BACKGROUND: There is a need to understand more about modifiable health behaviors that may be related to asthma control. Sleep is one such health behavior that has received little attention in pediatric asthma research.

OBJECTIVE: To examine sleep duration, sleep hygiene, and insomnia in adolescents with and without asthma.

METHODS: Adolescents (n = 298; 51% boys; age range, 12-17 years; 48% with asthma) from the general community completed an online survey that included the International Study of Asthma and Allergies in Childhood questionnaire, the Children’s Report of Sleep Patterns, and the Insomnia Severity Index. RESULTS: Sleep duration did not differ between the asthma severity groups, yet more adolescents with severe asthma reported insufficient weekday sleep (44%) versus adolescents without asthma (31%). Significant asthma group differences were found for sleep hygiene, with adolescents with severe asthma reporting poorer sleep hygiene. Almost twice as many adolescents with severe asthma reported clinically significant insomnia than adolescents with mild or no asthma. Sleep hygiene variables were correlated with insomnia, although these associations did not differ between adolescents with and without severe asthma. Finally, both insomnia severity and asthma severity were significant predictors of daytime sleepiness; however, asthma severity accounted for only 2% of the variance compared with 28% of the variance accounted for by insomnia severity.

CONCLUSIONS: Many adolescents with severe asthma regularly obtain insufficient sleep, have poor sleep hygiene, and experience clinically significant insomnia. It is important to ask adolescents with asthma about sleep duration, sleep hygiene, and insomnia because there are effective interventions that can improve sleep for these youths. © 2014 American Academy of Allergy, Asthma & Immunology (J Allergy Clin Immunol Pract 2014;2:562-9)

Key words: Sleep; Sleep disorders; Sleep deprivation; Adolescents; Asthma

Asthma is the most common chronic disease among youth. In spite of medical advances in the diagnosis and treatment of asthma, asthma prevalence has increased from 8.7% to 9.6% over the past decade. The economic burden of asthma in the United States is approximately $56 billion, with 33% of children and adolescents with asthma who reported an emergency department or urgent care visit in 2008, and 8% of youths were hospitalized for asthma. Beyond required medical care, youths with asthma miss an estimated 14.4 million school days annually because of asthma-related illness or exacerbation, which highlights a major functional consequence of this disease.

Nocturnal asthma symptoms are a marker of asthma severity. Mechanisms of inflammation and cytokine production have been shown to be under circadian control and involved in nocturnal asthma. Further, sleep may play a direct role in the worsening of asthma via a variety of factors, including the supine posture, nocturnal increase in airway inflammation and bronchial responsiveness, and greater airway resistance. For youths with asthma, sleep problems are common, including prolonged sleep-onset latency, frequent night wakings, and...
daytime sleepiness, even when asthma symptoms are well controlled.\textsuperscript{22,23} Further, when nocturnal asthma symptoms improve, an improvement in sleep and daytime functioning has also been found.\textsuperscript{11} Although it is well known that asthma affects sleep, there also is evidence that sleep affects asthma expression. One study found that youths who reported lower sleep quality had more severe asthma symptoms the following day; yet asthma symptoms did not significantly predict sleep the following night.\textsuperscript{17} Given that sleep may affect asthma symptoms, sleep habits are a possible target for intervention for youths with asthma.

In general, adolescents are known to be chronically sleep deprived, with decreased total sleep time, delayed sleep onset, and increased daytime sleepiness.\textsuperscript{18} This is due to a variety of factors, including decreased parental involvement, increased school and work obligations, and the misalignment of biologic circadian rhythms and early school start times.\textsuperscript{19} However, there are a number of other factors under the control of adolescents that also may contribute to insufficient sleep, including inconsistent bedtimes and poor sleep hygiene (eg, caffeine use late in the day, technology in the bedroom). Results of recent studies have demonstrated that brief interventions are effective in improving sleep patterns and sleep hygiene in adolescents.\textsuperscript{20,21} Insomnia also impacts a significant number of adolescents, with rates that range from 7% to 36%, depending on definition used and data collection methods.\textsuperscript{22,23} Recently, cognitive-behavioral therapy for insomnia, an empirically validated treatment for insomnia and the frontline treatment for insomnia in adults,\textsuperscript{24} has also been shown to be effective for adolescents.\textsuperscript{25,26}

