in the uncontrolled (1 h:50min a.m.) and controlled (1 h:55min a.m.) groups than in the non-asthma group (1 h:18min a.m.; $p < 0.001$).

On average, sleep duration on school days in students with uncontrolled asthma was shorter than in students without asthma (5.7 h ± 1.8 h *vs* 6.3 h ± 1.4 h; $p = 0.002$). No significant difference in social jetlag was found among the three groups (Table 2).

The ISAAC score was negatively correlated with the degree of disease control assessed by the ACT ($r = -0.117$, $p < 0.001$) and positively correlated with the global PSQI score ($r = 0.269$, $p < 0.001$), ESS score ($r = 0.176$, $p < 0.001$), and sleep onset on free days ($r = 0.117$, $p < 0.001$). No correlation was found between social jetlag and the ISAAC and ACT scores.

Logistic regression analysis was used to investigate the association between asthma (controlled or not) and sex, sleep quality, EDS, and chronotype. The results showed a 1.45 greater chance of asthma in females, as compared to male adolescents ($p = 0.016$). Students with asthma were 2.54-fold more likely to have poor sleep quality ($p < 0.001$), and 1.71-fold more likely to have EDS ($p < 0.001$), as shown in Table 3.

4. Discussion

This study shows that asthma is associated with poor sleep quality and EDS in urban high school adolescents. Students with uncontrolled asthma start to sleep later, on school and on free days, and have shorter sleep duration on school days, compared to those without asthma. A high frequency of social jetlag was found among the students, but no significant relationship with the presence of asthma and disease control was demonstrated.

In this study, the frequency of asthma was comparable to that previously described in Brazilian adolescents, which ranged from 18.3 to 23.2% for active asthma and 13.6 to 12.4% for physician-diagnosed asthma [13,23,24]. Confirming previous reports, female students had a higher prevalence of the disease [25,26,27,28]. It is recognized that, although childhood asthma is more common in boys, during puberty, probably due to hormonal changes and sex-specific differences in environmental exposures, it becomes more frequent in females [27,29]. Although it has been suggested that this increase of asthma in female adolescents could be related to

Table 1
Sociodemographic characteristics, school period, chronotype, sleep quality and degree of daytime sleepiness in adolescents with uncontrolled, controlled and without asthma. Teresina, Brazil.

	Uncontrolled asthma n = 120	Controlled asthma n = 130	Non- asthma n = 1207	p
Age (years, mean ± SD)	16.17 ± 1.05	16.20 ± 1.18	16.04 ± 1.10	0.209§
Gender				
Female, n (%)	90 (75.2%)	76 (58.3%)	623 (51.6%)	<0.001†
Male, n (%)	30 (24.8%)	54 (41.7%)	584 (48.4%)	
Work				
Yes, n (%)	14 (11.5%)	10 (7.8%)	93 (7.7%)	0.379†
No, n (%)	106 (88.5%)	120 (92.2%)	1114 (92.3%)	
School shift				
Morning, n (%)	52 (42.9%)	50 (38.3%)	467 (38.7%)	0.695†
Full-day, n (%)	68 (57.1%)	80 (61.7%)	740 (61.3%)	
Chronotypes				
Morning, n (%)	13 (11.2%)	14 (10.8%)	147 (12.2%)	0.152†
Intermediate, n (%)	71 (59.2%)	89 (68.5%)	831 (68.9%)	
Evening, n (%)	36 (29.6%)	27 (20.7%)	229 (18.9%)	
Sleep quality				
Poor quality, n (%)	98 (81.7%)	101 (77.4%)	682 (56.5%)	<0.001†
Good quality, n (%)	22 (18.3%)	29 (22.6%)	525 (43.5%)	
PSQI score (mean ± SD)	8.34 ± 3.05[a]	7.54 ± 2.74[b]	6.09 ± 2.57[a,b]	<0.001§
EDS				
Yes, n (%)	67 (56.2%)	73 (56.5%)	473 (39.2%)	<0.001†
No, n (%)	53 (43.8%)	57 (43.5%)	734 (60.8%)	
ESS score (mean ± SD)	11.86 ± 5.04[a]	11.66 ± 4.65[b]	9.43 ± 4.30[a,b]	<0.001§

Definition of abbreviations: ESS = Epworth sleepiness scale; EDS = excessive daytime sleepiness; PSQI = Pittsburgh Sleep Quality Index; SD = standard deviation. §Kruskall Wallis Independent Group Comparison Test. †Pearson's Chi-Square Test, at a significance level of 5%. Superscript characters indicate a statistically significant difference ($p < 0.05$) between groups: a = Uncontrolled asthma x Non asthma; b = Controlled asthma x Non asthma.

