HHS Public Access

Author manuscript

Pediatr Pulmonol. Author manuscript; available in PMC 2020 August 16.

Published in final edited form as:

Pediatr Pulmonol. 2016 March ; 51(3): 272–279. doi:10.1002/ppul.23238.

Differences in Spirometry Values Between US Children 6–11 Years and Adolescents 12–19 Years With Current Asthma, 2007–2010

Brian K. Kit, MD, MPH[1,2,*], **Alan E. Simon, MD**[3], **Timothy Tilert, BS**[1], **Sande Okelo, MD, PhD**[4], **Lara J. Akinbami, MD**[2,3]

[1]Division of Health and Nutrition Examination Surveys, National Center for Health Statistics, Centers for Disease Control and Prevention, Hyattsville, Maryland [2]United States Public Health Service, Rockville, Maryland [3]Office of Analysis and Epidemiology, National Center for Health Statistics, Centers for Disease Control and Prevention Hyattsville, Hyattsville, Maryland [4]Department of Pediatrics, Division of Pediatric Pulmonology, David Geffen School of Medicine at UCLA, Mattel Children's Hospital UCLA, Los Angeles, California

Abstract

Background—National Asthma Education and Prevention Program (NAEPP) guidelines recommend that periodic spirometry be performed in youth with asthma. NAEPP uses different spirometry criteria to define uncontrolled asthma for children (6–11 years) and adolescents (12+ years).

Objective—To describe differences in spirometry between US children and adolescents with current asthma.

Methods—We examined cross-sectional spirometry data from 453 US youth with current asthma age 6–19 years from the 2007–2010 National Health and Nutrition Examination Surveys. The main outcomes were percentage predicted forced expiratory volume at 1 sec (FEV1%) ≤80 and the ratio of FEV1 to forced vital capacity (FEV1/FVC) ≤0.80. We also examined the prevalence of youth with spirometry values consistent with uncontrolled asthma, using NAEPP age-specific criteria, defined for children aged 6–11 years as FEV1% ≤80 or FEV1/FVC ≤0.80, and for adolescents aged 12–19 years as FEV1% ≤80.

Results—Children 6–11 years and adolescents 12–19 years did not differ in prevalence of FEV1% ≤80 (10.1% vs. 9.0%) or FEV1/FVC ≤0.80 (30.6% vs. 29.8%). However, based on the NAEPP age-specific criteria, 33.0% of children 6–11 years and 9.0% of adolescents 12–19 years had spirometry values consistent with uncontrolled asthma (P<0.001).

*Correspondence to: Brian K. Kit, Division of Health and Nutrition Examination Surveys, National Center for Health Statistics, Centers for Disease Control and Prevention, 3311 Toledo Road, Room 4419, Hyattsville, MD 20782. bkit@cdc.gov.

Conflicts of interests: None.

Required disclaimer: The findings and conclusions in this report are those of the authors and not necessarily those of the Centers for Disease Control and Prevention.

Conclusion—Children 6–11 years and adolescents 12–19 years with current asthma did not differ in the percentage with FEV1% ≤80 or FEV1/FVC ≤0.80. However, the percent of children and adolescents with spirometry values consistent with uncontrolled asthma did differ. The difference appears to stem mainly from the different spirometry criteria for the two age groups.

Keywords

asthma; spirometry; child; adolescent; NHANES

INTRODUCTION

The National Asthma Education and Prevention Program's (NAEPP) evidence-based asthma guidelines recommend, in addition to symptom assessment, that spirometry be periodically performed in youth with asthma.[1] Spirometry detects uncontrolled asthma that may not otherwise be detected based on an assessment of only symptoms.[2–6] Youth with uncontrolled asthma benefit from clinical interventions including optimizing asthma medication regimens.[1] Despite recommendations to include spirometry during asthma clinical visits, spirometry is often times not performed.[7–9]

The National Health and Nutrition Examination Survey (NHANES) included spirometry in 2007–2010. An analysis of these data provides an opportunity to assess population based, as opposed to clinic based, spirometry data for US children and adolescents with current asthma, which to our knowledge, has not been previously examined. The NAEPP definition of uncontrolled asthma differs by age group. For children 6–11 years, both percentage predicted forced expiratory volume at 1 sec (FEV1%) and the ratio of FEV1 to forced vital capacity (FEV1/FVC) are used whereas in adolescents (12+ years), FEV1% is the only parameter used to assess control. Further, how spirometry-based estimates of uncontrolled asthma may be influenced by definitional differences has not been previously described. The objective of this study is to describe differences in spirometry between US children (age 6–11 years) and adolescents (age 12–19 years) with current asthma. We also examined the prevalence of youth with spirometry values consistent with uncontrolled asthma, using NAEPP age-specific criteria.

