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ORIGINAL RESEARCH

The Association Between Sleep Duration, Asthma-Related Episodes/Attacks and Emergency Department Visits

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Background: Inadequate sleep duration potentially increases the risk of allergic asthma; yet, the effect of different sleep duration on asthma-related episodes/attacks and emergency department (ED) visits has remained unclear. The purpose of this study is to evaluate the association between sleep duration, asthma-related episodes/attacks and ED visits.

Methods: This study included 1526 asthma participants from the Behavioral Risk Factor Surveillance System Questionnaire during 2013–2017. Self-reported sleep duration was classified into three groups: ≤6 h (short), 7 h to 8 h (optimal) and ≥9 h (long). Generalized additive model with binomial or Poisson regression was used to complete all statistical analyses.

Results: During a 12-month period, 857 participants reported acute episodes/attacks of asthma, and 279 participants reported asthma-related ED visits. Asthmatics with ED visits harbored significantly lower mean sleep duration (6.50 h vs 7.01 h, adjusted OR=0.93, 95% CI: 0.88–0.98) than those without episodes/attacks. After adjusting the potential confounding factors, the participants with long sleep duration were associated with lower risk of asthma-related episodes/attacks (adjusted OR=0.59, 95% CI: 0.41–0.86) than those with short sleep duration. The prevalence (adjusted OR=0.67, 95% CI: 0.47–0.94) and frequency (adjusted OR=0.83, 95% CI: 0.69–0.9996) of asthma-related ED visits among short sleepers were significantly higher than that among optimal sleepers. The differences of asthma-related episodes/attacks and ED visits between long and optimal sleepers were statistically insignificant.

Conclusion: Our study demonstrated that asthmatics with short sleep duration were associated with highest prevalence of asthma-related episodes/attacks and ED visits among the three sleep duration groups.

Keywords: sleep duration, asthma, attack

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Introduction

Asthma is a common, chronic respiratory disease affecting 1–18% of the population of different countries with chronic airway inflammation and variable symptoms of shortness of breath, wheeze, and chest tightness, etc.[1] An exacerbation of asthma represents a change in clinical symptoms, a progressive decrease in lung function, and a poor quality of life. Asthma-related exacerbation resulted in about 1.8 million emergency department (ED) visits and 497,000 hospitalizations each year with huge economic burden and potentially life threatening.[2] Factors affecting airway and systemic inflammation can increase the risk of asthma-related episodes/attacks,

which include viral respiratory infections, allergen exposure, outdoor air pollution, among others.[1]

Sleep health has an important role in the physical, social, mental well-being, and biological processes of children and adults. The optimal sleep duration differs among age groups. For adults, the proposed optimal sleep duration is 7 to 8 h per day. Many evidences have demonstrated that inadequate sleep duration was associated with high mortality and morbidity of metabolic disease, including hypertension, diabetes mellitus, cardiocerebrovascular diseases, and obesity.[3–6] In recent years, the association between inadequate sleep duration and allergic diseases also has been extensively investigated.[7] Epidemiological surveys suggested that inadequate sleep duration was potentially associated with higher risk of allergic diseases, including asthma,[8–11] dermatitis,[9,10] rhinitis,[10,12] and arthritis.[13,14] The previous studies revealed an robust association between poor sleep and asthma-related lung function deterioration.[15] A meta-analysis of Irwin et al showed that long sleep duration was associated with increases in markers of systemic inflammation, including C-reactive protein, interleukin-6, and tumor necrosis factor α.[16] However, there was no clinical studies related to the association between sleep duration and asthma-related ED visits.

We hypothesized that inadequate sleep duration affected the proportion of asthma-related episodes/attacks and ED visits. Based on a large population-based cohort study of Behavioral Risk Factor Surveillance System (BRFSS) respondents from 2013 to 2017, we examined the associations among sleep duration, asthma-related episodes/attacks and ED visits with the adjustment for confounding factors through Empower software and generalized additive model.

Methods

Data Sources

The BRFSS is an extensive and nationally representative health-related telephone survey conducted by state health departments in collaboration with the Centers for Disease Control and Prevention (CDC).[17] The BRFSS collects state data about US adult aged 18 years and older in all 50 states as well as the District of Columbia and three US territories regarding their health-related risk behaviors, medical conditions, and use of preventive services. As the largest continuously health survey system in the world, the BRFSS includes more than 400,000 adult interviews each year.