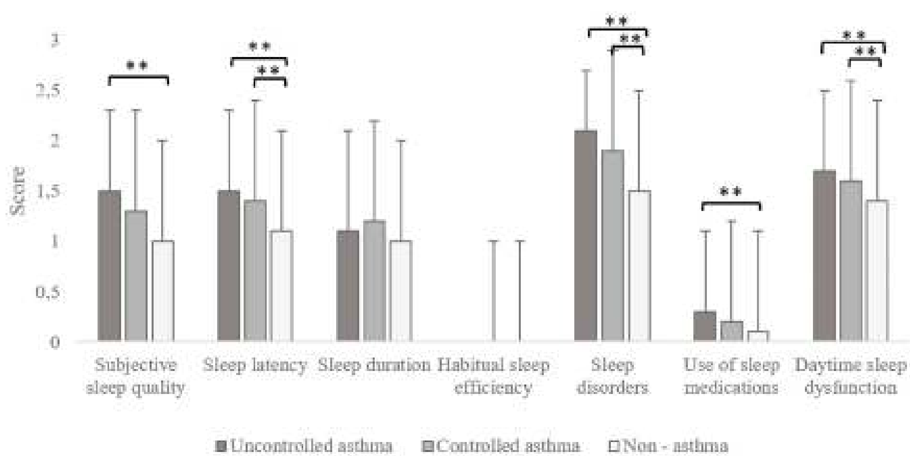

Fig. 1. Pittsburgh Sleep Quality Index domain scores in 1457 adolescents according to the presence or absence of asthma and level of disease control. Teresina, Brazil. Kruskal Wallis Independent Group Comparison Test. *<0.05; **<0.01.

Table 2
Sleep pattern of 1457 adolescents with uncontrolled asthma, controlled asthma and without asthma. Teresina, Brazil.

Variable	Uncontrolled asthma (ACT <20) n = 120	Controlled asthma (ACT ≥20) n = 130	Non-asthma n = 1207	p
	Mean ± SD	Mean ± SD	Mean ± SD	
School days				
Sleep onset (h:min)	11:54 ± 01:45[a]	11:45 ± 1:46	11:20 ± 01:27[a]	0.002
Wake-up time (h:min)	05:39 ± 00:33	05:40 ± 00:34	05:41 ± 00:41	0.932
Sleep duration (h)	5.7 ± 1.8[a]	5.9 ± 1.8	6.3 ± 1.4[a]	0.002
Mid-sleep time (h:min)	02:47 ± 00:57[a]	02:43 ± 00:58	02:30 ± 00:51[a]	0.006
Free days				
Sleep onset (h:min)	01:50 ± 01:53[a]	01:55 ± 01:43[b]	01:18 ± 01:53[a,b]	<0.001
Wake-up time (h:min)	09:39 ± 02:49	09:50 ± 02:24	09:35 ± 02:07	0.613
Sleep duration (h)	7.8 ± 2.8	7.9 ± 2.2	8.3 ± 2.2	0.099
Mid-sleep time (h:min)	05:44 ± 01:57	05:52 ± 01:46	05:27 ± 01:41	0.069
Social jetlag (h)	2.9 ± 1.7	3.2 ± 1.6	2.9 ± 1.5	0.489

Kruskal Wallis Independent Group Comparison Test. Superscript characters indicate a statistically significant difference ($p < 0.05$) between groups: a = Uncontrolled asthma x Without asthma; b = Controlled asthma x Without asthma.

Table 3
Logistic regression analysis between sex, chronotype, sleep quality and excessive daytime sleepiness in relation to the presence of asthma in high school adolescents. Teresina, Brazil.

Variable	OR (CI95%)	p
Gender - Female	1.45 (1.07–1.98)	0.016
Chronotypes		
Morning	1	
Intermediate	0.89 (0.55–1.43)	0.641
Evening	0.92 (0.54–1.59)	0.777
Poor sleep quality	2.54 (1.79–3.61)	<0.001
Excessive daytime sleepiness	1.71 (1.27–2.29)	<0.001

Definition of abbreviations: OR = Odds ratio; CI = Confidence Interval.

estrogen and progesterone levels, the mechanisms involved in this relationship are not fully understood [29]. Conversely, a protective effect of testosterone in asthma secondary to an immunosuppressive action has been proposed [27,30].

A little more than half of the students classified as asthmatics in this study showed complete or adequate disease control. This finding is higher than that of a previous study of 138 asthmatic Brazilian children and adolescents, where 31.2% of the participants presented with controlled asthma [31]. In the present study, the vast majority of adolescents with uncontrolled asthma were females. Previously, in 247 Swedish adolescents aged 14–15 years with current asthma, uncontrolled disease was reported to be significantly more frequent in girls than boys [32]. In contrast, a postal questionnaire survey of 572 Swiss children with wheeze aged 4–16 years found that poor asthma control was not related to gender [33].

