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The relationship between teen-reported nocturnal asthma symptoms and daily functioning

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ABSTRACT

Objective: This study aims to identify associations between nocturnal asthma awakenings and functional health outcomes in a cohort of teenagers with asthma.

Methods: We analyzed baseline data from teenagers enrolled in SB-ACT, an NIH-funded RCT. During an at-home baseline survey, teenagers with asthma answered questions about demographics, recent asthma symptoms, and functional health outcomes. We conducted regression analyses to explore the relationship between persistent nocturnal asthma symptoms (≥ 2 nights of nocturnal asthma awakenings in the past 14 days) and functional health measures.

Results: Of the 430 teens enrolled (Participation rate = 79%, Mean Age = 13.4), 30% reported persistent nocturnal asthma symptoms. Compared to teens with intermittent nocturnal asthma symptoms, teens with persistent nocturnal asthma symptoms were more likely to report physical limitation during strenuous activities (OR = 1.9, 1.3–3.0), moderate activities (OR = 1.9, 1.2–3.1), and school gym (OR = 2.4, 1.5–3.8). They were also more likely to report depressive symptoms (OR = 2.3, 1.5–3.6), more asthma-related school absenteeism in the past 14 days (0.81 vs 0.12, $p < 0.01$) and poorer quality of life (4.6 vs 5.9, $p < 0.01$). These findings remained significant when controlling for daytime asthma symptoms, weight status, race, ethnicity, gender, age, and smoke exposure.

Conclusions: In this cross-sectional study, persistent nighttime asthma symptoms were associated with poor functional health outcomes among teens, independent of day-time symptoms. Identifying nighttime symptoms and improving asthma control at night may positively impact daily functioning for these teens.

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Introduction

Asthma is one of the most common chronic childhood conditions (1), affecting about 1 in 12 children in the United States (2). Asthma morbidity and mortality disproportionately affects African American children and children living below the poverty threshold (2). The consequences of having uncontrolled asthma include not only more emergency room visits and hospitalizations (2), but also physical activity limitations (3,4), depression (5), asthma-related school absences (6,7), and poorer quality of life (4).

Many children with asthma experience worsening of symptoms at night, characterized by wheezing and shortness of breath that contribute to nighttime awakenings and disrupted sleep (6). About 1/3 of children with mild-moderate asthma experience nighttime awakenings from asthma (8) and 1/2 of children with

severe asthma in urban areas have at least 1 night of inadequate sleep per week (9). These frequent sleep disruptions may adversely affect other aspects of daily life (9).

Insufficient sleep can contribute to impaired cognitive functioning, poor emotional regulation, and mood changes among adolescents (6,10). Parent-reported sleep disruptions due to asthma have been associated with increased school absences, worsened mood, and decreased school performance in children (6). Lost sleep due to asthma among younger children (6–13 years) has also been related to an increase in asthma-related physical activity limitations (11). However, few studies have examined whether nocturnal asthma symptoms are similarly associated with daily functioning in the teenage population.

Focusing on teenagers and teen-reported outcomes is important as adolescence is a critical developmental

time period characterized by increased independence from guardians, increased responsibility for health and asthma management, and identity building at school. Understanding how teenagers perceive and report their nocturnal asthma symptoms and possible effects during the daytime is critical to their asthma care and well-being.

This study aims to determine the prevalence of persistent nocturnal asthma symptoms in a cohort of teenagers with asthma and to examine whether teen-reported persistent nocturnal asthma is associated with functional health outcomes. We hypothesized that persistent nocturnal asthma symptoms would be associated with poorer functional health outcomes like physical activity limitations, depressive symptoms, school absences, and poorer quality of life.

Methods

Subjects

We analyzed baseline data from SB-ACT, an NIH-funded RCT conducted from 2014 to 2018 in Rochester, NY. Full details of participant eligibility, enrollment, and data collection can be found in the original paper (12).

Briefly, our research team called caregivers of teenagers enrolled in the Rochester city School District with “asthma” or “breathing difficulties” listed on their school medical alert forms and screened for eligibility. Teenagers (12–16 years) were eligible if they had physician-diagnosed asthma and persistent or poorly controlled asthma, per NHLBI asthma criteria. Exclusion criteria included intermittent asthma symptoms, not English speaking, and having significant comorbidities like cystic fibrosis or congenital heart disease that could confound asthma symptoms. If eligible, the research team conducted a home visit to enroll the teenager in the study.