Based on the current literature, the purpose of this exploratory study was to examine sleep duration, sleep hygiene, and insomnia in adolescents with and without asthma, with the following 3 questions: (1) do sleep duration, sleep hygiene, and insomnia differ between adolescents with and without asthma; (2) is sleep hygiene related to sleep duration and insomnia, and does this differ between adolescents with and without severe asthma; and (3) does daytime sleepiness differ in adolescents with and without severe asthma, and, if so, is this a result of asthma or insomnia?

**METHODS**

Participants were 298 adolescents ages 12 to 17 years, (51\% boys; 48\% with asthma). Adolescents with and without asthma were recruited by using a national online research panel with approximately 3 million members (ZoomPanel; SurveyMonkey, Palo Alto, CA) who have opted-in to participate in surveys. The demographics of panel members is similar to US Census data, including race, household income, and region. Members receive points for completing each survey (worth approximately $1-$3 per survey), which can later be exchanged for prizes (eg, movies, music, gift cards). In September 2012, approximately 2600 members received an e-mail invitation to participate in the survey, with 1532 (approximately 59\%) responding to and viewing the survey (see Figure 1 for flow diagram). Quotas were established to prevent an oversampling of any age, sex, or asthma status (“Do you have asthma?”). The use of online survey panels has been shown to be reliable and valid compared with telephone and household surveys\textsuperscript{27,28} and has been used in multiple studies.\textsuperscript{29-32} This study was approved by the institutional review board at National Jewish Health.

**Measures**

**The International Study of Asthma and Allergies in Childhood Questionnaire.** This 8-item measure was developed as a core questionnaire to assess the prevalence and severity of asthma in a large international epidemiologic study.\textsuperscript{33} By following the guidelines of the International Study of Asthma and Allergies in Childhood Phase 3 Study Group,\textsuperscript{34} the International Study of Asthma and Allergies in Childhood questionnaire was used to create our groups of adolescents with and without asthma by using the question “Have you ever had asthma?” (Asthma Ever). For those with asthma, we further distinguished those with Current Wheeze (“Have you ever had wheezing or whistling in the chest at any time in the past?” and “Have you had wheezing or whistling in the chest in the past 12 months?”) and those with Severe Asthma (positive response to Current Wheeze and whether the adolescent in the past 12 months had (1) \(>4\) attacks of wheeze or (2) \(>1\) night per week sleep disturbance from wheeze, or (3) wheeze that affected speech).

**Children’s Report of Sleep Patterns.** The Children’s Report of Sleep Patterns is a 52-item self-report measure of sleep that includes modules for sleep patterns, sleep hygiene, sleep disturbances, and daytime sleepiness, and has been validated in children and adolescents with and without chronic illnesses.\textsuperscript{35-38} From this measure, we obtained sleep duration (calculated as hours from bedtime to wake time, less sleep-onset latency, and wake after sleep onset) as well as sleep hygiene and daytime sleepiness modules. The sleep hygiene indices included Caffeine Use, Stimulating Activities in the Hour Before Bed (eg, video games), Electronics Use at Sleep Onset (eg, television), Sleep Location (ie, falling asleep or waking up somewhere other than the child’s bed), and Negative Bedtime Cognitions (eg, worries about the next day that prevent sleep onset). Higher scores indicate poorer sleep hygiene and more daytime sleepiness. Categories of insufficient sleep duration (<7 hours), borderline sleep duration (7-9 hours), and optimal sleep duration (≥9 hours) were created based on US Centers for Disease Control and Prevention criteria.\textsuperscript{39}

**Insomnia Severity Index.** The Insomnia Severity Index (ISI) has 7 items that evaluate the severity of insomnia symptoms (eg, difficulties initiating and maintaining sleep) and the consequences of sleep problems and/or disruptions.\textsuperscript{40} Cutoff scores have been established to identify insomnia severity (no clinically significant insomnia [ISI score of 0-7], subthreshold clinically significant insomnia [ISI score of 8-14], clinically significant insomnia—moderate/severe [ISI score equal to or higher than 15]). Minimally important differences for the ISI have recently been identified in adult populations, with a reduction in ISI score by 6 points associated with improved health-related quality of life in 1 study\textsuperscript{41} and a reduction in ISI score by 7 points associated with moderately improved insomnia in another trial.\textsuperscript{42}