MATERIALS AND METHODS

The National Center for Health Statistics conducts NHANES, a series of nationally representative cross-sectional surveys of the US civilian, non-institutionalized population.[10,11] Each data collection uses a complex, stratified, and multistage probability cluster sampling design. Informed consent for survey participation is obtained for persons ≥18 years. For those <18 years, written parental consent is obtained, and child assent is obtained for those aged 7–17 years. The NCHS Research Ethics Review Board approved the survey. We used data from NHANES 2007–2008 and 2009–2010. This analysis was restricted to youth aged 6–19 years with current asthma, defined as an affirmative response to both: "Has a doctor or health professional ever told you that you have asthma?" and "Do you still have asthma?" Younger children were excluded because spirometry was assessed only for age 6–

79 years. Examination response rates for youth 6–19 years was 82% and 85% in 2007–2008 and 2009–2010.[12]

Asthma Control

Uncontrolled asthma is defined in the NAEPP guidelines by several criteria. In addition to spirometry, other criteria include additional measures of impairment (symptoms, nighttime awakenings, rescue medication use, and interference with normal activity) and risk (exacerbation requiring oral corticosteroids). Uncontrolled asthma is classified as the most severe of any of these criteria. Therefore, asthma control determined only by spirometry may underestimate the prevalence of uncontrolled asthma. However, because NHANES does not have data for the other criteria for similar recall periods specified by the NAEPP criteria, this study focuses on only spirometry.

Spirometry protocol

In NHANES 2007–2010,[13,14] youth were excluded from spirometry for current painful ear infection; eye, chest, or abdominal surgery in the last 3 months; current chest pain taking a deep breath, physical problem with forceful expiration, daytime use of supplemental oxygen, congenital heart disease, tuberculosis exposure, or coughing up blood. However, persons with other medical conditions, including recent upper respiratory infections, were not excluded.

NHANES used the Ohio 822/827 dry-rolling seal volume spirometers and the procedures met American Thoracic Society (ATS) recommendations.[15] Spirometry was performed in the standing position unless the participant was physically limited. Participants were asked to maximally exhale, after a deep inspiration, for 3 (6–10 years) or 6 sec (≥11 years). The goal was to achieve three acceptable exhalation maneuvers, with a maximal number of eight attempts. Acceptability criteria included a visible plateau in the volume–time spirogram and meeting goals for time spent in exhalation. After three acceptable maneuvers, the two highest values for FVC and FEV1 were assessed for reproducibility, i.e., the two highest FVC and FEV1 should agree within 150 ml of each other. The highest values of FEV1 and FVC were used for this analysis.[16] Therefore, FEV1 and FEV1/FVC could be reported from any of the individual acceptable curves that the participant performed. The quality of FEV1 and FVC were graded. For this analysis, we used spirometry values for persons with complete exams with ATS Grade A, B, or C for FVC and FEV1.

Prediction Equations

Prediction equations were used to obtain FEV1% predicted values based on race/ethnicity, age, sex, and height. Based on the ATS/European Respiratory Society recommendation for persons in the US[17] and an expert group,[18] prediction equations described by Hankinson[19] are used for non-Hispanic White (NHW), non-Hispanic Black (NHB), and Mexican American (MA) youth ages 8–19 years. Hankinson's equations do not include Asians, younger children, and Hispanics. For participants of "other" race/Hispanic origin, most commonly Asians, the NHW prediction equations are used with a correction factor of 0.88 as employed by Hankinson[20] and others.[21] Prediction equations for NHW and NHB children age 6–7 years are based on Wang,[22] also based on the ATS/European Respiratory Society

recommendation for persons in the US,[17] and an adjustment of 0.88 was applied to the NHW prediction equations for all other race/Hispanic origins. Hankinson MA prediction equations were used for all Hispanics.