In the present study, participants classified as asthmatics, irrespective of their degree of control, had a higher prevalence of poor quality sleep, compared to those without asthma. Analysis of PSQI domains shows that subjective sleep quality, sleep latency, sleep disorders, use of sleep medication, and daytime dysfunction were most affected.

The relationship between asthma control and sleep quality in adolescence has been previously evaluated in a limited number of studies. Perception of respiratory symptom severity in American adolescents with asthma has been related to sleep problems and degree of daytime sleepiness, suggesting that awakenings associated with nocturnal symptoms could negatively impact daytime sleepiness and satisfaction with sleep [34]. Previous studies in other age groups, have usually shown an association between quality of sleep and degree of asthma control. In a study of children aged one to four years, asthmatics had more nocturnal awakenings than children without asthma. Additionally, children with poor asthma control, compared to those with well-controlled asthma or no asthma, had poorer sleep patterns, more prolonged sleep latency, and more sleep disruptions [35]. In adults with mild-to-moderate asthma, inadequate disease control can lead to prolonged sleep latency, increased frequency of nighttime awakenings, and increased wake after sleep onset (WASO), as measured by actigraphy [36]. A multicentric, cross-sectional study of 222 adults with asthma and 60 normal controls reported an association between low level of asthma control and poor sleep. Interestingly, poor quality sleep was observed in a large proportion of patients without nocturnal symptoms of asthma, suggesting that the high frequency of sleep problems in these individuals cannot be secondary only to nighttime symptoms [37]. Other studies of adults with asthma reported worse subjective and objective sleep quality, EDS and sleep disturbances, as well as an increased use of sleep medication in these patients, compared to individuals without asthma [38,39]. In the present study, no significant difference in subjective sleep quality was found between controlled and uncontrolled asthma groups. It is important to recognize that poor asthma control can be related to multiple factors, including disease severity, resistance to therapy, low adherence, poor inhaler technique, smoking, and social attitudes. Additionally, other diseases that commonly coexist with asthma, such as gastroesophageal reflux and obstructive sleep apnea, can also affect sleep quality [1].

In this study, short sleep duration was common in adolescents with and without asthma, confirming previous reports of a high frequency of insufficient sleep in this age group [11,40,41]. Participants classified as asthmatics presented shorter sleep duration than non-asthmatics, both on school and on free days. Previously, the finding of asthma in individuals aged 15–17 years has been related to a greater propensity to sleep less than 7 h. In addition, an association between asthma and short sleep duration was reported, particularly in overweight participants. However, unlike in the present study, sleep duration was not assessed on weekends [42]. A cross-sectional study of 24,612 high school adolescents included in the 2009 and 2011 National Youth Risk Behavior Survey, carried out by the US Centers for Disease Control and Prevention, showed that, compared to students without current asthma, those with current asthma were more likely to report fewer hours of sleep [28]. Recently, analysis of web-based self-reported data from a large sample of physician-diagnosed asthma in adolescents in Korea, showed reduced sleep duration in asthmatics, compared to non-asthmatic controls. On average, sleep duration in asthmatics was 6.6 h on school days and 8.5 h on free days, higher than in the present study, both for the uncontrolled and controlled asthma groups. This difference might be related, at least in part, to socio-cultural factors [43]. A previous study involving a retrospective assessment of polysomnographic records of children and adolescents aged 5–17 years showed shorter sleep duration in asthmatic males compared to controls [44].

The high frequency of EDS found in this study corroborates previous reports [11,45]. Participants with asthma, regardless of disease control status, showed a higher frequency of EDS, compared to non-asthmatics, and EDS was significantly associated with the presence of asthma in this sample. Previously, nocturnal awakenings and perception of severe respiratory problems were associated with daytime sleepiness in 349 asthmatic adolescents [46]. Children and adolescents aged eight to 17 years with poorly controlled asthma were found to have more daytime sleepiness and worse quality of life than controls [47]. Another study in Sweden analyzed data from 25,160 participants aged between 16 and 75 years and identified 1830 asthmatic people. In these subjects, the presence of asthma was an independent risk factor for EDS and the risk of having EDS increased with the severity of the disease [48]. The high frequency of daytime sleepiness in asthma has been linked to several factors, including short sleep duration, sleep fragmentation and poor disease control [48,49].