Measures

During the baseline home visit, teenagers completed a survey with the research assistant, which included questions about demographics, recent asthma symptoms, and functional health outcomes. For demographics, the teenagers answered questions about age, sex, race, and ethnicity. Weight and height measurements were collected using a portable scale and stadiometer; these measurements were used to calculate baseline BMI values. To measure smoke exposure, cotinine levels were assessed from a saliva sample.

Teens answered several questions about their asthma. To assess the frequency of nocturnal symptoms, we asked, “In the past 14 days, how many nights did you wake up at night because of asthma symptoms like wheezing, shortness of breath, or chest tightness?” We defined persistent nocturnal asthma as ≥ 2 nights of nocturnal asthma awakenings in the past 14 days, and intermittent nocturnal asthma as < 2 nights of nocturnal asthma awakenings in the past 14 days. This threshold was chosen for two reasons. Asking about symptoms in the past 2 weeks versus the past month improves recall (13). Additionally, NHLBI criteria classify children with asthma who have 3 and 4 nights of nocturnal asthma awakenings in the past month as “persistent.” Thus, for consistency we classified a teen with “ ≥ 2 nights of nocturnal asthma awakenings per 2 weeks” as having persistent nocturnal asthma. We asked a similar question about the frequency of daytime symptoms.

The survey included many questions related to activities of daily living. Teens reported how much their asthma limited physical activity during strenuous activities, moderate activities, mild activities, and school gym in the past 2 weeks. Teens reported physical activity limitations on a 5-point Likert scale. Teens who responded “3. Limited some,” “4. Very Limited,” or “5. Totally limited” were categorized as reporting physical activity limitations in statistical analyses. We assessed teen depression symptoms using the Center for Epidemiological Studies-Depression (CES-D) scale, a 20-item, 4-point Likert scale that assesses depressive symptoms in the prior week (14). Only 1 item in the instrument asks a sleep-related question. Using the CES-D cutoff score as a guideline, teens with sum score ≥ 16 on the CES-D scale were categorized as having reported depressive symptoms in statistical analyses.

Additionally, the teens reported the number of asthma-related missed school days in the past two weeks. Finally, teens completed the Pediatric Asthma Quality of Life Questionnaire (PAQLQ), a 23-item, 7-point Likert scale survey that assess asthma-related quality of life (QOL) over the past week. The survey includes three QOL subscales: Activity Limitations ($n=5$), Emotional ($n=8$), and Symptoms ($n=10$). The Likert scale ranges from 1 to 7 with higher scores indicating better QOL. We calculated the mean scores of the overall QOL and each subscale (15).

Statistical analysis

Using SPSS software version 27, we conducted bivariate analyses (Chi-Square, non-parametric T-tests) to explore the relationship between persistent nocturnal

asthma symptoms and functional health measures, including physical activity limitation, depressive symptoms, quality of life, and school absenteeism. Controlling for daytime asthma symptoms, weight status, race, ethnicity, gender, age, and smoke exposure, we also conducted multivariate logistic and linear regression analysis to explore the independent relationship of persistent nocturnal asthma symptoms and functional health measures. A p value of <0.05 was considered statistically significant.

Results

Baseline data were analyzed from the 430 teenagers enrolled in the SB-ACT study (response rate = 79%; Table 1). The mean age of the participants was 13.4 years, and more than half were male, African American, overweight or obese, and reporting severe persistent asthma symptoms at baseline. Most teens (84%) had public health insurance.

In this cohort of teenagers with a history of persistent moderate-severe asthma or poorly controlled asthma per parent report, more than $\frac{1}{4}$ (30%, $n=127$) of teens reported persistent nocturnal asthma symptoms (i.e. greater than or equal to 2 nights of asthma-related nighttime awakenings in the prior 14 days). Almost $\frac{1}{2}$ of teens (41%, $n=178$) reported at least one night of asthma-related nighttime awakenings in the prior 14 days. Females and those with severe persistent asthma were more likely to report persistent nocturnal asthma symptoms (Table 1).