**Data analysis**

Outcome variables (sleep duration, sleep hygiene, insomnia severity, and daytime sleepiness) were examined for normality, and square root and logarithm transformations were conducted.
for non-normal variables. Preliminary analyses were conducted to examine demographic differences among the 4 groups by using 1-way ANOVA for continuous variables and the $\chi^2$ test for categorical variables.

**Question 1. Do sleep duration, sleep hygiene, and insomnia differ between adolescents with and without asthma?** One-way ANOVA was used to compare group differences for continuous data, with the Tukey honestly significant difference test used for post hoc analyses. The $\chi^2$ analysis was used to compare frequency differences for categorical variables.

**Question 2. Is sleep hygiene related to sleep duration and insomnia, and does this differ between adolescents with and without severe asthma?** The Pearson bivariate correlation was used to examine the relationship among sleep hygiene, sleep duration, and insomnia, with correlations run separately for those with and without severe asthma (severe vs no asthma, ever asthma, current wheeze). The Fisher $r$-to-$z$ transformation (transforming the correlation coefficient to a $z$ score, then comparing the $z$ scores by making use of the sample size by using formula 2.8.5 from Cohen and Cohen) was used to determine whether the correlations significantly differed between the 2 groups (with and without severe asthma).
severe asthma).44 A z score of $\geq 2.58$ is considered significant at a $P$ value of .01.

**Question 3. Does daytime sleepiness differ in adolescents with and without severe asthma, and, if so, is this a result of asthma or insomnia?** One-way ANOVA was used to examine differences in daytime sleepiness for those with and without asthma, with the Tukey honestly significant difference used for post hoc analyses. Hierarchical multiple regression was used to examine whether asthma (severe vs no asthma, ever asthma, current wheeze) or insomnia severity was more predictive of daytime sleepiness.

**RESULTS**

Complete demographic data for the 4 asthma groups are presented in Table I. No significant differences were found among the 4 International Study of Asthma and Allergies in Childhood asthma categories for any demographic variables.

**Question 1. Do sleep duration, sleep hygiene, and insomnia differ between adolescents with and without asthma?**

Sleep duration. Age was found to be significantly correlated with weekday sleep duration, thus age was controlled for in the weekday total sleep time analysis of covariance. No significant difference between asthma severity groups was found for weekday total sleep time, $F(3,293) = 0.14, P = .93$. No significant difference was found between the asthma severity groups for weekend total sleep time, $F(3,294) = 0.31, P = .82$ (see Table I for means [SE]). Although not significantly different, 44% of adolescents with Severe Asthma reported regularly obtaining insufficient sleep ($< 7$ hours) on weekdays compared with only 31% of adolescents with No Asthma, $\chi^2(6) = 4.48, P = .61$ (Figure 2).

Sleep hygiene. Significant racial differences were found for Electronics Use at Sleep Onset and Negative Bedtime Cognitions, thus race was controlled for in analyses that included these variables. Significant asthma severity group differences were found for Stimulating Activities in the Hour Before Bed, $F(3,294) = 2.78, P = .04$, Sleep Location, $F(3,294) = 3.69, P = .01$, and Negative Bedtime Cognitions, $F(3,293) = 2.81, P = .04$ (see Table I for means [SE]). Significant post hoc analyses suggest that adolescents with Severe Asthma more frequently slept somewhere other than their own bed (parent bed, sibling bed, couch) compared with both adolescents with No Asthma or Ever Asthma, and adolescents with Severe Asthma had more Negative Bedtime Cognitions that interfered with sleep onset compared with adolescents with No Asthma.