Selection and Categorization of Spirometry Measures

The analysis focused on FEV1 and FEV1/FVC because these are the guideline-recommended measures to assess asthma control and are also recommended as core outcomes for asthma research.[18] We examined FEV1% ≤80 and FEV1/FVC ≤0.80. We further examined mutually exclusive categories: FEV1% ≤80 only; FEV1/FVC ≤0.80 only; and both FEV1% ≤80 and FEV1/FVC ≤0.80 to capture all lung function patterns which are consistent with uncontrolled asthma. We also assessed the percent of participants with spirometry consistent with the NAEPP age-specific criteria for uncontrolled asthma, defined as: FEV1% ≤80% or FEV1/FVC ≤0.80 for age 6–11 years and FEV1% ≤80 for age 12–19 years. For children 6–11 years, in whom two different spirometry criteria are used to assess asthma control, categorization is based on the most severe level of impairment.[1]

Statistical Methods

Statistical analyses were performed using SAS software, version 9.3 (SAS Institute, Inc., Cary, NC), and SUDAAN software, version 11.0 (RTI, Research Triangle Park, NC). Sample weights, which account for differential probabilities of selection, nonresponse, and differences between the final sample and the total population, were used to obtain estimates representative of the civilian, non-institutionalized US population.[10] Standard errors were calculated using Taylor Series Linearization, a method used to account for the complex survey design.[10] Statistical significance was determined at a *P*-value of <0.05 using a two-sided *t*-test.

Missing Data

Of the 566 eligible children age 6–19 years with current asthma, six were excluded because of missing height and 107 were excluded for incomplete spirometry (Fig. 1). Of the 107, 46 did not perform spirometry due to safety concerns, the most common reasons were: reported difficulty in taking a deep breath (n =24), painful ear infection (n =7), and exposure to tuberculosis (n =5) (data not shown).

Missingness was related to age, with a higher amount of missing spirometry data among 6 and 7 years olds. To evaluate the impact of missing spirometry data, alternative estimates of FEV1% ≤80 and FEV1/FVC ≤0.8 were obtained using direct adjustment for the age groups, sex, and race/Hispanic origin via proc wtadjust in SUDAAN (RTI)[23] which reweights the data to achieve correct population totals based on the non-missing data. Estimates with or without adjustment were similar (i.e., differed by <1% and SE differing by <0.5) and the study conclusions were unchanged. Therefore, estimates without adjustments are presented to enhance reproducibility. However, non-response could be related to characteristics other than sex, age, and race/Hispanic origin, which, if present, would not be adjusted for in our analyses and the possibility of bias due to non-response may still exist.

Sensitivity Analyses

We undertook two sensitivity analyses. The first was to evaluate the impact of altering prediction equations for children 6–7 years and for race/ethnic groups categorized as "other." The second sensitivity analysis evaluated the role of preventive asthma medications (PAM) in classification of spirometry values. PAM use could identify a group of children with more severe asthma or at risk of uncontrolled asthma. Therefore, we classified individuals reporting PAM, as described elsewhere,[30] to assess if prevalence of abnormal spirometry differed by PAM use.

RESULTS

The sample size was 453 after excluding 113 individuals with missing data, of which 207 participants were aged 6–11 years and 246 aged 12–19 years (Table 1). Overall, the mean FEV1% was 99.1 (SE: 0.6) and mean FEV1/FVC was 83.0% (SE: 0.5).

Overall, 9.4% (SE: 1.1) of youth had FEV1% ≤80 and 30.1% (SE: 3.7) had FEV1/FVC ≤0.80 (Table 2). The prevalence of FEV1% ≤80 did not differ between 6–11 and 12–19 year olds overall (P =0.695) or within sex (boys, P =0.512; girls, P =0.681) and race/Hispanic origin subgroups (non-Hispanic Black, P =0.837; Hispanic, P =0.685). The prevalence of FEV1/FVC ≤0.80 also did not differ between 6–11 and 12–19 year olds overall (P =0.854) or within sex (boys, P =0.721; girls, P =0.368) and race/Hispanic origin subgroups (non-Hispanic White, P =0.399; non-Hispanic Black, P =0.450; Hispanic, P =0.410).