Compared to teens with intermittent nocturnal asthma symptoms, teens with persistent nocturnal asthma were more likely to report activity limitations in the past 14 days during strenuous activities (58% vs 41%; aOR = 1.9, 1.3–3.0) moderate activities (32% vs 19%; aOR = 1.9, 1.2–3.1), and school gym (36% vs 19%; aOR = 2.4, 1.5–3.8). There was no significant difference in feeling limited during mild activities between the two groups (13% vs 8%; aOR = 1.7, 0.59–2.57). These findings remained significant when

controlling for daytime asthma symptoms, race, ethnicity, gender, age, weight status, and smoke exposure (Figure 1). In the multivariate logistical regression, female sex was significantly associated with limitations during school gym ($p<0.01$), mild (<0.01), moderate ($p=0.038$), and strenuous activities ($p=0.045$). Younger teens were more likely to report feeling limited in strenuous activities ($p=0.02$), and frequency of daytime symptoms was positively associated with limitations in strenuous activities only ($p=0.004$).

Teens with persistent nocturnal symptoms were also more likely to report depressive symptoms (41% vs. 23%, aOR = 2.3, 1.5–3.6; Figure 1), more asthma-related school absenteeism in the past 14 days (0.81 vs 0.12, $p<0.01$; Table 2, Figure 2), and poorer asthma-related quality of life (4.6 vs 5.9, $p<0.01$; Table 2, Figure 3) compared to teens with mild or no nocturnal symptoms. All three subscales for QOL were also significant: Activity Limitations (4.5 vs 5.6, $p<0.01$), Emotional (5.0 vs 6.1, $p<0.01$), and Symptoms (4.4 vs 5.8, $p<0.01$). These findings remained significant when controlling for daytime asthma symptoms, weight status, race, ethnicity, gender, age, and smoke exposure (Table 2, Figure 3). Notably, in regression analyses, increased frequency of daytime symptoms was also associated with more depressive symptoms ($p=0.004$), school absences ($p<0.001$), poorer overall QOL ($p<0.001$), poorer activity QOL ($p<0.001$), poorer emotional QOL ($p<0.001$), and poorer symptom QOL ($p<0.001$).

Discussion

Nocturnal asthma symptoms are a common occurrence amongst children and adolescents with persistent asthma and can cause nighttime awakenings that disrupt sleep (6). In our cohort of 430 urban teenagers with a history of severe or uncontrolled asthma, 30% reported experiencing ≥ 2 asthma related nighttime awakenings in the past 2 weeks (persistent nocturnal symptoms) and 41% reported at least 1

Table 1. Demographic information of study population.

	N=430	Intermittent nocturnal symptoms N=303	Persistent nocturnal symptoms N=127	p-value
Mean Age in Years	13.4 (1.2)	13.4 (1.2)	13.5 (1.3)	0.94
% Male	240 (56%)	180 (59%)	60 (47%)	0.02
% African American	239 (56%)	173 (57%)	66 (52%)	0.33
% Hispanic	139 (32%)	95 (31%)	44 (35%)	0.51
% Medicaid Insurance	363 (84%)	254 (84%)	109 (86%)	0.65
% Overweight or Obese	246 (57%)	171 (57%)	75 (59%)	0.64
% Severe persistent Asthma	246 (58%)	143 (47%)	103 (81%)	<0.001
Mean Days of Daytime asthma symptoms in past 14 days	3.9 (4.1)	3.2 (3.8)	5.7 (4.4)	<0.001
Mean Salivary Cotinine in ng/ml (SD)	9.4 (39.5)	7.3 (28.1)	14.1 (58.0)	0.10

