Published in final edited form as:

J Am Soc Hypertens. 2018 March ; 12(3): 204–210. doi:10.1016/j.jash.2017.12.010.

Severe Obstructive Sleep Apnea in Children with Elevated Blood Pressure

Jane Hinkle^{*}, Heidi V. Connolly, MD[#], Heather R. Adams, PhD[^], and Marc B. Lande, MD, MPH[#]

^{*}Strong Children's Research Center, Department of Pediatrics, University of Rochester Medical Center, Rochester, NY

[#]Department of Pediatrics, University of Rochester Medical Center, Rochester, NY

[^]Department of Neurology, University of Rochester Medical Center, Rochester, NY

Abstract

The objective was to determine the prevalence of habitual snoring and obstructive sleep apnea (OSA) in a cohort of children referred for elevated BP, and to determine the association between OSA and blood pressure elevation, learning difficulties, and behavioral problems. We performed a retrospective review of 446 consecutive new patients referred for elevated BP. One hundred four (23%) had habitual snoring. Patients with habitual snoring were more likely to be obese (86.5 vs 55.6%, $p < 0.001$) and to have Medicaid insurance (52.4 vs 36%, $p = 0.004$). Seventy-four patients had polysomnography, of which 57 (77%) had OSA; 21 (37%) had severe OSA. Severe OSA was associated with higher office systolic BP index after adjusting for body mass index, age, sex, and SES ($\beta = 0.07$, $p = 0.014$). Fifty-two percent of patients with severe OSA had office systolic BP in the stage 2 hypertension range. Children with habitual snoring or OSA were not at increased risk of receiving school services for a learning disability or receiving medications for inattention or mood problems. In summary, habitual snoring is common in children referred for elevated BP, and those with severe OSA are at higher risk of significantly increased BP.

Keywords

Hypertension; habitual snoring; obesity; cognition; pediatric

Introduction

The prevalence of elevated blood pressure (BP) in children increased significantly from 1988 to 2008,(1) a public health phenomenon that parallels the current childhood obesity

Corresponding Author: Marc B. Lande, MD, MPH, 601 Elmwood Ave., Box 777, Rochester, NY 14642, (Ph) 585-275-9784, (Fax) 585-756-8054, marc_lande@urmc.rochester.edu.

Conflicts of interest: none

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

epidemic. School screening studies show that the prevalence of hypertension is as high as 10% in children who are overweight, a remarkably high number given that nearly 20% of adolescents in the US are obese.(2) In addition to the association with hypertension, obesity is also associated with sleep disordered breathing and obstructive sleep apnea (OSA).(3) In adults, there is a well-established relation between obesity, obstructive sleep apnea, and elevated BP, and it has been shown that OSA predicts incident primary hypertension.(4) In children, reports also suggest an association between OSA and elevated BP but the relation is less well-defined, with most studies limited to measures of BP obtained during visits for polysomnography in children suspected of having OSA.(5) In addition to a possible association with elevated BP, OSA in children has also been associated with cognitive and behavioral problems such as altered mood, hyperactivity, inattention, decreased neurocognitive test performance, and reduced academic performance.(6–10)

Almost all children with OSA snore, and the American Academy of Pediatrics (AAP) recommends that all children with habitual snoring and symptoms/signs of OSA (i.e., overweight or hypertension) undergo polysomnography or be referred to a sleep specialist or otolaryngologist for further evaluation of possible OSA.(11) Furthermore, national consensus guidelines for the evaluation and treatment of children with high BP recommend that children with hypertension who have loud, frequent snoring should be referred for polysomnography.(12, 13) However, the prevalence of habitual snoring and OSA in children with elevated BP is not known. Our objective was to determine the prevalence of habitual snoring and OSA in a cohort of children referred for elevated BP, and to determine the association between OSA and blood pressure elevation, learning difficulties, and behavioral problems.

Methods

We performed a retrospective review of consecutive patients referred to the Pediatric Hypertension Clinic at the University of Rochester Medical Center over a four-year period from January 2013 to December 2016. All patients had been referred to the clinic due to elevated blood pressure obtained in their primary physician's office. Patients with secondary hypertension or known developmental delay were excluded.