Only 2.4% (SE: 0.9) of children 6–11 years and 3.0% (SE: 1.2) of adolescents 12–19 years had FEV1% ≤80, but not FEV1/FVC ≤0.80 (Fig. 2). The prevalence of having FEV1/FVC ≤0.80 but not FEV1% ≤80 was 23.0% (SE:4.1) for children 6–11 years and 23.8% (SE: 4.2) for adolescents 12–19 years. Also, 7.6% (SE: 2.0) of children 6–11 years and 6.0% (SE: 1.5) of adolescents 12–19 years had both FEV1% ≤80 and FEV1/FVC ≤0.80. Among children 6–11 years and adolescents 12–19 years, 33.0% (SE: 4.0) and 32.8% (SE: 4.3) had either FEV1% ≤80 or FEV1/FVC ≤0.80. There was no statistical difference between the percentage of children 6–11 years and percentage of adolescents 12–19 years in any of the categories: both FEV1% ≤80 and FEV1/FVC ≤0.80 (P =0.568), FEV1/FVC ≤0.80 only (P =0.859), and FEV1% ≤80 only (P =0.709).

Almost one in five (17.8% (SE: 2.1)) youth age 6–19 years with current asthma had spirometry values consistent with uncontrolled asthma (Fig. 3), but in contrast to the similarity of results for abnormal FEV1% and FEV1/FVC, there were differences between age groups for prevalence of spirometry values consistent with uncontrolled asthma. Prevalence of spirometry values consistent with uncontrolled asthma was threefold higher (P <0.001) in children age 6–11 years than adolescents age 12–19 years (33.0% (SE: 4.0) and 9.0% (SE: 1.6)). Similarly, for boys (P <0.001), non-Hispanic Whites (P <0.001), non-Hispanic Blacks (P =0.010), and Hispanics (P =0.004) the prevalence of spirometry values consistent with uncontrolled asthma between 6–11 and 12–19 year old were statistically different but it was not for girls (P =0.054). The non-significant finding in girls may be attributed to lower power resulting from smaller sample sizes.

In a sensitivity analysis examining the impact of using the Hankinson's prediction equations for 6 and 7 year olds rather than Wang, 7.7% (SE:1.7) of the 6–11 year old, rather than our reported 10.1% (SE: 2.0), would have been classified as having a FEV1% ≤80. In an analysis without applying the 0.88 correction factor, 10.4% (SE: 1.4), 12.4% (SE: 2.5), and 9.3% (SE: 1.5) of youth 6–19, 6–11, and 12–19 years had a FEV1% ≤80 as opposed to the 9.4% (SE: 1.1), 10.1% (SE: 2.0), and 9.0% (SE: 1.6) obtained using the correction factor.

In a sensitivity analysis examining differences by use of PAM (29.9% (SE: 3.1) reported use of PAM), there were no significant difference in FEV1% ≤80 (PAM users: 8.2% (SE: 2.8), PAM non-users: 9.9% (SE: 1.6)) or FEV1/FVC ≤0.80 (PAM users: 31.0% (SE: 6.9), PAM non-users: 29.6% (SE: 3.7)). Moreover, among those who reported PAM use, 18.3% (SE: 3.6) overall, 26.4% (SE: 6.1) age 6–11 years, and 8.7% (SE: 4.9) age 12–19 years had spirometry values consistent with uncontrolled asthma (P =0.032 for 6–11 vs. 12–19 years) whereas the comparable estimates for those who did not report use of PAM was 17.7% (SE: 2.7), 38.2% (SE: 5.6), and 9.1% (SE: 1.9), respectively (P <0.001 for 6–11 vs. 12–19 years). The sample sizes for sensitivity analyses among PAM users are relatively small (n =127 overall, n =79 age 6–11 years, and n =48 age 12–19 years) and the relative standard error, a measure of statistical reliability, is high for adolescents 12–19 years, therefore, caution should be used in interpretation of these estimates.