Ethics

All related data came from the open BRFSS, and no participants were involved in the recruitment and conduct of the study. This study was deemed exempt for review by the Institutional Review Board at China, Three Gorges University.

Study Population

Our study population included individuals with asthma. The participants were asked the following four questions: "Has a doctor, nurse, or other health professional even told you that you had asthma?", "Do you still have asthma?", "During the past 12 months, have you had an episode of asthma or an asthma attack?", and "During the past 12 months, how many times did you visit an emergency room (ED) or urgent care center because of your asthma?" The detailed BRFSS data about the participants with asthma from 2013 to 2017 are shown in Table S1.

Interviews and Measurements

The measurement of sleep duration in asthmatics was according to a self-reported questionnaire: "On average, how many hours of sleep do you get in a 24-hour period?" Sleep duration was divided into three groups: short sleep duration (≤6 h), optimal sleep duration (7–8 h) and long sleep duration (≥9 hours).

The following variables of the participants with asthma were used to adjust the potential associations among sleep duration, asthma-related episode/attack and ED visits, including age (<65 years old/≥65 years old), sex (female/male), race (white, black and other), marital status (current married/unmarried), body mass index (normal <25/≥25 obese), smoking (now smokes every day/now smokes some days/former smoker/never smoked), heavy drinkers (adult men having more than 14 drinks per week and adult women having more than 7 drinks per week, yes/no), physical activity (yes/no), the diagnosis of chronic respiratory diseases (including chronic obstructive pulmonary disease, emphysema or chronic bronchitis, yes/no), myocardial infarction (yes/no), coronary heart disease (yes/no), stroke (yes/no), diabetes (yes/no), connective tissue disease (yes/no), depressive disorder (yes/no), and asthmatic medical prescription (yes/no). According to GINA 2019, we also assessed the level of asthma symptom control (well controlled/partial controlled/uncontrolled). Pregnant women,

and the participants with incomplete records of key analysis variables were not included in this study.

Statistical Analysis

The study population was divided into three sleep duration groups. The demographic and clinical characteristics of the study population were merged, cleaned, and compared using Microsoft Excel and SPSS. Categorical variables were presented as counts and percentages (%) and examined with a chi-square test to determine the differences among the three groups. Means and standard deviations were available to express continuous variables with Mann–Whitney *U*-test for skewed continuous variables and Student's *t*-test for normally distributed continuous variables. The normality of distribution of the data was tested by chi-square goodness-of-fit and Kolmogorov–Smirnov test. Our main objective was to explore the associations among sleep duration, asthma-related episodes/attacks and ED visits. We also estimated whether the level of asthma symptom control and the use of asthmatic medical prescription affected sleep duration. The associations were statistically analyzed through Empower (R) (www.empowerstats.com; X&Y solutions, Inc., Boston, MA) and R software, version 3.1.2 (http://www.r-project.org).[18–20] In accordance with the smooth function, generalized additive model with binomial regression for the proportion and Poisson regression for the frequency were used to calculate the proportion of asthma-related episodes/attacks, the proportion of ED visits, the frequency of ED visits in the three groups and to compare the differences among them. The statistical analyses of the associations included two steps. In the first step, we only analyzed the associations among sleep duration, asthma-related episodes/attacks and ED visits. In the second step, we determined the associations among sleep duration, asthma-related episodes/attacks and ED visits with adjusting potential risk factors. The odds ratios (ORs) with 95% confidence intervals (CIs) were estimated to assess the differences, and a two-tailed $P < 0.05$ was considered statistically significant.

Results

Demographic and Clinical Characteristics of Study Population

A total of 2,297,925 participants were added to the cohort study of BRFSS from 2013 to 2017. Of those, 316,023 participants reported the diagnosis of asthma with a proportion of 13.5%. About 9.25% of the participants (216,007) still had asthma. 4067 asthma participants answered whether or not they had asthma-related episodes/attacks, and 1897 participants had ED visits. Finally, 1526 asthmatics were incorporated into this study with complete information of the aforementioned variables. Figure 1 displays the consort diagram of study population.