In order to screen for inclusion and exclusion criteria for other ongoing studies, our hypertension clinic initial visit template includes questions about possible OSA and possible learning problems. During the study period, all referred patients were asked during the initial hypertension clinic visit about the presence of habitual snoring, defined as loud, nightly snoring. All referred patients 10 years old were also asked about the presence of a learning disability (LD), defined as having a current Individualized Education Plan or Section 504 Plan for a learning disability, both formal indicators of a student's need for services to address an educational problem. Attention-Deficit/Hyperactivity Disorder (ADHD) was defined as being currently prescribed a psychostimulant or other medication indicated for management of ADHD symptoms. Mood problems were defined as being currently prescribed medication to treat anxiety or depression. At the initial hypertension clinic visit, all patients had a sitting right arm BP measured 2 – 3 times by auscultation at 5 minute intervals and the office BP for the current study was calculated as the average of these

readings. All BPs were indexed to the 95th percentile for age, sex, and height.(12) For patients with initial clinic mean BP in the hypertensive range, BP was categorized as stage 1 or stage 2, as defined by the National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents.(12) When available, ambulatory blood pressure monitoring (ABPM) and echocardiography results were recorded. However, both ABPM and echocardiography were obtained at the discretion of the physician as clinically indicated and were not available for all patients. Left ventricular hypertrophy (LVH) was defined as left ventricular mass indexed to height^{2.7} 95th percentile for age and sex.(14) Medical records were reviewed for demographic characteristics including age, sex, and body mass index (BMI) z-score. Overweight was defined as BMI 85th percentile for age and gender, obesity as BMI 95th percentile, and morbid obesity as BMI 99th percentile. Medicaid insurance status was used as a proxy for low SES.(15) Race and ethnicity were not available. Records were also reviewed for any history of referral to the Pediatric Sleep Clinic at the University of Rochester Medical Center. Those referrals may have been made by the child's primary care provider prior to the initial HTN clinic visit, or by the hypertension physician because a history of snoring was identified at the initial hypertension clinic visit. Results of polysomnography studies were reviewed. Obstructive sleep apnea on polysomnography was categorized by the Apnea Hypopnea Index (AHI) as mild (AHI, 2 but < 5 events/hr), moderate (AHI, 5 but < 10 events/hr), or severe (AHI, 10 events/hr).(16) Patients with AHI < 2 events/hr on polysomnography were categorized as no OSA (primary snoring). Records were also reviewed for referral to an otolaryngologist for evaluation of possible OSA and previous tonsillectomy and/or adenoidectomy prior to the initial hypertension clinic visit.

Patient characteristics were compared between groups via 2-sample *t* tests for continuous variables and the Fisher exact test for categorical variables. Results were reported as mean $\pm$ SD or percentiles, where appropriate. Multivariate linear regression analyses were performed to examine the relationship between office BP index and OSA, and multiple logistic regressions were performed to examine the relationship between LVH and OSA, habitual snoring and low SES (Medicaid insurance), and stage 2 hypertension BP elevation and severity of OSA. Analyses were performed with SAS software version 9.3 (SAS institute). The significance level of the data analysis was set at 0.05. The study protocol was approved by the Research Subjects Review Board at the University of Rochester Medical Center.

Results

Four hundred forty-six consecutive patients met the inclusion criteria. Of those patients, 104 (23%) had habitual snoring compared to 342 (77%) who did not. Patients with habitual snoring were similar to those without habitual snoring in age, sex, systolic BP index, diastolic BP index, but were more likely to be overweight and to have Medicaid insurance. Patients with habitual snoring were more than twice as likely to be morbidly obese compared with patients without habitual snoring (Table 1). The association between habitual snoring and Medicaid insurance remained significant after adjusting for obesity, age, and sex (odds ratio = 1.76, 95% CI: 1.1, 2.8, *p* = 0.02).

Of the 104 patients with habitual snoring, 96 were overweight and therefore met AAP criteria for referral to a sleep specialist or otolaryngologist for evaluation for OSA. However, record review showed that only 36 (37.5%) had been evaluated for OSA prior to referral to the hypertension clinic. Patients who had been previously evaluated for OSA were similar to those who had not been evaluated for OSA in age, sex, systolic and diastolic BP index, and proportion with obesity, (data not shown) but were more likely to have Medicaid insurance (67% vs 45%, $p = 0.03$).

