

# Nocturnal Awakenings and Asthma Control in Urban School-Age Children

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A Part of Sage

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## Abstract

This study evaluated the extent to which the sleep is disrupted by nighttime awakenings in urban children with and without asthma and examined racial/ethnic differences in sleep outcomes. Three hundred and seventy-nine urban children aged 7 to 9 years with ( $n = 250$ ) and without ( $n = 129$ ) asthma were included. Participants were 45% Latino, 34% black, and 21% non-Latino white (NLW). Nighttime awakenings were assessed via actigraphy. Asthma status was assessed by a clinician and via self-report. Children with asthma had significantly more awakenings than those without. Latino children with asthma had more and longer awakenings compared to Latino children without asthma; these effects were not observed among black or NLW participants. Poor asthma control was associated with more awakenings. Urban children face higher risks for poor sleep and asthma outcomes. Multicomponent interventions addressing asthma management and culturally tailored sleep hygiene strategies are necessary to improve asthma and sleep outcomes in this highly burdened population.

## Keywords

asthma, sleep awakenings, health disparities, urban children, nocturnal asthma

## Introduction

Shorter and disrupted sleep has been associated with reduced academic performance, mental health challenges, and impaired quality of life.<sup>1–4</sup> Children from urban and minoritized backgrounds are at higher risk of poorer sleep outcomes compared to non-Hispanic white children.<sup>5,6</sup> Asthma prevalence and morbidity disproportionately affect urban minority children compared to their non-Latino white peers,<sup>7,8</sup> and this group is more vulnerable to shorter and poorer quality sleep.<sup>6,9,10</sup> Children from urban communities are also exposed to poverty, acculturative stress, environmental allergens/irritants, and language barriers that can impact asthma morbidity<sup>8,11–13</sup> and sleep.<sup>6,14</sup>

Our prior work demonstrates that in urban children, especially those with heightened asthma morbidity, nocturnal asthma symptoms disrupt sleep and contribute to frequent night awakenings and diminished sleep quality.<sup>6,15,16</sup> Nighttime awakenings are a critical indicator of children's asthma control.<sup>17</sup> Further exploration of the relationship between night awakenings and asthma control in children is needed to fill a key research gap and inform bedtime asthma management strategies for this highly burdened group.

In this study, we assessed through objective methods the extent to which nighttime awakenings disrupt sleep in urban children with and without asthma, and whether the differences in the number of awakenings between these groups vary based on ethnicity. For children with asthma, we examined whether the frequency and duration of nighttime awakenings and average length of time

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between awakenings differed based on asthma control status. Based on prior research, we hypothesized that children with asthma would have more frequent and longer nighttime awakenings compared to healthy peers. Our prior work found a significant interaction between race/ethnicity, asthma status, and sleep; Latinos with asthma had a shorter sleep duration compared to non-Latino whites (NLWs).<sup>6</sup> Given this, we hypothesized that Latino and black participants would have more frequent and longer awakenings compared to NLW participants, and this would correspond to poorly controlled asthma.

## Methods

All data were obtained from the larger study, Project NAPS: Nocturnal Asthma and Performance in School (R01 HD057220, DK-M, PI). This Institutional Review Board (IRB)-approved observational study assessed the co-occurrence of asthma, sleep quality, and academic functioning in children (7-9 years) with (N = 249) and without asthma (N = 130) from an urban area of the northeast United States between 2010 and 2014. Participants were recruited from 4 of the largest urban school districts in a Northeastern city, outpatient pediatric ambulatory clinics, and a hospital-based asthma education program. "Consent to Contact" forms were distributed in these locations; forms signed and returned by the caregiver allowed study staff to call the family to describe the study and determine the child's eligibility and the family's interest in participating. Detailed information about the sample and procedures was previously published.<sup>9,18</sup>

Clinical research assistants contacted caregivers of children with and without asthma to assess eligibility and interest in the study. Eligibility requirements included child age between 7 and 9 years old, black, Latino, or non-Latino white ethnic/racial background, and school attendance in 1 of 4 targeted urban cities. The subsample of children with asthma had the following additional eligibility requirements: persistent, physician-diagnosed asthma or breathing problems during the previous 12 months defined by 1 or more of the following: (a) the child was prescribed and adherent to a controller asthma medication, (b) the caregiver endorsed repeated daytime/nighttime asthma symptoms, limitations on the child's activity due to asthma, and/or repeated rescue inhaler use, and/or (c) the child was administered an oral steroid burst for asthma 2 or more times in the past 12 months. Children in the "no-asthma" control group had no asthma, allergies, or allergic skin conditions. Children who were prescribed stimulant medication for attention-deficit/hyperactivity disorder (ADHD), had other pulmonary diseases or chronic health conditions, and/or had a physician-diagnosed

sleep disorder or medical condition(s) that may confound study results were excluded. Each enrollee's study participation occurred throughout 1 academic year. Data presented herein were collected during the fall and early winter of a participant's enrollment year. During the initial study visit, caregivers and children completed the informed consent and assent process. Caregivers of children in the clinical group provided information about their child's prescribed asthma and allergy medications.<sup>19</sup> Caregivers in both groups completed a demographics questionnaire and other study assessments.<sup>18,20</sup>