The distribution of sleep duration showed that only 41.4% of asthmatics reported optimal sleep duration, while 47.4% of asthmatics slept for 6 h or less per day and 11.2% slept for 9 h or more per day. The mean sleep

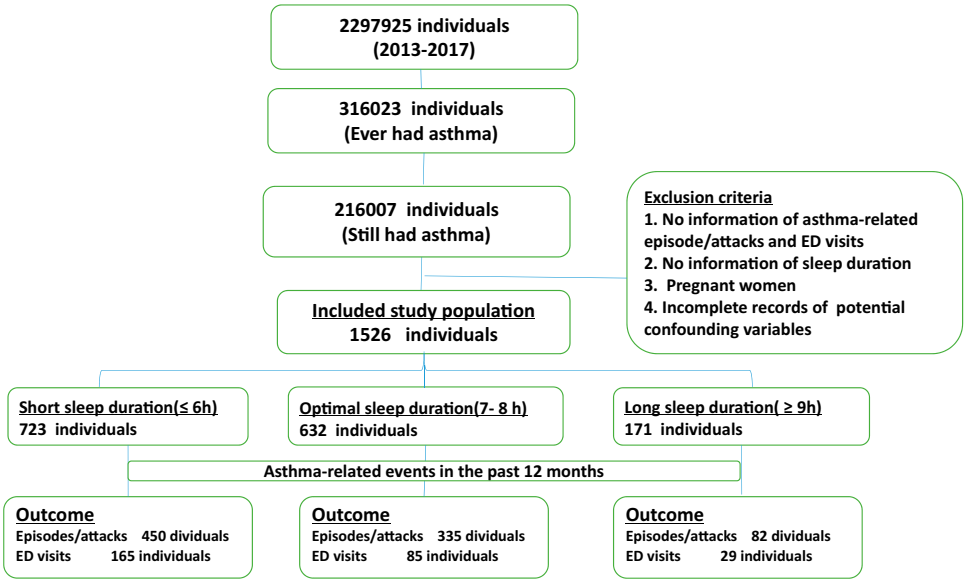

Figure 1 Consort diagram of study population.

duration was 6.76 ± 1.97 h. Our study population consisted mainly of female (74.8%). Most participants were under 65 years old (69.8%) and had obese (BMI ≥ 25, 75.8%). The number of non-smoking participants (51.9%) were smokers. Many participants reported that they engaged in physical activities and did not heavily drink alcohol. Among the participants, 41% of asthmatics were diagnosed with other chronic respiratory diseases. The prevalence of connective tissue disease and depressive disorder in our study population was 56.6% and 38.3%, respectively. During a 12-month period, 857 participants reported acute episodes/attacks of asthma, and 279 participants reported asthma-related ED visits. The mean frequency of asthma-related ED visits was 2.33 within a 12-month period in those who reported ED visits. 73.1% of asthmatics used asthmatic medical prescription to prevent asthma-related attack.

There were 24.9% asthmatics with well-controlled symptoms and 26.1% asthmatics with uncontrolled symptoms, respectively. More detailed demographic and clinical characteristics are shown in Table 1.

Sleep Duration Among Different Asthma Outcomes, Symptom Controlled Levels, and Medical Prescriptions

The unadjusted OR suggested that less sleep duration was associated with worsen asthma outcomes (see Table 2). Compared with uncontrolled asthmatics, well-controlled asthmatics were associated with more sleep duration (uncontrolled 6.58 h vs well controlled 6.99 h, crude OR=0.94, 95% CI: 0.89–0.99, P = 0.03). When adjusting for potential confounding factors, asthmatics with episodes/attacks and ED visits still harbored less sleep duration than that without episodes/attacks (6.50 h vs 7.01 h, adjusted OR=0.93, 95% CI: 0.88–0.98, $P < 0.01$). The level of asthma symptom control and the use of asthmatic medical prescription seemingly had no impact on sleep duration (see Table 2 and Figure 2).

Association Between Sleep Duration and the Prevalence of Asthma- Related Episodes/Attacks

The unadjusted analysis demonstrated that the proportion of asthma-related episodes/attacks, respectively, was 53% among optimal sleepers (crude OR=0.68, 95% CI: 0.55–0.85, $P < 0.01$) and 48% among long sleepers (crude OR=0.56, 95% CI: 0.40–0.78, $P < 0.01$), which was significantly lower than that among short sleepers (62%). After adjusting for potential confounding factors, the ORs suggested that long sleepers (long vs short, 49% vs 62%, adjusted OR=0.59, 95% CI: 0.41–0.86, $P < 0.01$) still were associated with lower proportion of asthma-related episodes/attacks than short sleepers (see Figure 3A).