In the present sample, no association between asthma and chronotype was demonstrated. An online survey of a large number of adolescents in South Korea found a modest association between medical diagnosis of asthma and evening chronotype [50]. Analysis of data on 1684 Indian adolescents, aged between 13 and 14 years, from the Prevalence and Risk Factors of Asthma and Allergy-Related Diseases among Adolescents study showed consistently more respiratory symptoms, such as current wheeze, in evening-type subjects than in morning types. This effect was not restricted to evening-types and was observed, to a smaller degree, among the intermediate types [51]. In Finland, a study of 6089 adults aged from 25 to 74 years reported increased odds for asthma among evening chronotypes [52]. In contrast, a Brazilian study of 100 asthmatic patients and 100 controls without asthma, with a mean age of 35 years, observed no significant difference in chronotype distribution between the two groups [53]. It should be noted that the degree of ambient luminosity, a factor that can have an influence on chronotype, was not evaluated in this or other studies mentioned above. It is reasonable to assume that asthmatic patients with prominent nocturnal symptoms, as frequently occurs in inadequate disease control, are more exposed to artificial light, which could secondarily lead to problems of circadian timing system adjustment [54]. Further studies on the sleep-wake pattern of asthmatic subjects with adequate measurement of ambient luminosity should be conducted to investigate this issue.

It has been previously reported that the use of asthma controller medications may reduce nighttime symptoms and daytime sleepiness in the pediatric population. Previous work in adolescents has shown a reduction in treatment adherence in comparison to younger children or older patients with asthma [2] In the present study, no information on the use of asthma medication was collected. A potential link between nocturnal asthma, use of medication and chronotype should be explored in future studies.

In this study, social jetlag was observed in adolescents from all study groups, in keeping with previous reports [55,56]. Participants with uncontrolled asthma had a later sleep onset, both on school and free days, and a later mid-sleep on school days than students without asthma. However, there was no significant difference in social jetlag between asthmatics without disease control and non-asthmatics. Previous studies on the relationship between asthma and social jetlag in this age group are very scarce. Early mid-sleep on free days was previously reported in 311 adults with asthma on follow-up compared to a control group from the general population, matched for age and sex, assessed via the Internet [57].

It is important to keep in mind that social jetlag and sleep debt (i.e., short sleep duration due to sleep restriction or sleep deprivation) can be mutually related. A previous study of 4505 adult Japanese workers found that both social jetlag and sleep debt have a detrimental effect on daytime sleepiness, mood, and work performance. However, the impact of sleep debt was reportedly more intense and a sleep debt greater than 2 h masked the negative effects of social jetlag on daytime function in that particular population [58]. We are not aware of similar studies carried out in adolescents; however, it is possible to speculate that the sleep debt secondary to the marked reduction in sleep duration, particularly, among asthmatics, may have obscured some consequences of the social jetlag, such as EDS, in the present sample.

Some limitations of this study require proper consideration. First, it should be noted that asthma was identified by the asthma component of the ISAAC written questionnaire, a standardized tool that has been widely used for this purpose and has been previously translated and validated for Brazilian subjects [21]. It is important to consider that instruments like this, which include questions about clinical manifestations characteristic of asthma, can be advantageous in low- and middle-income countries, where up to half of the cases of asthma still remain undiagnosed [1,24]. Second, sleep quality was assessed subjectively by the PSQI. However, it should be recognized that this instrument has been widely used for this purpose and previous reports indicate that subjective criteria may be superior to polysomnography in identifying sleep disorders, such as insomnia [59]. Third, daytime sleepiness was not measured objectively. The Multiple Sleep Latency Test, which evaluates the ability to fall asleep in repeated opportunities along the day, is considered the standard objective measure of EDS. However, its use in the study would not be practical. It should also be kept in mind that the Brazilian Portuguese version of the ESS used in the present study is based on the original English version of this scale, developed as a measure of sleepiness for adults, with minor adaptations [20]. Previously, the same translated version has been used in adolescents with satisfactory results [11]. Additionally, it is important to highlight that, due to the cross-sectional design, it is not possible to make inferences about causality or the direction of the relationships found in this study.

In conclusion, both controlled and uncontrolled asthma are associated with poor sleep and EDS in high school adolescents from an urban center. There was no evidence of an association between social jetlag and asthma control. Overall, the present results highlight the importance of taking into account to relationship between sleep and asthma when caring for adolescents with this disease. Further well designed prospective studies to investigate the chronobiological aspects of asthma in adolescence are warranted.

CRediT authorship contribution statement

Luana Gabrielle de França Ferreira: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Writing – original draft, Writing – review & editing. **Diogo Augusto Frota de Carvalho:** Formal analysis, Investigation, Methodology, Writing – original draft. **Felipe Rocha Alves:** Conceptualization, Investigation, Methodology, Writing – review & editing. **Veralice Meireles Sales de Bruin:** Conceptualization, Formal analysis, Investigation, Methodology, Writing – review & editing. **Pedro Felipe Carvalhedo de Bruin:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing.

Declaration of competing interest

None.

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