The second research visit occurred approximately 2 weeks later. For asthma group participants, this visit took place at the hospital-based asthma/allergy clinic, where the study clinician evaluated children's allergy and asthma status. No-asthma controls completed a second home visit where information about children's sleep, medication use and adherence, and asthma symptoms was collected. All participants then completed a 4-week home-monitoring period involving daily objective monitoring of sleep and (for the asthma group) asthma status.<sup>20</sup> Participants' sleep was monitored via an actigraphy device worn on the child's wrist (Actiwatch 2; Philips Respironics, Pittsburgh, Pennsylvania). To monitor asthma status, Asthma group participants used an AM2 handheld spirometer (ERT, Yorba Linda, California). Procedures for training participants on the proper morning and evening use of both devices, and procedures for reviewing values are detailed elsewhere.<sup>18,21</sup> The highest FEV1 value at each time point was retained for analysis. Families also completed a diary every morning and evening regarding the child's daily sleep behaviors (eg, bedtime, lights-out time, whether participant awoke during night), and, for children with asthma, information about the child's asthma symptoms. Participants in the asthma group completed an Asthma Control Test at the end of the monitoring period. Trained RAs checked in with participant families frequently during monitoring to enhance protocol adherence and troubleshoot technical problems or other challenges.

Families received compensation for all research visits and, when needed, transportation to the clinic visit. All study materials were available in English and Spanish, and families received study materials in their preferred language. Measures were translated from English to Spanish using a standardized procedure.<sup>22</sup>

## Measures

### *Demographic and Descriptive Information*

During enrollment, caregivers completed a self-report questionnaire concerning their family's demographic information, including ethnic origins, nationality, and self-identified racial groups. (Table 1)

**Table 1.** Participant Characteristics: Full Sample and by Ethnicity/Racial Group.

	Study population	Latino	Black	NLW	Ethnic/racial group differences <sup>a</sup>	Effect sizes <sup>b</sup>
N (%)	379	171 (45%)	129 (34%)	79 (21%)	—	—
Age, M (SD)	8.3 (0.86)	8.3 (0.9)	8.3 (0.8)	8.2 (0.8)	0.32	.08
Sex, Male (n, %)	201 (53%)	93 (54%)	73 (57%)	35 (44%)	0.20	.09
At/below poverty threshold (%)	235 (66%)	130 (80%)	79 (65%)	36 (37%)	<.001	.34
<b>Asthma clinical characteristics</b>						
Asthma Control Score	20.60 (4.09)	20.76 (3.52)	19.86 (4.63)	21.57 (4.16)	0.06	.15
Asthma poorly controlled (n,%)	89 (36%)	36 (31%)	40 (46%)	13 (28%)	0.05	.15
Asthma well-controlled (n,%)	160 (42%)	91 (53%)	43 (33%)	26 (33%)	.01	.19
No asthma (n,%)	130 (34%)	44 (26%)	46 (36%)	40 (51%)	.01	.19

Abbreviations: NLW, non-Latino white.

<sup>a</sup>P-value

<sup>b</sup>Cohen's d value.

### Asthma Diagnosis and Control Status

**Physician query.** Caregivers provided the names and contact information of their child's asthma medical providers and signed an authorization form permitting research staff to contact the physicians. Providers were asked to complete a "physician query," asking for the participants' relevant medical history. Physicians of the children in the clinical group also confirmed the participant's asthma diagnosis, triggers, and current asthma plan. This information was used to confirm group assignment of clinical and control participants.

**Asthma control.** During the clinic visit, the study clinician confirmed asthma status and determined asthma severity using established asthma clinical guidelines (NHLBI EPR-3).<sup>23</sup>

At the end of the sleep monitoring period, parents and children in the clinical group completed the Childhood Asthma Control Test (C-ACT),<sup>24</sup> a well-validated questionnaire of asthma control for this age group. Standardized procedures were used to classify clinical group participants as having good or poor asthma control based on their C-ACT score.<sup>25</sup> The C-ACT consists of 7 items summed for a total score (0-27). A score of 20 or above was classified as good asthma control. A score of 19 or below was classified as poor asthma control.<sup>25</sup> The daily diary for asthma group participants also included a twice-daily self-report of the child's asthma symptoms to assess severity.