Association Between Sleep Duration and the Risk of Asthma-Related ED Visits

In the unadjusted analysis (Table 3), asthmatics in the optimal sleep duration group (25%) were less likely to experience asthma-related ED visit than those in the short (37%). After adjusting for potential confounding factors (see Table 3), asthmatics with short sleep duration had significantly increased proportion of asthma-related ED visits than that among optimal sleepers (short vs optimal, 37% vs 28%, adjusted OR=0.67, 95% CI: 0.47–0.94, $P=0.02$) (see Table 3 and Figure 3B). Long sleepers among asthmatics had the slightly lower prevalence of ED visits than short sleepers among asthmatics, but no significantly different (long vs short, 31% vs 37%, adjusted OR=0.77, 95% CI: 0.45–1.34, $P=0.36$).

The unadjusted analysis (crude OR=0.80, 95% CI: 0.67–0.96) suggested that the mean frequency of asthma-related ED visits in the short sleep duration group (2.47) was significantly more than that in the optimal sleep duration group (1.99). The mean frequency of asthma-related ED visits in the long sleep duration group (2.55) was the highest among the three groups. With the adjustment of potential confounding factors, short sleepers still experienced more frequent asthma-related ED visits compared with optimal sleepers (short vs optimal, 2.47 vs 2.05, adjusted OR=0.83, 95% CI: 0.69–0.9996, $P=0.0495$) (see Table 3 and Figure 3C). The frequency of ED visits among short sleepers with asthmatics was similar to that among long sleepers with asthmatics (short vs long, 2.47 vs 2.39, adjusted OR=0.97, 95% CI: 0.75–1.24, $P=0.79$).

Discussion

Our study showed that the mean sleep duration among asthmatics with episodes/attacks and ED visits was significantly less than that among asthmatics without episodes/attacks. However, the level of asthma symptom control and the use of asthmatic medical prescription did not affect sleep duration. To our best knowledge, we did find any previous study evaluating the risk of asthma-related ED visits among asthmatics with different sleep

Table 1 Demographic and Clinical Characteristics of Study Population

	No Episodes/Attacks (N= 659, 43.2%)	Episodes/Attacks Without ED Visits (N= 588, 38.5%)	Episodes/Attacks with ED Visits (N= 279, 18.3%)	*P*
Sleep duration				<0.001
≤6 h	273 (41.4%)	285 (48.5%)	165 (59.1%)	
7–8 h	297 (45.1%)	250 (42.5%)	85 (30.5%)	
≥9 h	89 (13.5%)	53 (9.0%)	29 (10.4%)	
Sex				<0.001
Male	186 (28.2%)	152 (25.9%)	46 (16.5%)	
Female	473 (71.8%)	436 (74.1%)	233 (83.5%)	
Age				<0.001
<65 y	411 (62.4%)	430 (73.1%)	224 (80.3%)	
≥65 y	248 (37.6%)	158 (26.9%)	55 (19.7%)	
Race				<0.001
White, Non-Hispanic	414 (62.8%)	403 (68.5%)	143 (51.3%)	
Black, Non-Hispanic	221 (33.5%)	139 (23.6%)	117 (41.9%)	
Other	24 (3.6%)	46 (7.8%)	19 (6.8%)	
Marital status				0.018
Currently married	247 (37.5%)	258 (43.9%)	98 (35.1%)	
Unmarried	412 (62.5%)	330 (56.1%)	181 (64.9%)	
Body mass index				0.04
<25	180 (27.3%)	133 (22.6%)	57 (20.4%)	
≥25	479 (72.7%)	455 (77.4%)	222 (79.6%)	
Smoking				0.523
Now smokes every day	104 (15.8%)	92 (15.6%)	45 (16.1%)	
Now smokes some days	35 (5.3%)	38 (6.5%)	25 (9.0%)	
Former smoker	177 (26.9%)	146 (24.8%)	72 (25.8%)	
Never smoked	343 (52.0%)	312 (53.1%)	137 (49.1%)	
Heavy drinkers				0.879
Yes	26 (3.9%)	24 (4.1%)	13 (4.7%)	
No	633 (96.1%)	564 (95.9%)	266 (95.3%)	
Physical activity				0.013
Yes	268 (40.7%)	213 (36.2%)	130 (46.6%)	
No	391 (59.3%)	375 (63.8%)	149 (53.4%)	
Chronic respiratory diseases				<0.001
Yes	247 (37.5%)	230 (39.1%)	149 (53.4%)	
No	412 (62.5%)	358 (60.9%)	130 (46.6%)	
Myocardial infarction				0.351
Yes	62 (9.4%)	70 (11.9%)	31 (11.1%)	
No	597 (90.6%)	518 (88.1%)	248 (88.9%)	
Coronary heart disease				0.027
Yes	72 (10.9%)	92 (15.6%)	44 (15.8%)	
No	587 (89.1%)	496 (84.4%)	235 (84.2%)	
Stroke				0.001
Yes	48 (7.3%)	59 (10.0%)	42 (15.1%)	
No	611 (92.7%)	529 (90.0%)	237 (84.9%)	