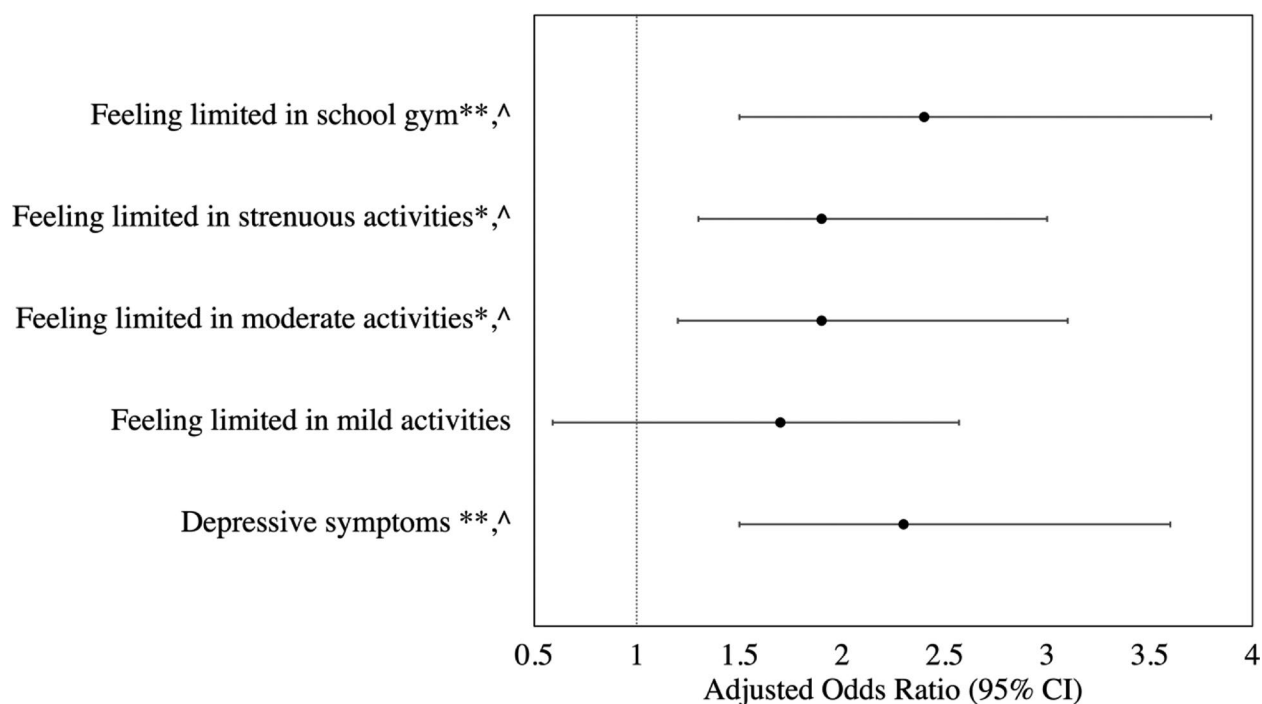


Figure 1. Forest plot of persistent nocturnal asthma symptoms and functional health outcomes in teenagers.

Table 2. *Regression models include: daytime asthma symptoms, weight status, race, ethnicity, gender, age, and smoke exposure.

	Intermittent Nocturnal Asthma	Persistent Nocturnal Asthma	β	95%
School Absences ^{**} , ^{^^}	0.1 ± 0.5	0.8 ± 1.5	0.58	(0.4, 0.8)
Quality of life ^{**} , ^{^^}	5.8 ± .9	4.6 ± 1.4	-0.92	(-1.1, -0.7)
Quality of Life Activity ^{**} , ^{^^}	5.6 ± 1.1	4.5 ± 1.5	-0.76	(-1.0, -0.5)
Quality of Life Emotional ^{**} , ^{^^}	6.1 ± 1.1	5.0 ± 1.6	-0.79	(-1.1, -0.5)
Quality of Life Symptoms ^{**} , ^{^^}	5.8 ± 1.0	4.4 ± 1.4	-1.10	(-1.3, -0.9)

Bivariate p values: * $P < 0.05$, ** $P < 0.001$.

Multivariate p values: [^] $P < 0.05$, ^{^^} $P < 0.001$.

asthma awakening in the same time period. Previous studies have estimated that between 30%-94% of children with asthma experience nocturnal symptoms (8,9,16). This wide range likely reflects differences between studies with respect to patient demographics, asthma severity, patient age, and differences in defining nocturnal asthma. Additionally, most estimates in the literature are derived from caregiver report and focus on younger children. Although our estimate of persistent nocturnal symptoms is on the lower end of this range, it was reported by teenagers who are directly experiencing the nightly awakenings. This study helps establish that persistent nocturnal asthma symptoms are commonly described by teenagers with uncontrolled asthma.