A total of 74 patients had polysomnography available for analysis. Of these, 43 patients had obtained the study prior to referral to the hypertension clinic (including both overweight and normal weight patients). The reason for prior referral for polysomnography by the primary care provider was not available. Another 63 patients with habitual snoring were referred to the pediatric sleep clinic from the hypertension clinic, but only 31 (49%) attended a sleep clinic appointment and subsequent polysomnography. Of the 74 patients with polysomnography, 17 (23%) had primary snoring (no OSA) and 57 (77%) had OSA. Of those 57, 18 (31.6%) had mild OSA, 18 (31.6%) moderate OSA, and 21 (36.8%) severe OSA.

Patients with severe OSA had a significantly higher office systolic BP index at their hypertension clinic visit compared with those with mild and moderate OSA. Patients with no OSA (primary snoring), moderate OSA, and severe OSA had similar BMI z-scores, suggesting that the group differences in office systolic BP among these subgroups was not secondary to differences in weight. By contrast, office diastolic BP index did not differ by degree of OSA severity (Table 2). Multiple linear regression analysis confirmed that severe OSA remained independently associated with higher office systolic BP index after adjusting for age, sex, BMI z-score, and Medicaid insurance ($\beta = 0.07$, SE 0.028, $p = 0.01$). Patients with severe OSA were much more likely to have a hypertension clinic systolic BP in the stage 2 hypertension range compared with patients with mild or moderate OSA (Figure 1). After adjustment for BMI z-score, age, and low SES, patients with severe OSA were almost 9 times more likely to have office systolic BP in the stage 2 hypertension range compared with patients with mild-to-moderate OSA (odds ratio = 8.9, 95% CI = 2.0, 40.3, $p = 0.004$). In a separate analysis of patients with OSA, we compared the proportion of patients who had office systolic BP in the stage 2 hypertension range in patients referred for polysomnography by the primary care provider prior to the hypertension clinic referral to that of patients who had been referred for polysomnography from their initial hypertension clinic visit. Patients with OSA who had been diagnosed prior to referral to hypertension clinic had a similar proportion with office systolic BP in the stage 2 hypertension range compared with patients with OSA who were referred for polysomnography from their initial hypertension clinic visit (35% vs 21%, $p = 0.36$).

Two hundred eighteen patients (49%) of the 446 patients had ABPM at the hypertension clinic visit. However, only 37 (36%) of the 104 patients with habitual snoring had ABPM. Of the patients with available ABPM, the 37 patients with habitual snoring did not differ from the 181 with ABPM data without habitual snoring in daytime systolic BP index, nighttime systolic BP index, daytime diastolic BP index, nighttime diastolic BP index, 24hr systolic BP load, 24hr diastolic BP load, nocturnal dip, or percent with nocturnal dip < 10

mm Hg (data not shown). Only 17 (30%) of the patients with OSA had ABPM. Twenty-seven percent of patients who had ABPM were morbidly obese compared with 49% of patients without ABPM ($p < 0.001$), suggesting that practitioners in the hypertension clinic were less likely to obtain ABPM to evaluate for white coat hypertension in very overweight patients or that some very overweight patients had an arm circumference that was too wide for the extra-large adult ABPM cuff. However, morbid obesity was a prominent characteristic of patients with habitual snoring, especially in patients with moderate-to-severe OSA, resulting in a bias against having ABPM available for analyses in these patients. As a consequence, only 4 patients with severe OSA had ABPM. Therefore, the association between ABPM parameters and OSA severity could not be accurately evaluated. Two hundred ninety-seven (67%) of the 446 patients had an echocardiogram, including 71 (68%) of the 104 patients with habitual snoring and 40 (70%) of the 57 subjects diagnosed with OSA. There was no significant difference in the prevalence of LVH in patients with habitual snoring compared with those without habitual snoring (23% vs 16%, $p = 0.16$). Patients with OSA had a higher prevalence of LVH compared with those without OSA (36% vs 15%, $p = 0.003$); however this difference did not remain significant after adjustment for BMI z-score and office systolic BP index ($\beta = 0.59$, SE 0.42, $p = 0.15$). Furthermore, there was no significant difference in the prevalence of LVH in patients with severe OSA compared with patients with mild-to-moderate OSA (46% vs 30%, $p = 0.48$).