### Sleep Outcomes

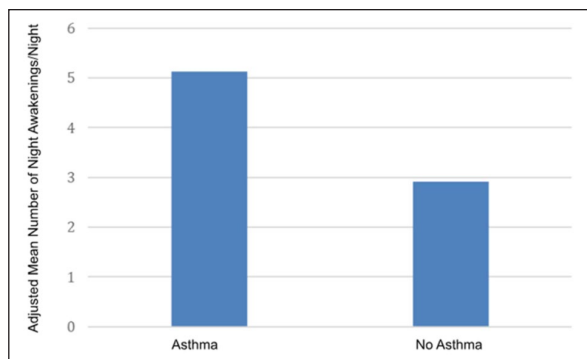
Researchers evaluated nighttime sleep outcomes using actigraphy data from the 4-week home-monitoring period. Children wore the actigraph on their nondominant hand at all times except when bathing and swimming during the

monitoring period. Child participants were instructed to create Actiwatch event markers by pushing a button at "lights out" at night and "lights on" in the morning. Research assistants scored participants' sleep data using established scoring rules.<sup>20,26</sup> Each 1-minute epoch during monitoring was categorized as sleep or wakefulness. Nighttime sleep outcomes included the number of nighttime awakenings (wake length during the sleep period of at least 3 minutes in length), average time between, and average length of each awakening.

Data were excluded from analysis for the following reasons: (a) the Actiwatch was off wrist for all or a large part of the sleep period, (b) a diary report for the time period was not available, (c) the caregiver reported an illness (other than asthma) in the diary that could have affected sleep, and/or (d) the majority of the sleep period occurred while the child was in external motion (eg, sleeping in a car). Actigraphy data for 379 children were available, with an average of 18 scorable nights per participant.

**Analysis plan.** Socio-demographic data were summarized in the aggregate sample and compared between children with and without asthma using *t*-tests (for continuous variables), chi-squared tests (for categorical variables), and non-parametric tests as appropriate. Mean daily awakenings were summarized in the full sample, in children with vs without asthma, and in children with poor vs well-controlled asthma.

A series of longitudinal mixed-effects models were conducted to assess differences in sleep awakening parameters (number and length of awakenings and length in between awakenings) between asthmatic and healthy children. Models included time effects (night of monitoring) and random intercept and slope terms (to account for individual trajectories of each child). A similar modeling strategy was used to compare the sleep



**Figure 1.** Differences in mean number of night awakenings between children with asthma and children without asthma.

outcomes (awakenings) of children with well-controlled and poorly controlled asthma.

Finally, longitudinal mixed-effects models were used to assess whether race/ethnicity moderated differences in sleep outcomes between the asthma and control groups. Models included the main effects of race/ethnicity (effect-coded to allow for all pairwise comparisons), no-asthma control vs asthma, time, all 2- and 3-way interactions, and a subject-specific intercept to adjust for repeated sleep measures within-child.

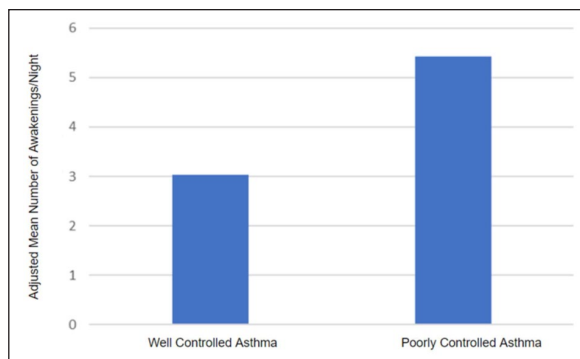
All analyses were run on the intent-to-treat sample, with all enrolled children included in the analyses. Models used a likelihood-based approach to estimation and thus made use of all available data without directly imputing missing outcomes. The significance level was set at 5% a priori, and models were run in SAS 9.3.

## Results

A full description of the study sample is presented in Table 1. Participants ( $n = 379$ ) had a mean age of 8.3 years ( $SD = 0.86$ ), and 66% had asthma (64.4% well-controlled vs 35.6% poorly controlled asthma). In the aggregate sample, 45% identified as Latino, 34% black, and 21% non-Latino white.