Average number of school absences in past 2 weeks ^{**},^{^^}

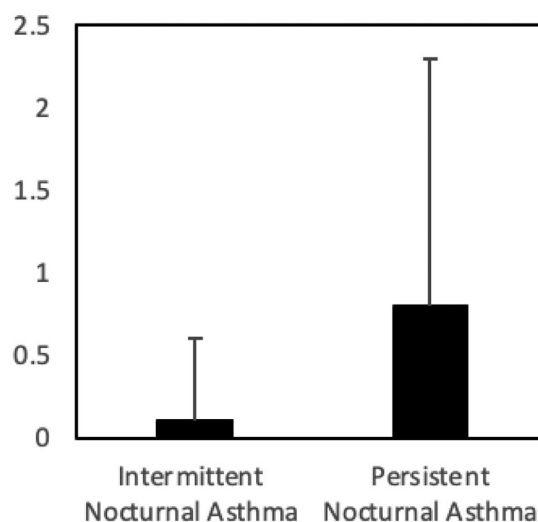


Figure 2. Persistent Nocturnal Asthma Symptoms and School Absences (Bivariate and Multivariate Linear Regression Analysis) Error bars represent 1 std deviation from mean.

As hypothesized, teenagers with persistent nocturnal symptoms were more likely to report poorer functional outcomes, including more physical activity limitations, more depressive symptoms, more asthma-related school absences, and poorer asthma-related QOL, compared to teenagers with

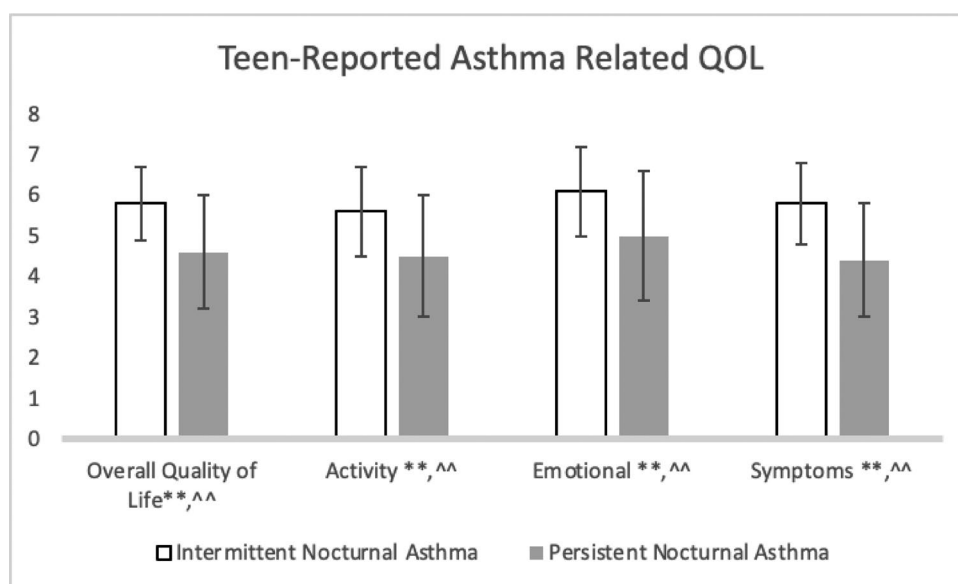


Figure 3. Persistent Nocturnal Asthma Symptoms and Quality of Life using PAQLQ¹⁷ (Bivariate and Multivariate Linear Regression Analysis). Error bar represents 1 standard deviation from the mean.

fewer or no nocturnal symptoms. Other studies have reported similar results in younger children (11,17,18).