Only patients 10 years of age were asked about the presence of receiving services at school for a LD. Of the 446 patients in the cohort, 404 were 10 years of age. Data on the presence of receiving school services for a LD were available for 340 (84%) of the 404 patients 10 years of age, including 80 (89%) of 90 patients with habitual snoring, 62 (84%) of 74 patients with polysomnography, and 40 (83%) of 48 patients with OSA on polysomnography. Data on the presence of ADHD and mood problems were available for all 446 patients in the cohort. There was no difference in the prevalence of receiving LD services, a diagnosis of ADHD, or mood problems between patients with or without habitual snoring or a diagnosis of OSA, or between patients with severe vs. mild-to-moderate OSA (Table 3).

Of the 74 patients who underwent polysomnography, 17 (23%) were receiving services for a LD and 57 (77%) were not. Patients with LD did not have worse polysomnography respiratory parameters compared with those without LD (Table 4).

Discussion

Previous studies in children have evaluated the relation between sleep disordered breathing and BP by measuring BP in patients referred to sleep clinics for suspected OSA.⁽⁵⁾ To our knowledge, we are the first to evaluate the prevalence of habitual snoring in children referred to a pediatric hypertension clinic for evaluation of elevated BP. Children with elevated BP are often obese, a common comorbidity known to be associated with sleep disordered breathing and OSA. Furthermore, OSA is thought to play a role in the pathophysiologic mechanism of obesity-related hypertension in children.⁽⁵⁾ We found that almost one-quarter of children referred for elevated BP had habitual snoring. The majority of the patients with

habitual snoring were morbidly obese, and they were more likely to be of low socioeconomic status, as estimated by having Medicaid insurance.

The importance of recognizing habitual snoring in children with elevated BP is underscored by the finding that almost 80% of patients with available polysomnography had confirmed OSA, with over a third having severe OSA. The common prevalence of severe OSA in this patient population has important clinical implications, as patients with severe OSA were much more likely to have systolic BP in the stage 2 hypertension range, an office BP associated with a higher likelihood of confirmed sustained hypertension.(17) Others have also reported an association between OSA severity and degree of BP elevation in children. (18, 19) In addition, studies have shown that treating OSA results in lower BP, in particular improved nocturnal hypertension, so recognition and treatment of severe OSA has the potential for improving cardiovascular outcomes in these patients.(20)

In adults, OSA is independently associated with LVH, a risk factor that is associated with increased cardiovascular mortality. In children, LVH is a common manifestation of hypertensive target organ damage, but the association between OSA and the development of LVH is less clear.(5) We found that OSA was not associated with an increased prevalence of LVH, after adjusting for obesity and increased BP, factors known to have an impact on the development of LVH. Furthermore, severe OSA was not associated with a significantly higher prevalence of LVH compared with mild-to-moderate OSA.

Sleep disordered breathing, including habitual snoring and OSA, have been associated with mood disturbances, behavior problems, lower neurocognitive test performance, and decreased academic performance.(6, 21) However, the effect sizes of the differences from children without sleep disordered breathing are modest and often occur within the normal range of the cognitive or behavioral measures. In addition, studies have shown a lack of correlation between severity of sleep disordered breathing and neurobehavioral measures. (22) Treatment of OSA with tonsillectomy and adenoidectomy has been shown to improve both behavioral and neurocognitive measures, but the correlation of improvement in these measures with improvement in post treatment respiratory parameters on polysomnography is poor.(22) If the neurocognitive and behavioral problems associated with sleep disordered breathing were severe enough to significantly impact daily functioning, then one might anticipate that children with sleep disordered breathing would be more likely to be receiving services at school for learning problems, and they would be more likely to be receiving medication for inattention and negative affect. However, we did not find an increased prevalence of learning disability, medication for ADHD, or medication for mood disturbances in patients with habitual snoring or patients with OSA. Furthermore, severe OSA was not associated with an increased prevalence of learning disability, medication for ADHD, or medication for mood disturbance compared with patients with mild-to-moderate OSA. In addition, the presence of a learning disability was not associated with worse respiratory parameters on polysomnography. It is possible that the neurobehavioral deficits associated with sleep disordered breathing in our cohort were not severe enough to translate into the need for the interventions reported in this study. Alternatively, the learning problems and mood disturbances associated with sleep disordered breathing were under recognized and therefore under treated. Furthermore, learning problems and mood problems are known

to be under recognized and under treated in disadvantaged youth,(23, 24) a group with increased prevalence in our cohort of children with habitual snoring as evidenced by an increased proportion with Medicaid insurance.