Overall, children awoke 4.44 times during the night on average ( $SD = 0.42$ ), with an adjusted average of 5.1 awakenings in the asthma group ( $SD = 0.34$ ) compared to 2.92 awakenings ( $SD = 0.39$ ) among children without asthma (controls). Models of differences in nighttime awakenings between children with asthma and controls showed significantly more awakenings on average over time for children with asthma compared to controls ( $b = 2.21$ ,  $SE = .06$ ,  $P = .05$ , Figure 1). There were no significant group-based differences in average length of awakening or bouts between awakenings ( $P = .54$  and  $P = .62$ , respectively).

Within the sample of children with asthma, children with poorly controlled asthma had a greater number of



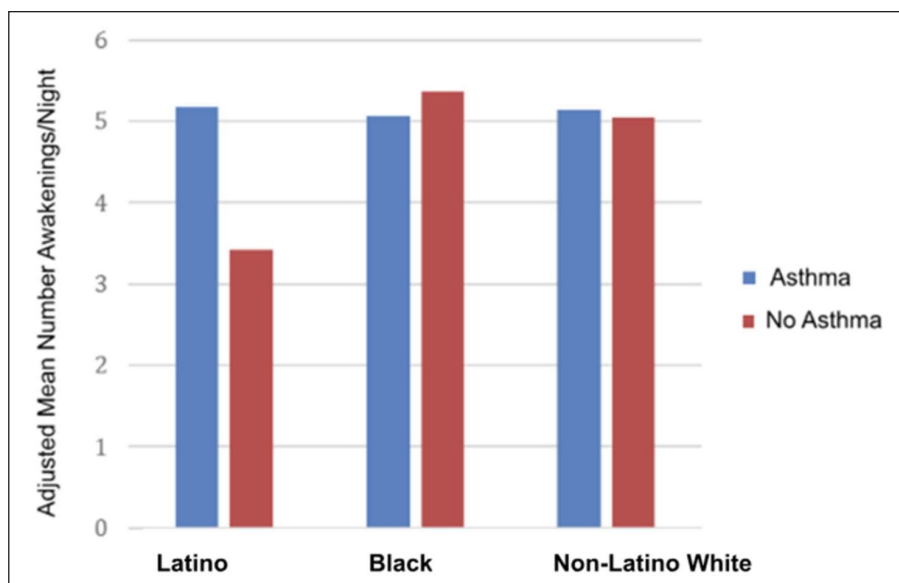
**Figure 2.** Differences in mean number of night awakenings between children with poorly controlled vs well-controlled asthma adjusted for time and random intercept/slope terms.

awakenings ( $b = 2.40$ ,  $SE = 1.07$ ,  $P = .03$ , Figure 2) compared to children with well-controlled asthma in adjusted models. Furthermore, there was a trend suggesting those with poorly controlled asthma had, on average, a longer period of awakening ( $b = 1.15$ ,  $SE = .56$ ,  $P = .09$ ).

The next set of analyses examined whether race/ethnicity moderated the association between health status (asthma vs control) and nighttime awakenings in our sample of children. Results indicate a significant 3-way interaction ( $P = .04$ ). Specifically, among Latino children, there was a significant difference in the mean number of nighttime awakenings between children with asthma vs control ( $b = 1.66$ ,  $SE = .33$ ,  $P = .01$ , Figure 3), with those with asthma having a higher number of awakenings. There was no significant effect of health status on night awakenings for black or NLW children ( $P$ 's  $> .05$ ). A similar significant interaction between race/ethnicity and health status was identified ( $P = .04$ ). Specifically, among Latino children, there was a significant association between health status and average length of awakenings ( $b = -3.68$ ,  $SE = .18$ ,  $P = .01$ ), such that children with asthma were awake longer than controls. These effects were not observed among black or NLWs ( $P$ 's  $> .05$ ). Table 2 summarizes the sleep parameters by race/ethnicity and asthma status.

## Discussion

This study examined the extent to which the nighttime sleep period is disrupted by nighttime awakenings in urban children with asthma compared to those without asthma. We objectively examined the frequency and duration of night awakenings and the time between awakenings. Sleep is critical for optimal health, social and emotional development, and overall functioning in childhood, and disrupted sleep has a marked, negative impact on children's daily functioning.<sup>2-4</sup> Understanding



**Figure 3.** Differences in mean number of night awakenings between children with asthma and children without asthma by ethnic group adjusted for time and random effects.