(*Continued*)

Table 1 (Continued).

	No Episodes/Attacks (N= 659, 43.2%)	Episodes/Attacks Without ED Visits (N= 588, 38.5%)	Episodes/Attacks with ED Visits (N= 279, 18.3%)	*P*
Diabetes				0.002
Yes	155 (23.5%)	135 (23.0%)	93 (33.3%)	
No	504 (76.5%)	453 (77.0%)	186 (66.7%)	
Connective tissue disease				0.238
Yes	360 (54.6%)	335 (57.0%)	169 (60.6%)	
No	299 (45.4%)	253 (43.0%)	110 (39.4%)	
Depressive disorder				<0.001
Yes	207 (31.4%)	248 (42.2%)	130 (46.6%)	
No	452 (68.6%)	340 (57.8%)	149 (53.4%)	
Level of asthma symptom control				<0.001
Well controlled	250 (37.9%)	106 (18.0%)	24 (8.6%)	
Partial controlled	325 (49.3%)	316 (53.7%)	106 (38.0%)	
Uncontrolled	84 (12.7%)	166 (28.2%)	149 (53.4%)	
Asthmatic medical prescription				<0.001
Yes	405 (61.5%)	465 (79.1%)	246 (88.2%)	
No	254 (38.5%)	123 (20.9%)	33 (11.8%)	

Table 2 Sleep Duration Among Different Asthma Outcomes, Symptom Controlled Level, and Medical Prescription

	Crude Value	Crude RR	P	Adjusted Value*	Adjusted RR*	P
Sleep duration in three asthma outcomes groups						
No Episodes/attacks	7.01 (6.81, 7.22)			7.01 (6.59, 7.47)		
Episodes/attacks without ED visits	6.63 (6.43, 6.84)	0.94 (0.90, 0.98)	0.01	6.72 (6.32, 7.15)	0.96 (0.92, 1.00)	0.06
Episodes/attacks with ED visits	6.42 (6.13, 6.72)	0.91 (0.87, 0.97)	< 0.01	6.50 (6.03, 7.00)	0.93 (0.88, 0.98)	< 0.01
Sleep duration in different levels of asthma symptom control						
Well controlled	6.99 (6.73, 7.26)			6.99 (6.55, 7.46)		
Partial controlled	6.74 (6.55, 6.93)	0.96 (0.92, 1.01)	0.12	6.77 (6.36, 7.20)	0.97 (0.92, 1.02)	0.18
Uncontrolled	6.58 (6.33, 6.83)	0.94 (0.89, 0.99)	0.03	6.69 (6.23, 7.18)	0.96 (0.90, 1.01)	0.13
Sleep duration between asthmatics with medical prescription and asthmatics without medical prescription						
No	6.78 (6.54, 7.04)			6.79 (6.35, 7.25)		
Yes	6.74 (6.60, 6.90)	0.99(0.95,1.04)	0.8	6.76 (6.37, 7.17)	1.00 (0.95, 1.04)	0.86

Note: *Adjusted confounding variables: age, sex, race, marital status, body mass index, smoking, heavy drinkers, physical activity, chronic respiratory diseases, myocardial infarction, coronary heart disease, stroke, diabetes, connective tissue disease, and depressive disorder.

durations. This study suggested that short sleep duration seemed to be associated with the highest prevalence of asthma-related episodes/attacks and ED visits among three sleep duration groups. An interesting result was observed in our study that long sleepers were associated with the lower prevalence of asthma-related episodes/attacks and the higher prevalence and frequency of asthma-related ED visits compared with optimal sleepers.