Insomnia. Because girls reported more insomnia symptoms than boys, insomnia analyses controlled for sex. Adolescents with Severe Asthma reported more severe insomnia than adolescents with No Asthma or Asthma Ever, $F(3,293) = 7.67, P < .001$, (see Table I for means [SE]). Notably, 39.9% of adolescents with Severe Asthma reported moderate-to-severe clinical insomnia, more than twice that of the other 3 asthma groups, and only 23.3% of adolescents with Severe Asthma reported no insomnia compared with 62.3% of adolescents with No Asthma, $\chi^2(6) = 27.2, P < .001$ (Figure 3).

**Question 2. Is sleep hygiene related to sleep duration and insomnia, and does this differ between adolescents with and without severe asthma?** (Table II)

Sleep hygiene and weekday sleep duration. For adolescents with Severe Asthma, weekday sleep duration was not significantly correlated with any sleep hygiene variables. For adolescents Without Severe Asthma, weekday sleep duration was significantly correlated with Stimulating Activities in the Hour Before Bed and Electronics Use at Sleep Onset, with coefficients

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**TABLE I.** Group differences for demographic and sleep variables

<table>
<thead>
<tr>
<th></th>
<th>Severe Asthma (n = 43)</th>
<th>Current Wheeze (n = 41)</th>
<th>Asthma Ever (n = 44)</th>
<th>No Asthma (n = 170)</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys, % (n)</td>
<td>46.5 (20)</td>
<td>58.5 (24)</td>
<td>45.5 (25)</td>
<td>52.2 (83)</td>
<td>.56</td>
</tr>
<tr>
<td>Race, % (n)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.74</td>
</tr>
<tr>
<td>White</td>
<td>72.1 (31)</td>
<td>78.0 (32)</td>
<td>78.2 (43)</td>
<td>83.6 (133)</td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>14.0 (6)</td>
<td>9.8 (4)</td>
<td>10.9 (6)</td>
<td>6.9 (11)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>14.0 (6)</td>
<td>12.2 (5)</td>
<td>10.9 (6)</td>
<td>9.4 (15)</td>
<td></td>
</tr>
<tr>
<td>Age, mean (SE)</td>
<td>14.7 ± 0.27</td>
<td>15.0 ± 0.30</td>
<td>14.1 ± 0.22</td>
<td>14.5 ± 0.13</td>
<td>.10</td>
</tr>
<tr>
<td>Weekday Total Sleep Time (h), mean ± SE*</td>
<td>7.7 ± 0.16</td>
<td>7.8 ± 0.16</td>
<td>7.8 ± 0.14</td>
<td>7.8 ± 0.08</td>
<td>.93</td>
</tr>
<tr>
<td>Weekend Total Sleep Time (h), mean ± SE</td>
<td>9.0 ± 0.22</td>
<td>8.8 ± 0.21</td>
<td>9.1 ± 0.18</td>
<td>9.0 ± 0.10</td>
<td>.82</td>
</tr>
<tr>
<td>Caffeine Use, mean ± SE†</td>
<td>8.9 ± 0.09</td>
<td>8.4 ± 0.08</td>
<td>8.2 ± 0.07</td>
<td>8.1 ± 0.04</td>
<td>.51</td>
</tr>
<tr>
<td>Stimulating Activities in the Hour Before Bed, mean ± SE</td>
<td>18.6 ± 0.46</td>
<td>18.9 ± 0.43</td>
<td>18.2 ± 0.38</td>
<td>17.6 ± 0.24</td>
<td>.04</td>
</tr>
<tr>
<td>Sleep Location, mean ± SE‡</td>
<td>10.1 ± 0.03</td>
<td>8.6 ± 0.02</td>
<td>8.0 ± 0.02</td>
<td>8.3 ± 0.03</td>
<td>.01</td>
</tr>
<tr>
<td>Electronics Use at Sleep Onset, mean ± SE</td>
<td>7.6 ± 0.45</td>
<td>7.4 ± 0.46</td>
<td>6.6 ± 0.40</td>
<td>6.5 ± 0.23</td>
<td>.08</td>
</tr>
<tr>
<td>Negative Bedtime Cognitions, mean ± SE†</td>
<td>3.7 ± 0.03</td>
<td>3.5 ± 0.30</td>
<td>3.3 ± 0.03</td>
<td>3.0 ± 0.02</td>
<td>.04</td>
</tr>
<tr>
<td>Insomnia Severity Index, mean ± SE*‡</td>
<td>10.6 ± 0.02</td>
<td>8.0 ± 0.04</td>
<td>7.4 ± 0.04</td>
<td>6.5 ± 0.04</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