DISCUSSION

Children 6–11 years and adolescents 12–19 years with current asthma did not differ in the percentage with FEV1% ≤80 or FEV1/FVC ≤0.80. However, the percent of children 6–11 years and adolescents 12–19 years with spirometry values consistent with uncontrolled asthma, based on the age-specific NAEPP criteria, did differ. The difference between age groups, however, appears to stem mainly from the different age-specific spirometry criteria. The younger age group can meet spirometry criteria for uncontrolled asthma using either of two criteria whereas the older age group has one criterion.

The mean FEV1% and FEV1/FVC % (99.1 and 83.0) among children with current asthma in our study are consistent with those based on NHANES III data from 1988–1994[24] and others.[25,26] The similarities across study settings may reflect others' observations that "many school-age children with asthma demonstrate normal or even 'supernormal' spirometry readings outside of exacerbations.[27]" Due to differences in study populations; criteria for enrollment, including age ranges; and prediction equations used, there are limitations in comparing studies but generally our results for a nationally representative population are similar to previous studies.

Spirometry is an objective measure to assess asthma control, however, an assessment of asthma symptoms in addition to spirometry is an integral component of identifying uncontrolled asthma. At the same time, without spirometry, uncontrolled asthma may be underestimated.[28,29] In one study of outpatient pulmonology visits, Nair et al. wrote spirometry "results were just as likely to be abnormal in patients with normal history and exam as in patients with abnormal history and/or exam.[2]" Uncontrolled asthma prevalence measured using both symptoms and spirometry would likely be higher than our estimates.

Poor agreement between FEV1% and FEV1/FVC to assess asthma control was previously reported based on a sample of 4–11 year old in South Africa.[5] In our sample, although approximately 7% of children and adolescents had both FEV1% ≤80 and FEV1/FVC ≤0.80, most children categorized as having abnormal spirometry had a low value for one of the measure but not the other. For example, about 2% of children 6–11 years had FEV1% ≤80 but FEV1/FVC >0.80. Conversely, just over 20% of children 6–11 years had an FEV1/FVC ≤0.8 but FEV1% >80. Thus, conclusions related to asthma control may be sensitive to the criteria used.

One of the outcomes we examined was spirometry values consistent with uncontrolled asthma, based on the NAEPP guidelines. However, these same guidelines also provide spirometry classifications for asthma severity. We analyzed the data based on asthma control, rather than severity, because approximately one-third of youth with current asthma report using preventative asthma medications.[30] As noted by the NAEPP, "severity is most easily and directly measured in a patient who is not receiving long-term control therapy" whereas after treatment is started "the emphasis is on assessing asthma control." In our sensitivity analysis, estimates of FEV1% ≤80 and FEV1/FVC ≤0.80 were similar between participants with and without reported use of preventative asthma medications.

This study is the first nationally representative study to quantify the extent of abnormal spirometry among US children with asthma. Our study is population based, rather than clinic based, which may allow us to capture a wider range of asthma control and provides a unique opportunity to assess spirometry values in a nationally representative sample. Limitations include the cross-sectional analysis and single spirometry measure. For any individual, a variety of factors, including season, may impact their spirometry results. However, in the clinical setting, as noted by other authors, "initial therapeutic decisions must be based on such limited information.[28]" Approximately 18% of children were missing spirometry exams, with a higher amount of missing data in younger children. Analyses with adjusted sample weights suggested minimal bias as a result of the missing data. We used different sets of prediction equations for children 6–7 years old than for youth 8–19 years. Previous research has suggested that conclusions related to airway obstruction using the Wang and Hankinson prediction equations are similar in the age ranges that overlap (8–18 years),[31] moreover, in our sensitivity analysis using the Hankinson equations for 6–7 year old, we demonstrated the magnitude of the difference in prevalence estimates may be small.

CONCLUSION

In conclusion, FEV1% and FEV1/FVC were similar between children 6–11 years and adolescents 12–19 years with asthma in the US. Although children 6–11 years and adolescents 12–19 years had a different prevalence of spirometry values consistent with uncontrolled asthma, the age-specific NAEPP spirometry criteria used to define uncontrolled asthma contributed to the observed differences.

Acknowledgments

We thank Dr. Charles Dillon for his contribution to the NHANES spirometry component and for his thoughtful comments. B. K. K. had full access to all of the data in the study and takes responsibility for the integrity of the data

and the accuracy of the data analysis. B. K. K., A. E. S., T. T., S. O., and L. J. A. contributed substantially to the study design, data analysis and interpretation, and the writing of the manuscript.