Prior studies mainly assessed the sleep duration between asthma severity groups and compared the sleep duration in asthmatics with normal controls.[11,21-24]

The sleep duration of individuals with asthma was longer than that of individuals without asthma.[11] The previous studies indicated that there was no significant difference of sleep duration between severe and nonsevere asthma.[21,22] Although not significantly different, adolescents with severe

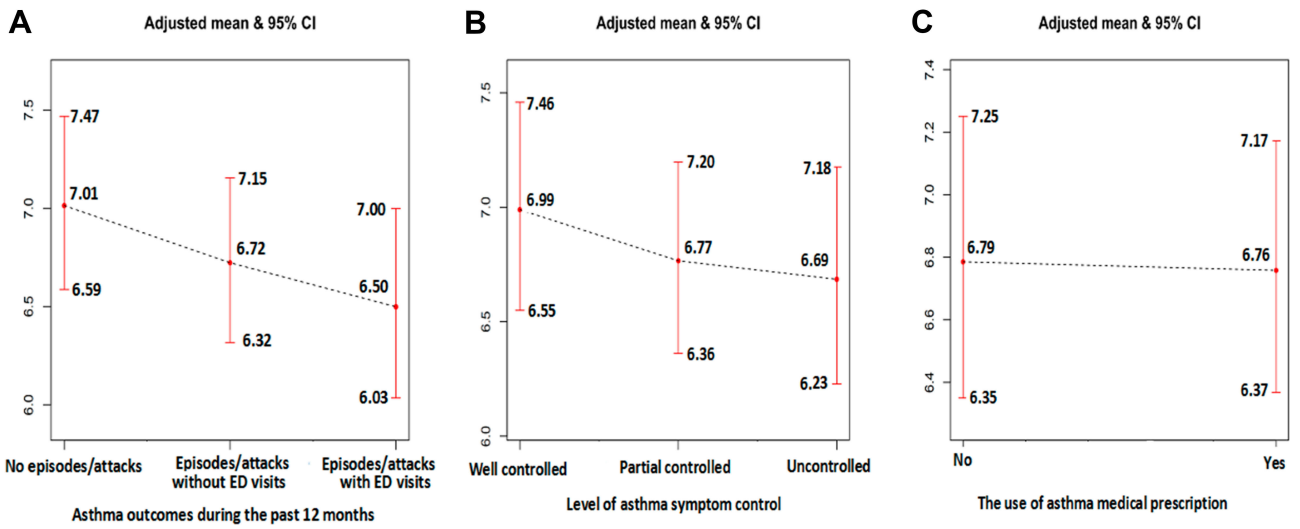

Figure 2 Sleep duration among different asthma outcomes, symptom controlled levels, and medical prescriptions: (**A**) Sleep duration in three asthma outcomes groups; (**B**) sleep duration in different levels of asthma symptom control; (**C**) sleep duration between asthmatics with medical prescription and asthmatics without medical prescription.