The AAP recommends that all children with habitual snoring with signs/symptoms of OSA undergo evaluation for OSA.(11) Despite these recommendations, we found that only a minority of patients who met these criteria had been previously referred for evaluation for OSA prior to their referral to the pediatric hypertension clinic. While it is possible that some patients had had a prior evaluation for OSA that we did not detect by our record review, that possibility is unlikely to be the case for most, as the University of Rochester Pediatric Sleep Clinic is the primary center for children with suspected sleep disordered breathing in our referral area. In addition, a significant number of patients who were referred from the pediatric hypertension clinic to the pediatric sleep clinic did not attend the sleep clinic appointment or the subsequent polysomnography session, suggesting family barriers may be limiting implementation of the AAP guidelines as well. Our findings strongly suggest that the AAP guidelines are not being followed for many children with habitual snoring and that therefore, OSA is being under diagnosed.

The current study had several limitations. The retrospective, cross sectional nature of the study precludes inference regarding causality between severe OSA and elevated BP. In addition, it is possible that there was selection bias among individuals who ultimately received polysomnography, in that those with the most overt and severe sleep disordered breathing may have been more inclined to comply with the referral to the sleep clinic. Furthermore, mean office BP for this study was calculated from BP measurements from a single session, not from several sessions over time as required to diagnose sustained hypertension. Also, due to the retrospective nature of the study, ABPM was not obtained in all patients and there was bias against obtaining ABPM in morbidly obese patients, which resulted in inadequate ABPM data for analysis in patients with OSA. This limitation prevented detection of nocturnal hypertension and blunted nocturnal dipping, findings that have been previously reported to be prominent in patients with OSA. The diagnosis of learning disability was by parent report of an IEP or Section 504 Plan, not direct neurocognitive testing or review of school records. Also, diagnoses of ADHD and mood disorders were inferred based on pharmacologic treatment rather than direct evaluation of patients to determine if they met formal diagnostic criteria for these behavioral health conditions, limitations which may explain the difference between our results and the results of previous studies showing an association between sleep disordered breathing and academic underperformance, symptoms of ADHD and mood dysregulation. Lastly, we did not have detailed information on the recommendation for and compliance with previous treatments for OSA such as continuous positive airway pressure therapy (CPAP).

In summary, we found that habitual snoring is common among children referred for elevated BP. The majority of children with habitual snoring were diagnosed with OSA following polysomnography, many with severe OSA. Children with severe OSA had a striking prevalence of office BP within the stage 2 hypertension range, a finding often predictive of sustained hypertension. The relation between sleep disordered breathing and neurobehavioral problems was less clear. The presence of OSA in children with elevated BP

appears to be widely under diagnosed. These findings underscore that identifying children with OSA is important in potentially ameliorating cardiovascular risk in children with elevated BP.

Acknowledgments

This work was funded by the Strong Children's Research Center, University of Rochester, Department of Pediatrics (J Hinkle) and the National Institutes of Health, National Heart, Lung, and Blood Institute (R01HL098332; PI, M Lande). We thank Erik Abell for excellent administrative support of this project.