**Table 2.** Sleep Parameters by Race/Ethnicity and Asthma Group.

	Latino	Black	NLW	Ethnic/racial group differences*	Effect sizes <sup>a</sup>
N (%)	171 (45%)	129 (34%)	79 (21%)	–	–
Nighttime awakenings	4.98 (2.87)	5.17 (3.34)	5.10 (4.06)	.03	.88
Length of awakenings	70.68 (20.22)	75.59 (21.05)	73.83 (19.51)	.15	.11
Bouts between awakenings	2.86 (2.59)	2.76 (2.29)	3.02 (2.83)	.04	.76
	Well-controlled	Poorly controlled	No asthma	Group differences*	Effect sizes <sup>a</sup>
N (%)	91 (53%)	36 (31%)	44 (26%)		
Nighttime awakenings	4.94 (2.74)	5.43 (3.23)	4.70 (1.92)	.04	.18
Length of awakenings	72.52 (18.66)	80.97 (25.20)	68.54 (16.80)	.01	.19
Bouts between awakenings	2.53 (2.10)	2.65 (2.42)	3.30 (2.93)	.02	.13

<sup>a</sup>Cohen's d value.

\*P-value.

which children are more vulnerable to awakenings during the night and how sleep may be disrupted in specific groups is valuable information that can be used to guide future asthma and sleep interventions for those most burdened.

In our current study, we found that children with asthma had a higher number of awakenings during the sleep period, on average, compared to their peers without asthma. However, this association was only marginally significant ( $p = .05$ ) and should be interpreted as exploratory. In children with asthma, those with poorly controlled asthma had more night awakenings than children with well-controlled asthma. Children may have been

more likely to wake up due to asthma symptoms or other factors related to urban status or the sleep environment. Environmental irritants such as air pollution, allergens, noise, and chemical pollutants can trigger respiratory symptoms, increase airway inflammation, and directly disturb the sleep-wake cycle, leading to more frequent awakenings, reduced sleep efficiency, and increased risk of sleep disorders.<sup>2</sup> The cause of awakenings should be analyzed in future research and used to inform tailored support provided to those more vulnerable to poor asthma control and sleep disruption.

In this sample, ethnic/racial subgroup and health status analyses showed that Latino children with asthma

compared to all other sub-groups of children were more likely to experience awakenings during the night, and these awakenings tended to be longer, on average, in this group. This might be due to additional cultural stressors<sup>10</sup> and frequency and duration of napping during the daytime.<sup>27</sup> More research is required to assess specific factors related to children's asthma management process, sleep behaviors and the sleep environment, and other sociocultural factors that may contribute to increased night awakenings in children with asthma.

There are several limitations of the study that should be noted. First, these data were collected between 2010 and 2014; it is important to replicate this study with a larger sample to establish generalizability of the reported findings in the current sociodemographic context. Second, we did not assess sociocultural factors or environmental exposures known to impact sleep hygiene behaviors, the sleep environment, and/or asthma control, which may have contributed to awakenings and should be assessed in future work. In this study, we did not assess objective measures of environmental irritants that can also impact asthma control and sleep integrity. Our future work will focus on the interaction of sleep factors and asthma triggers in the sleep environment in urban children to better understand the impact of asthma and the sleep environment on sleep health. The third limitation of this study is the restricted generalizability of the findings, as the participant sample was limited to a narrow age range and drawn exclusively from a single urban location. In addition, the absence of a non-urban comparison group further constrains the applicability of the results to broader populations. Finally, our study was also limited by fall and winter assessments and thus cannot be generalized to other times of the year.

This study provides new, objective evidence that urban children with asthma—particularly those with poorly controlled asthma—experience significantly more frequent nighttime awakenings compared to their healthy peers. Notably, Latino children with asthma were found to be especially vulnerable, exhibiting both a higher frequency and longer duration of awakenings than other ethnic groups. Proper assessment of nocturnal asthma and discussing the impact of asthma on sleep should be highlighted during clinical visits. The clinical question “how often do you wake up at night because of your asthma” remains an important question to ask children and their families during clinic visits and is supported by the objective findings in this study. Environmental irritants such as air pollution, allergens, noise, and chemical pollutants are increasingly recognized as important disruptors of sleep integrity in urban children. Multicomponent interventions addressing

asthma management strategies prior to bedtime and during sleep (eg, using rescue medication prior to bed if needed, keeping this medication in proximity if needed) as well as culturally tailored sleep hygiene strategies are necessary to improve both asthma and sleep outcomes in this high-burdened population.

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### Author Contributions

MHA and DKM contributed to the study conception and design. SJK, SD, CAE and DKM performed material preparation, data collection and analysis. MHA and DKM wrote the first draft of the manuscript. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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### Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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