Funding source: No external funding obtained.

ABBREVIATIONS

ATS	American Thoracic Society
FEV1	forced expiratory volume at 1 second
FEV1%	% predicted FEV1
FVC	forced vital capacity
NAEPP	National Asthma Education and Prevention Program
NCHS	National Center for Health Statistics
NHANES	National Health and Nutrition Examination Survey
SE	standard error

References

1. National Asthma Education and Prevention Program (National Heart Lung and Blood Institute). Guidelines for the diagnosis and management of asthma: Full report 2007. Bethesda, MD: U.S. Dept. of Health and Human Services, National Institutes of Health, National Heart, Lung, and Blood Institute; 2007. Third Expert Panel on the Management of Asthma; xxii326
2. Nair SJ, Daigle KL, DeCuir P, Lapin CD, Schramm CM. The influence of pulmonary function testing on the management of asthma in children. J Pediatr. 2005; 147:797–801. [PubMed: 16356434]
3. Holt EW, Tan J, Hosgood HD. The impact of spirometry on pediatric asthma diagnosis and treatment. J Asthma. 2006; 43:489–493. [PubMed: 16939987]
4. Shirai T, Furuhashi K, Suda T, Chida K. Relationship of the asthma control test with pulmonary function and exhaled nitric oxide. Ann Allergy Asthma Immunol. 2008; 101:608–613. [PubMed: 19119704]
5. Green RJ, Klein M, Becker P, Halkas A, Lewis H, Kitchin O, Moodley T, Masekela R. Disagreement among common measures of asthma control in children. Chest. 2013; 143:117–122. [PubMed: 22878380]
6. Sardon-Prado O, Korta-Murua J, Valverde-Molina J, Fernandez-Paredes JJ, Mintegui J, Corcuera-Elosegui P, Emparanza JI, Perez-Yarza EG. Association among lung function, exhaled nitric oxide, and the CAN questionnaire to assess asthma control in children. Pediatr Pulmonol. 2010; 45:434–439. [PubMed: 20425850]
7. Rabe KF, Vermeire PA, Soriano JB, Maier WC. Clinical management of asthma in 1999: the Asthma Insights and Reality in Europe (AIRE) study. Eur Respir J. 2000; 16:802–807. [PubMed: 11153575]
8. Dombkowski KJ, Hassan F, Wasilevich EA, Clark SJ. Spirometry use among pediatric primary care physicians. Pediatrics. 2010; 126:682–687. [PubMed: 20819894]
9. Janson S, Weiss K. A national survey of asthma knowledge and practices among specialists and primary care physicians. J Asthma. 2004; 41:343–348. [PubMed: 15260468]
10. Johnson CL, Paulose-Ram R, Ogden CL, Carroll MD, Kruszon-Moran D, Dohrmann SM, Curtin LR. National Health and Nutrition Examination Survey: analytic guidelines, 1999–2010. Vital Health Stat. 2013; 161:1–24.