References

1. Rosner B, Cook NR, Daniels S, Falkner B. Childhood blood pressure trends and risk factors for high blood pressure: The NHANES experience 1988–2008. *Hypertension*. 2013 Aug; 62(2):247–54. [PubMed: 23856492]
2. McNiece KL, Poffenbarger TS, Turner JL, Franco KD, Sorof JM, Portman RJ. Prevalence of hypertension and pre-hypertension among adolescents. *J Pediatr*. 2007 Jun. 150(6):640, 4, 644.e1. [PubMed: 17517252]
3. Tauman R, Gozal D. Obesity and obstructive sleep apnea in children. *Paediatr Respir Rev*. 2006 Dec; 7(4):247–59. [cited 20061113]. [PubMed: 17098639]
4. Peppard PE, Young T, Palta M, Skatrud J. Prospective study of the association between sleep-disordered breathing and hypertension. *N Engl J Med*. 2000 May 11; 342(19):1378–84. [cited 20000511]. [PubMed: 10805822]
5. Acosta, AA. Obstructive sleep apnea and hypertension. In: Flynn, JT, Ingelfinger, JR., Portman, RJ., editors. *Pediatric Hypertension*. 3. New York: Humana Press; 2013.
6. O'Brien LM, Mervis CB, Holbrook CR, Bruner JL, Klaus CJ, Rutherford J, et al. Neurobehavioral implications of habitual snoring in children. *Pediatrics*. 2004 Jul; 114(1):44–9. [PubMed: 15231906]
7. Owens JA. Neurocognitive and behavioral impact of sleep disordered breathing in children. *Pediatr Pulmonol*. 2009 May; 44(5):417–22. [PubMed: 19382210]
8. Lande MB, Hooper SR, Batisky DL, Kupferman JC, Szilagyi PG, Samuels JA, et al. Sleep disordered breathing as measured by SRBD-PSQ and neurocognition in children with hypertension. *Am J Hyperten*. 2015 Apr; 28(4):552–8.
9. Bourke R, Anderson V, Yang JSC, Jackman AR, Killedar A, Nixon GM, et al. Cognitive and academic functions are impaired in children with all severities of sleep-disordered breathing. *Sleep Med*. 2011 May; 12(5):489–96. [PubMed: 21493135]
10. Hunter SJ, Gozal D, Smith DL, Philby MF, Kaylegian J, Kheirandish-Gozal L. Effect of sleep-disordered breathing severity on cognitive performance measures in a large community cohort of young school-aged children. *Am J Respir Crit Care Med*. 2016 Sep 15; 194(6):739–47. [PubMed: 26930303]
11. Marcus CL, Brooks LJ, Draper KA, Gozal D, Halbower AC, Jones J, et al. Diagnosis and management of childhood obstructive sleep apnea syndrome. *Pediatrics*. 2012 Sep; 130(3):e714–55. [PubMed: 22926176]
12. National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. *Pediatrics*. 2004 Aug; 114(2 Suppl 4th Report):555–76. [PubMed: 15286277]
13. Flynn JT, Kaelber DC, Baker-Smith CM, Blowey D, Carroll AE, Daniels SR, et al. Clinical practice guideline for screening and management of high blood pressure in children and adolescents. *Pediatrics*. 2017 Sep. 140(3)
14. Khoury PR, Mitsnefes M, Daniels SR, Kimball TR. Age-specific reference intervals for indexed left ventricular mass in children. *Journal of the American Society of Echocardiography*. 2009 Jun; 22(6):709–14. [PubMed: 19423289]

15. Marcin JP, Schembri MS, He J, Romano PS. A population-based analysis of socioeconomic status and insurance status and their relationship with pediatric trauma hospitalization and mortality rates. *Am J Public Health*. 2003 Mar; 93(3):461–6. [PubMed: 12604496]
16. Berry RB, Budhiraja R, Gottlieb DJ, Gozal D, Iber C, Kapur VK, et al. Rules for scoring respiratory events in sleep: Update of the 2007 AASM manual for the scoring of sleep and associated events. deliberations of the sleep apnea definitions task force of the american academy of sleep medicine. *Journal of Clinical Sleep Medicine*. 2012 Oct 15; 8(5):597–619. [PubMed: 23066376]
17. Sorof JM, Poffenbarger T, Franco K, Portman R. Evaluation of white coat hypertension in children: Importance of the definitions of normal ambulatory blood pressure and the severity of casual hypertension. *Am J Hypertens*. 2001 Sep; 14(9 Pt 1):855–60. [PubMed: 11587149]
18. Li AM, Au CT, Ng C, Lam HS, Ho CKW, Wing YK. A 4-year prospective follow-up study of childhood OSA and its association with BP. *Chest*. 2014 Jun; 145(6):1255–63. [PubMed: 24384690]
19. Li AM, Au CT, Sung RYT, Ho C, Ng PC, Fok TF, et al. Ambulatory blood pressure in children with obstructive sleep apnoea: A community based study. *Thorax*. 2008 Sep; 63(9):803–9. [PubMed: 18388205]
20. Vlahandonis A, Nixon GM, Davey MJ, Walter LM, Horne RSC. Improvement of sleep-disordered breathing in children is associated with a reduction in overnight blood pressure. *Sleep Med*. 2013 Dec; 14(12):1295–303. [PubMed: 24157094]
21. Beebe DW, Ris MD, Kramer ME, Long E, Amin R. The association between sleep disordered breathing, academic grades, and cognitive and behavioral functioning among overweight subjects during middle to late childhood. *Sleep*. 2010 Nov; 33(11):1447–56. [PubMed: 21102986]
22. Owens JA. Neurocognitive and behavioral impact of sleep disordered breathing in children. *Pediatr Pulmonol*. 2009 May; 44(5):417–22. [PubMed: 19382210]
23. Richardson LP, DiGiuseppe D, Garrison M, Christakis DA. Depression in medicaid-covered youth: Differences by race and ethnicity. *Arch Pediatr Adolesc Med*. 2003 Oct; 157(10):984–9. [PubMed: 14557159]
24. Coker TR, Elliott MN, Toomey SL, Schwebel DC, Cuccaro P, Tortolero Emery S, et al. Racial and ethnic disparities in ADHD diagnosis and treatment. *Pediatrics*. 2016 Sep.