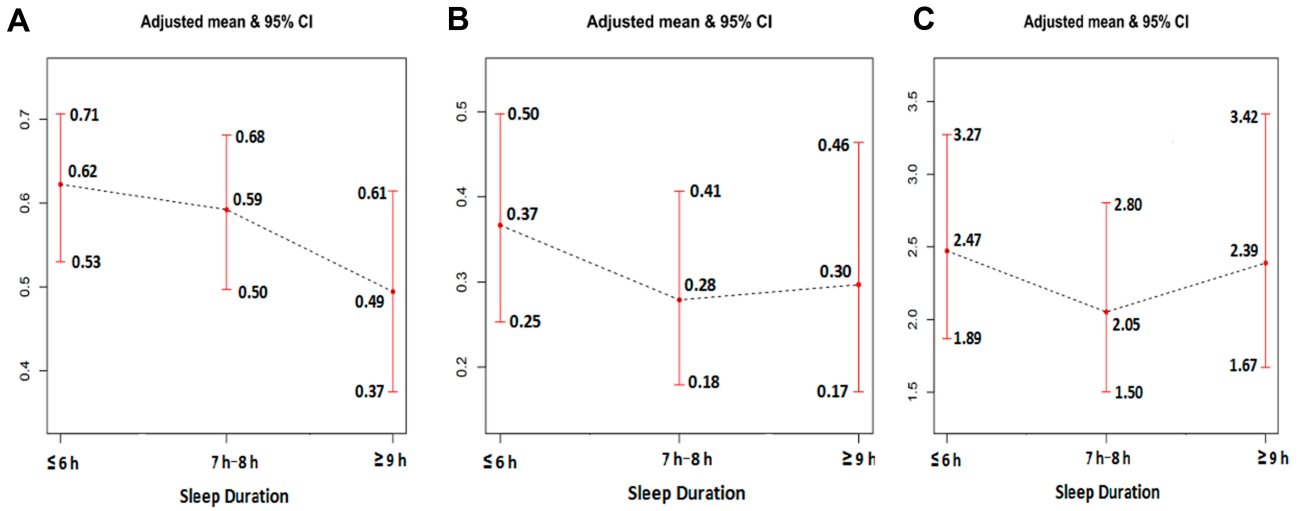

Figure 3 The associations among sleep duration, asthma-related episodes/attacks and emergency department visits: (**A**) The prevalence of asthma-related episodes/attacks in three sleep duration groups; (**B**) the prevalence of asthma-related emergency department visits in three sleep duration groups; (**C**) the frequency of asthma-related emergency department visits in three sleep duration groups.

asthma seemed to obtain more insufficient sleep (sleep duration <7 h) compared with adolescents with no asthma and even asthma.[21] Our study showed that sleep duration among asthmatics with well controlled was slightly lower than that among asthmatics with uncontrolled, but no significantly different (well controlled 6.99 h vs uncontrolled 6.69 h, adjusted OR= 0.96, 95% CI: 0.90, 1.01, P=0.13). Our study also suggested that sleep duration had the positive association with asthmatic outcomes, but showed no association with the use of asthmatic medical prescription. No similar study was found as yet.

Respiratory infections and allergic sensitization are two important triggers of asthma-related episodes/attacks.[1] Compared with allergic sensitization, asthma-related episodes/attacks secondary to respiratory infection was more likely to need ED visits. The asthmatics who need ED visits theoretically had more inflammation compared with those who experienced asthma-related episodes/attacks. Zhang and the colleagues[25] examined the relationship between sleep duration and the risk of allergic sensitization among 1534 Chinese adolescents. Compared with long sleepers (8.9–14.7 h), those who slept less (3.0–7.8 h) were more likely to manifest allergic sensitization with an OR of 1.9 (95% CI: 1.3–2.7) for any food allergen and 1.5 (95% CI: 1.1–2.0) for any aeroallergen. Adolescents who slept for

Table 3 The Association between Sleep Duration, Asthma-Related Episode/Attack and Emergency Department Visits

	Crude Value	Crude RR	P	Adjusted Value*	Adjusted RR*	P
The revalence of asthma-related episodes/attacks in three sleep duration groups						
≤6 h	0.62(0.59, 0.66)			0.62(0.53, 0.71)		
7–8 h	0.53(0.49, 0.57)	0.68(0.55, 0.85)	<0.01	0.59(0.50, 0.68)	0.88(0.69, 1.13)	0.31
≥9 h	0.48(0.40, 0.55)	0.56(0.40, 0.78)	<0.01	0.49(0.37, 0.61)	0.59(0.41, 0.86)	<0.01
The prevalence of asthma-related emergency department visits in three sleep duration groups						
≤6 h	0.37(0.32, 0.41)			0.37(0.25, 0.50)		
7–8 h	0.25(0.21, 0.30)	0.58(0.43, 0.80)	<0.01	0.28(0.18, 0.41)	0.67(0.47, 0.94)	0.02
≥9 h	0.35(0.26, 0.46)	0.95(0.58, 1.55)	0.82	0.30(0.17, 0.46)	0.73(0.43, 1.25)	0.25
The frequency of asthma-related emergency department visits in three sleep duration groups						
≤6 h	2.47(2.24, 2.72)			2.47(1.87, 3.27)		
7 h–8 h	1.99(1.71, 2.31)	0.80(0.67, 0.96)	0.017	2.05(1.50, 2.80)	0.83(0.69, 0.9996)	0.0495
≥9 h	2.55(2.03, 3.20)	1.03(0.81, 1.32)	0.8	2.39(1.67, 3.42)	0.96(0.75, 1.24)	0.79

Note: *Adjusted confounding variables: age, sex, race, marital status, body mass index, smoking, heavy drinkers, physical activity, chronic respiratory diseases, myocardial infarction, coronary heart disease, stroke, diabetes, connective tissue disease, depressive disorder, level of asthma symptom control and asthmatic medical prescription.