11. Curtin LR, Mohadjer LK, Dohrmann SM, Montaquila JM, Kruszan-Moran D, Mirel LB, Carroll MD, Hirsch R, Schober S, Johnson CL. The National Health and Nutrition Examination Survey: sample design, 1999–2006. Vital Health Stat. 2012; 155:1–39.
12. National Center for Health Statistics. NHANES Response Rates and CPS Totals. 2014
13. Centers for Disease Control and Prevention/National Center for Health Statistics. Spirometry - 1st Test & 2nd Test Bronchodilator Studies. 20132011
14. Centers for Disease Control and Prevention/National Center for Health Statistics. Respiratory Health Spirometry Procedures Manual. 2012
15. Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A, Crapo R, Enright P, van der Grinten CP, Gustafsson P, et al. Standardisation of spirometry. Eur Respir J. 2005; 26:319–338. [PubMed: 16055882]
16. Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A, Enright P, van der Grinten C, Gustafsson P, Jensen R, et al. Standardisation of lung function testing: the authors' replies to readers' comments. Eur Respir J. 2010; 36:1496–1498. [PubMed: 21119213]
17. Pellegrino R, Viegi G, Brusasco V, Crapo RO, Burgos F, Casaburi R, Coates A, van der Grinten CP, Gustafsson P, Hankinson J, et al. Interpretative strategies for lung function tests. Eur Respir J. 2005; 26:948–968. [PubMed: 16264058]
18. Tepper RS, Wise RS, Covar R, Irvin CG, Kercsmar CM, Kraft M, Liu MC, O'Connor GT, Peters SP, Sorkness R, et al. Asthma outcomes: pulmonary physiology. J Allergy Clin Immunol. 2012; 129:S65–S87. [PubMed: 22386510]
19. Hankinson JL, Odencrantz JR, Fedan KB. Spirometric reference values from a sample of the general U.S population. Am J Respir Crit Care Med. 1999; 159:179–187. [PubMed: 9872837]
20. Hankinson JL, Kawut SM, Shahar E, Smith LJ, Stukovsky KH, Barr RG. Performance of American Thoracic Society-recommended spirometry reference values in a multiethnic sample of adults: the multi-ethnic study of atherosclerosis (MESA) lung study. Chest. 2010; 137:138–145. [PubMed: 19741060]
21. Tilert T, Dillon C, Paulose-Ram R, Hnizdo E, Doney B. Estimating the U. S. prevalence of chronic obstructive pulmonary disease using pre- and post-bronchodilator spirometry: the National Health and Nutrition Examination Survey (NHANES) 2007–2010. Respir Res. 2013; 14:103. [PubMed: 24107140]
22. Wang X, Dockery DW, Wypij D, Fay ME, Ferris BG Jr. Pulmonary function between 6 and 18 years of age. Pediatr Pulmonol. 1993; 15:75–88. [PubMed: 8474788]
23. Research Triangle Institute. SUDAAN Language Manual, Release 10. Research Triangle Park, North Carolina: Research Triangle Institute; 2008.
24. Mannino DM, Homa DM, Redd SC. Involuntary smoking and asthma severity in children: data from the Third National Health and Nutrition Examination Survey. Chest. 2002; 122:409–415. [PubMed: 12171810]
25. Bacharier LB, Strunk RC, Mauger D, White D, Lemanske RF Jr, Sorkness CA. Classifying asthma severity in children: mismatch between symptoms, medication use, and lung function. Am J Respir Crit Care Med. 2004; 170:426–432. [PubMed: 15172893]
26. van Dalen C, Harding E, Parkin J, Cheng S, Pearce N, Douwes J. Suitability of forced expiratory volume in 1 second/forced vital capacity vs percentage of predicted forced expiratory volume in 1 second for the classification of asthma severity in adolescents. Arch Pediatr Adolesc Med. 2008; 162:1169–1174. [PubMed: 19047545]
27. Szefler SJ, Chmiel JF, Fitzpatrick AM, Giacoia G, Green TP, Jackson DJ, Nielsen HC, Phipatanakul W, Raissy HH. Asthma across the ages: knowledge gaps in childhood asthma. J Allergy Clin Immunol. 2014; 133:3–13. [PubMed: 24290281]
28. Stout JW, Visness CM, Enright P, Lamm C, Shapiro G, Gan VN, Adams GK 3rd, Mitchell HE. Classification of asthma severity in children: the contribution of pulmonary function testing. Arch Pediatr Adolesc Med. 2006; 160:844–850. [PubMed: 16894085]
29. Fuhlbrigge AL, Weiss ST, Kuntz KM, Paltiel AD. Forced expiratory volume in 1 second percentage improves the classification of severity among children with asthma. Pediatrics. 2006; 118:e347–e355. [PubMed: 16864642]

30. Kit BK, Simon AE, Ogden CL, Akinbami LJ. Trends in preventive asthma medication use among children and adolescents, 1988–2008. Pediatrics. 2012; 129:62–69. [PubMed: 22144697]

31. Quanjer PH, Weiner DJ. Interpretative consequences of adopting the Global Lungs 2012 reference equations for spirometry for children and adolescents. Pediatr Pulmonol. 2014; 49:118–125. [PubMed: 24115510]