Highlights

Habitual snoring is common in children referred for elevated blood pressure (BP).

Obstructive sleep apnea (OSA) is common in children with snoring and elevated BP.

Severe OSA is associated with high office systolic BP.

Children with elevated BP and habitual snoring are under-referred for OSA evaluation.

Figure 1.
Percent of patients with office systolic BP in the stage 2 hypertension range by degree of OSA severity on polysomnography.

Table 1

Demographic characteristics of patients with habitual snoring vs those without snoring.

Characteristics	Snorers (n= 104)	Non-Snorers (n=342)	p-value
Age, y	13.7 ± 3.0	14.0 ± 3.0	0.43
Males %	69.2	66.4	0.63
Systolic BP Index	1.02 ± 0.09	1.02 ± 0.08	0.95
Diastolic BP Index	0.92 ± 0.12	0.92 ± 0.13	0.76
BMI z-score	2.29 ± 0.70	1.55 ± 1.12	<0.001
Obese, %	86.5	55.6	<0.001
Morbidly Obese, %	65.4	31.0	<0.001
Medicaid, %	52.4	36.0	0.004

Table 2

Office BP and BMI z-score by degree of OSA severity on polysomnography.

Characteristics	No OSA (N = 17)	Mild OSA (N = 18)	Moderate OSA (N = 18)	Severe OSA (N = 21)
BMI z-score	2.23 ± 0.64	1.98 ± 1.06*	2.61 ± 0.36	2.66 ± 0.78
Office SBP Index	1.00 ± 0.06*	1.01 ± 0.08*	1.01 ± 0.09*	1.08 ± 0.11
Office DBP Index	0.91 ± 0.11	0.95 ± 0.10	0.92 ± 0.13	0.97 ± 0.15
SBP < 95 th percentile, %	40.5	33	39	19
SBP stage 1 HTN range, %	47	56	50	29
SBP stage 2 HTN range, %	12.5*	11*	11*	52

* P < 0.05 vs severe OSA;

SBP = systolic blood pressure; DBP = diastolic blood pressure

Table 3

Prevalence of cognitive and mood problems

Cognitive or Mood Problem	Snorers	Non-Snorers	p-Value	OSA	No OSA	p-value	Mild-to-Mod OSA	Severe OSA	p-value
Learning Disability (%)	26	19	0.21	26	20	0.42	21	28	0.73
ADHD (%)	18	19.5	0.76	18	19	0.99	10.5	22	0.45
Mood Problem (%)	10	7	0.40	7	8	0.99	9.5	5	0.61

Table 4

Polysomnography parameters of patients with a learning disability vs those without a learning disability.

Polysomnography parameter	Learning disability (N = 17)	No learning disability (N = 45)	P - value
Mean sleep efficiency	80.3 ± 10.0%	83.5 ± 11.3%	0.33
Arousal index	23.5 ± 13.7	27.0 ± 27.9	0.56
Apnea hypopnea index	7.6 ± 9.2	13.5 ± 25.0	0.19
Obstructive apnea hypopnea index	9.3 ± 9.8	13.8 ± 25.6	0.36
Mean lowest total percent oxygen saturation	89.8 ± 3.8%	89.2 ± 6.0%	0.75
Mean percent sleep time below oxygen saturation of 90%	0.12 ± 0.30%	1.1 ± 3.6%	0.34
Mean percent sleep time with end tidal CO ₂ >50 mmHg	0.23 ± 0.72%	4.9 ± 12.1%	0.03