7.8–8.9 h also were at higher risk of allergic sensitization than long sleepers. A significant dose–response relationship was shown between the number of positive skin prick tests and percentage of short sleep duration (3.0–7.8 h). Another study of Esteban et al[26] evaluated the relationship between sleep outcome and allergic sensitization and among 196 urban schoolchildren asthmatics. The asthma children with poor sleep outcome experienced more positive test results. Therefore, we speculate that one underlying mechanism of the increased risk of asthma-related episodes/attacks and ED visits in short sleepers is an increased allergic sensitization. Inadequate sleep duration was also found to increase the risk of respiratory infections. A prospective study of 56,953 female nurses from the Nurses, Health Study II cohort demonstrated that short sleepers (≤5 h) experienced higher relative risks of developing pneumonia than 8-h sleepers after adjusting for potential confounding factors.[27] Another study showed that participants who slept <6 h per night were four times more likely to be diagnosed with upper respiratory infection than those who slept 7 to 9 h per night.[28] Therefore, upper respiratory Infection secondary to short sleep is another underlying mechanism of the increased risk of asthma-related episodes/attacks and ED visits in short sleepers. Our study also showed that long sleepers had a lower proportion of asthma-related episodes/attacks and a higher risk of asthma-related ED visits than optimal sleepers. A prospective study demonstrated that long sleepers (≥9 h) were associated with higher risks of pneumonia than 8-h sleepers.[27] A meta-analysis of 72 studies has reported significantly higher levels of inflammatory markers among long sleepers than those among optimal sleepers.[16] The underlying mechanism may be that long sleepers were associated with less allergic sensitization but a greater risk of respiratory infection and systemic inflammatory than optimal sleepers.

There were some strengthens in our study. First, we estimated the mean sleep duration among different asthma outcomes and symptom controlled levels through generalized additive model and Poisson regression. Poisson regression with robust standard errors provides a more decisive and consistent method to estimate risk compared with logistic regression for count data.[29] Second, our study not only explored the associations between sleep duration and the proportion of asthma-related episodes/attacks and ED visits, but also estimated the frequency of asthma-related ED visits among the participants with different sleep durations. Third, we adjusted more than 17 variables to make our results more credible, especially the level of asthma symptoms and the use of asthmatic medical prescriptions. Our study demonstrated that the level of asthma symptoms and the use of asthmatic medical prescriptions had the crucial impact on asthma-related episodes/attacks and ED visits.

There were some limitations in our study. First, self-reported sleep duration and the diagnosis of asthma were subjective and maybe have recall bias. Participants had other respiratory illness that could mimic asthma in

symptoms and exacerbation. Objective sleep duration based on polysomnography and the diagnosis of asthma with lung function test may be used to validate our results. Second, lung function, the level of FeNO and serum eosinophils was important for asthma-related outcomes. Inadequate sleep duration had the impact on three variables. We cannot obtain these information from BRFSS, thus did not better assess the association between sleep duration and asthma-related outcome based on these variables. Third, only <5% of asthmatics answered whether or not they had asthma-related episodes/attacks and the presence of ~40% of other chronic respiratory diseases like COPD were included in the analysis, which potentially affected our results. Four, as a cross-sectional study, a causal relationship between sleep duration cannot be determined in our study. Further prospective studies are available to explore the associations among sleep duration, asthma-related exacerbation and ED visits.

Conclusions

Our study showed that short sleepers are at increased risk of asthma-related episodes/attacks compared to optimal and long sleepers. Short sleepers also experienced a higher proportion and more frequent asthma-related ED visits than optimal sleepers. If inadequate sleep duration indeed is one of the risk factors for asthma-related episodes/attacks and ED visits, the global burden of asthma could be dramatically reduced by providing appropriate behavioral intervention measures regarding sleep duration for asthmatics.

Data Sharing Statement

The data underlying this study were obtained from the Behavioral Risk Factor Surveillance System (BRFSS). All relevant data are within the paper and its supporting information files.

Ethics Approval

This study was deemed exempt for review by the Institutional Review Board at China, Three Gorges University.

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Author Contributions

Zhigang Hu and Yufeng Tian are co-first authors. All authors contributed to data analysis, drafting or revising the article, gave final approval of the version to be published, and agree to be accountable for all aspects of the work.

Disclosure

This was not an industry supported study. The authors have declared that there are no conflicts of interest.

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