*Estimated marginal means when controlling for race.
†Geometric means.
‡Tukey honestly significant difference post hoc significant differences between Severe Asthma and both Ever Asthma and No Asthma.
§Estimated marginal means when controlling for sex.
|
that suggested that shorter sleep duration on weekdays was associated with more activities in the hour before bed and more electronics use at bedtime. The relationship between the sleep hygiene variables and weekday sleep duration did not differ between adolescents with and without severe asthma (Table II).

**Sleep hygiene and weekend sleep duration.** For adolescents with Severe Asthma, weekend sleep duration was not significantly correlated with any sleep hygiene variables. For adolescents Without Severe Asthma, weekend sleep duration was significantly correlated with Electronics Use at Sleep Onset, with the coefficient suggesting that shorter sleep duration on weekends was associated with greater electronics use at bedtime. The relationship between the sleep hygiene variables and weekend sleep duration did not differ between adolescents with and without severe asthma (Table II).

**Sleep hygiene and insomnia.** For adolescents with Severe Asthma, Sleep Location, Electronics Use at Sleep Onset, and Negative Bedtime Cognitions were all significantly correlated with insomnia, which suggests that adolescents with Severe Asthma who sleep somewhere other than their own bed, use more electronics at bedtime, and have more negative cognitions at bedtime also report more insomnia. For adolescents Without Severe Asthma, all sleep hygiene variables were positively correlated with insomnia, which suggests that poorer sleep hygiene is associated with more insomnia in these youths. The relationship between the sleep hygiene variables and insomnia did not differ between adolescents with and without severe asthma (Table II).

**Question 3. Does daytime sleepiness differ in adolescents with and without severe asthma, and, if so, is this a result of asthma or insomnia?**

Adolescents with Severe Asthma had significantly higher mean (SD) daytime sleepiness (2.11 ± 1.5) than adolescents with No Asthma (mean ± SD, 1.54 ± 1.5), Asthma Ever (mean ± SD, 1.50 ± 1.5), and Current Wheeze (mean ± SD, 1.66 ± 1.5); F(3,294) = 8.12, P < .001. In the final regression model, both asthma severity and insomnia severity were significant predictors of daytime sleepiness (Table III). However, asthma severity only accounted for an additional 2% of the variance above insomnia severity (which accounted for 28% of the variance).

**DISCUSSION**

This exploratory study extends previous reports that many adolescents obtain insufficient sleep to adolescents with
asthma, which demonstrated that more adolescents with asthma reported insufficient sleep than adolescents without asthma. Although the impact of insufficient sleep on asthma remains to be determined, a recent study demonstrated that adolescents were able to successfully extend sleep duration with sleep hygiene education and by gradually moving their bedtime earlier. This simple intervention would also likely be beneficial for adolescents with asthma. It was notable that almost 40% of adolescents with severe asthma reported clinically significant insomnia. Not only is this more than twice as much as adolescents with mild or no asthma, it is higher than previously reported adolescent insomnia prevalence rates in the United States and around the world. Because insomnia has been shown to be effectively treated with cognitive-behavioral therapy for insomnia, it is important to screen for insomnia in adolescents with asthma.

Sleep hygiene also was found to differ between adolescents with and without asthma, which provided another area for clinical intervention. In particular, adolescents with severe asthma were found to sleep somewhere other than their own bed. Although more information is needed about why adolescents with severe asthma were not sleeping in their own beds, anecdotally, we see a number of families who like to have their child close by during an asthma exacerbation to monitor breathing and provide treatment if needed. This may lead to the development of a sleep-onset association in the youths, who then need to have a parent nearby to facilitate sleep onset and sleep maintenance. Alternatively, parents may be hesitant to have a child return to his or her own sleeping environment after an asthma exacerbation due to concerns about a recurrence.