Teens with persistent nocturnal symptoms also reported a greater burden of daytime symptoms compared to those with intermittent nocturnal asthma. This is consistent with prior studies that have shown that the presence of nocturnal asthma can predict risk for future asthma symptoms (both daytime and nighttime) (17,19). For instance, it is possible that disrupted sleep affects future lung function, and therefore increases daytime asthma severity. In fact, two independent studies have demonstrated that, among children and adolescents with asthma, greater quantity of sleep (after either 1 night or 5 nights) predicted better lung function (as measured by either FEV1 or PEF%) and less severe asthma symptoms the next morning (20,21). Thus, for teenagers with persistent nocturnal asthma, it is possible that their lung function is worse the next morning, which could cause daytime asthma symptoms and functional limitation. Importantly, in this study, the association between nocturnal symptoms and functional outcomes remained significant even when controlling for daytime asthma symptoms.

In addition to daytime asthma symptoms, we also explored demographic characteristics that have been shown to influence asthma outcomes. In this cohort, more females reported persistent nocturnal asthma symptoms and physical activity limitations. Female sex has been cited as a risk factor for poor asthma control in adolescents, possibly driven by factors like reporting bias and later age of asthma onset (22).

Further, while 57% of teenagers in the study were either overweight or obese according to their measured BMI (higher than the national prevalence of 42% reported by the CDC) (23), there was no difference in weight status by persistent nocturnal symptoms. The mean salivary cotinine in our cohort of teenagers was 9.4 ± 39.5 ng/ml, suggesting significant smoke exposure (>5 ng/ml) (24) in the population, which is known to exacerbate nocturnal asthma (25). Interestingly, there was no significant difference in smoke exposure between teens who reported persistent nocturnal asthma and teens who reported intermittent nocturnal asthma in our study. This may be related to limited power and the large range of cotinine concentration in the sample. While there are many potential factors that can influence asthma outcomes in this population, we continued to find significant associations between nocturnal asthma symptoms and functional health outcomes after controlling for these variables.

A strength of the study is the large study population with over 400 urban teenagers. To our knowledge, this is one of the largest studies to examine whether nocturnal asthma symptoms are associated with functional health outcomes. Moreover, having teens reflect and report on their asthma symptoms could serve as an initial step to motivate them for medication adherence and independent health responsibilities. Focusing on how teenagers perceive their asthma is valuable as it can help highlight their unique needs as they increase their responsibility for managing their own health and health behaviors.

There are several limitations worth considering. Because this study has a cross-sectional design, causation and directionality of relationships cannot be inferred. There are a few confounding variables not measured in the present study that must be considered. For instance, obstructive sleep apnea, also known to affect daily functional health outcomes (26), is a common co-morbidity for adults with asthma and is associated with more frequent severe asthma exacerbations (27). In the pediatric population, snoring is a common co-morbidity and is associated with increased asthma burden (28). Our survey did not include measures for snoring and obstructive sleep apnea and therefore we were unable to control for these variables. Also, the negative impact of sleep deprivation on cognitive function and emotional regulation (6,10) may contribute to poor adherence with daily controller therapy and drive nocturnal symptoms. Moreover, since sleep duration and sleep quality were not quantified in this study, we cannot tell whether teenagers with persistent nocturnal asthma have poorer or less sleep than those with intermittent nocturnal asthma. Finally, responses to the survey may be influenced by recall bias. It is possible that teenagers are under-reporting nocturnal symptoms or daytime limitations, especially if their asthma symptoms are so commonplace that the teenager may not consider them abnormal.

Teen-reported persistent nocturnal asthma symptoms are associated with poorer functional health outcomes. Providers should specifically ask adolescents about the burden of nocturnal asthma symptoms and possible interference with daytime functioning. Additional studies are needed to determine whether strategies to reduce nocturnal asthma symptoms, such as stepping up asthma therapy, adjusting the timing of medication doses (29), or increasing physical activity (30) can lead to improvements in both nighttime symptoms and daily functioning among teens with asthma. Identifying nocturnal asthma symptoms and improving nocturnal asthma control may positively impact daily functioning for teenagers with asthma.

Conclusion/key findings

Persistent nocturnal asthma symptoms are common among teens with uncontrolled asthma. Teen-reported persistent nocturnal asthma symptoms are associated with poorer functional health outcomes, independent of daytime symptoms. Providers should ask teens about the possible burden of nighttime asthma symptoms.

Declaration of interest

The authors declare no conflicts of interest in preparing this article.

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