Another area of sleep hygiene that may respond to intervention is the Negative Bedtime Cognitions that were higher in adolescents with severe asthma. This aspect of sleep hygiene inquires about whether adolescents are scared, upset, or worried when they are trying to fall asleep. Although this study does not elucidate why adolescents with more severe asthma had more Negative Bedtime Cognitions, it may be possible that this is a result of worries or fears about nocturnal asthma. However, the unintended consequence of these fears may be delayed sleep onset and shorter sleep duration. Not surprisingly, Negative Bedtime Cognitions were significantly associated with insomnia severity. One component of cognitive-behavioral therapy for insomnia focuses solely on changing negative cognitions around sleep, which could easily be applied to adolescents with severe asthma. Daytime sleepiness also was found to be greater in adolescents with Severe Asthma compared with the other 3 groups. However, in our sample it was notable that daytime sleepiness was better accounted for by insomnia severity than by asthma severity. Again, this finding speaks to the importance of screening adolescents with asthma for insomnia and referring these youths for treatment of the insomnia.

There are several methodologic limitations with this study that must be noted. First, although adolescents have been shown to be accurate reporters of their sleep, this study only included self-reported data collected via the Internet. Studies that use an objective measure of sleep (eg, actigraphy) are needed. Second, the use of an Internet survey without clear tracking of those who responded and those who did not may have introduced sample bias. However, the demographics of our sample were similar to other reports of youths with asthma, including race and the frequency of asthma severity. Third, we only collected data at 1 point by asking about typical sleep in the past 2 weeks.

### Table II. Pearson bivariate correlations among sleep hygiene, sleep duration, and insomnia for adolescents with and without severe asthma

<table>
<thead>
<tr>
<th>Sleep Duration</th>
<th>Severe Asthma (n = 43)</th>
<th>No Asthma (n = 255)</th>
<th>Z score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caffeine Use</td>
<td>-0.002</td>
<td>-0.002</td>
<td>0</td>
</tr>
<tr>
<td>Stimulating Activities in the Hour Before Bed</td>
<td>0.185</td>
<td>-0.202</td>
<td>2.30</td>
</tr>
<tr>
<td>Sleep Location</td>
<td>0.096</td>
<td>-0.077</td>
<td>1.02</td>
</tr>
<tr>
<td>Electronics Use at Sleep Onset</td>
<td>-0.135</td>
<td>-0.269</td>
<td>0.82</td>
</tr>
<tr>
<td>Negative Bedtime Cognitions</td>
<td>0.007</td>
<td>-0.069</td>
<td>0.45</td>
</tr>
</tbody>
</table>

Table III. Hierarchical multiple regression predicting daytime sleepiness

<table>
<thead>
<tr>
<th>Daytime Sleepiness</th>
<th>B</th>
<th>SE</th>
<th>β</th>
<th>ΔR²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insomnia Severity</td>
<td>0.31</td>
<td>±0.03</td>
<td>0.49†</td>
<td>0.280</td>
</tr>
<tr>
<td>Asthma Severity</td>
<td>0.07</td>
<td>±0.03</td>
<td>0.15‡</td>
<td>0.021</td>
</tr>
</tbody>
</table>

*Significant correlation (P ≤ .006) between sleep hygiene variable and sleep duration or insomnia.

*B, SE, and β values for final model, with Insomnia Severity entered as step 1 and Asthma Severity as step 2.

†P ≤ .001.

‡P ≤ .01.
Longitudinal studies are needed because asthma and sleep patterns may change throughout the school year. Finally, the cross-sectional design precludes conclusions on the directional relationship among sleep duration, sleep hygiene, insomnia, and severe asthma in adolescents, which further supports the need for longitudinal research in this area.

Despite these limitations, the results of this study are important for clinical practice. Sleep quality has received limited attention in terms of asthma management, and the discussion of nocturnal asthma has received significantly less attention in the recent past. As a significant number of adolescents with severe asthma in this study reported insufficient sleep, poor sleep hygiene, and insomnia, it may be time for renewed attention to these issues. In particular, a careful evaluation of sleep issues by clinicians is needed, especially for those patients with severe asthma. Further research also is needed to help understand the mechanisms and additional outcomes that may be related to deficient sleep and insomnia in adolescents with asthma.

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