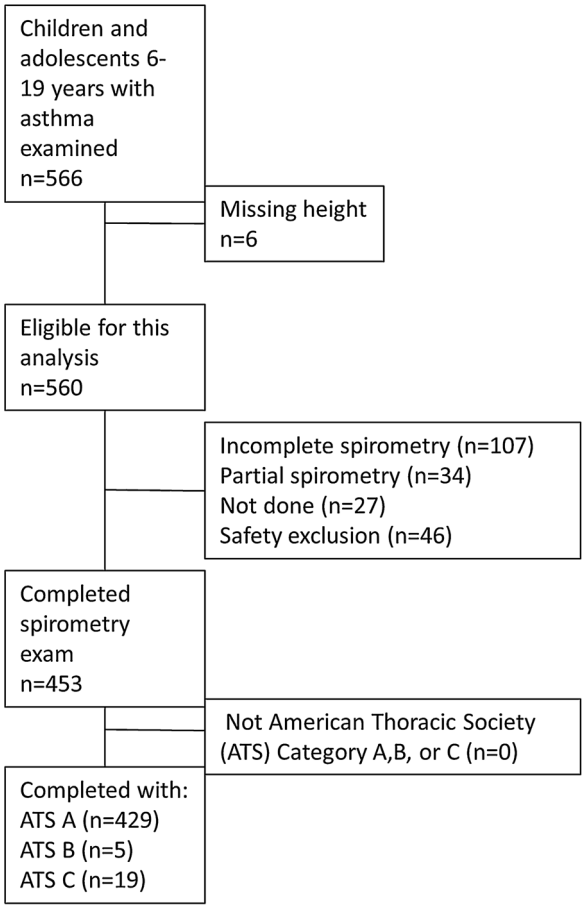

Fig. 1.

Final sample of children and adolescents age 6–19 years with current asthma[1], NHANES 2007–2010. Abbreviations: ATS, American Thoracic Society; NHANES, National Health and Nutrition Examination Survey. [1]Current asthma defined as an affirmative response to both of the following questions: “Has a doctor or health professional ever told you that you have asthma?” and “Do you still have asthma?”Notes: ATS Criteria for effort attribute: A—All 6 quality attributes acceptable; B—Large time to, or non-repeatable, peak flow; C—Either <6 sec of exhalation or no plateau.

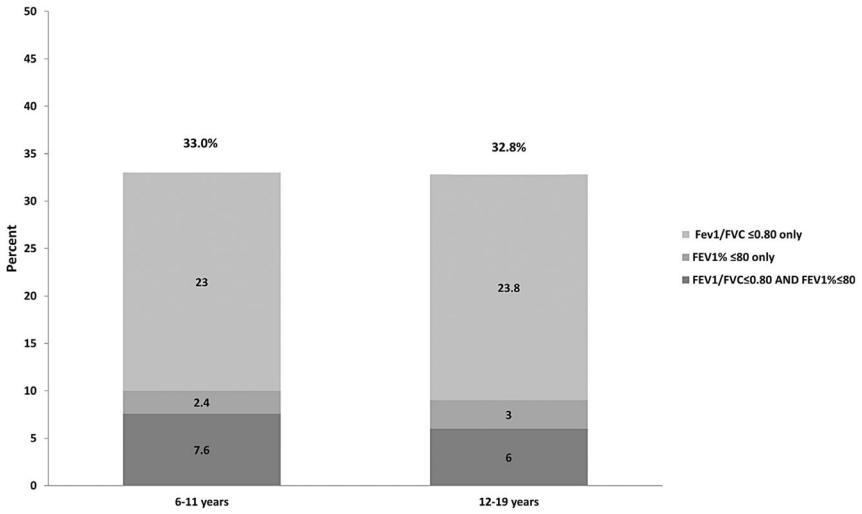

Fig. 2.

Mutually exclusive categories of FEV1% ≤80 and FEV1/FVC ≤0.80, by age, among children and adolescents age 6–19 years with current asthma[1], US, NHANES 2007–2010. Abbreviations: FEV1, forced expiratory volume at 1 sec; FEV1%, % predicted FEV1; FVC, forced vital capacity; NHANES, National Health and Nutrition Examination Survey. [1]Current asthma defined as an affirmative response to both of the following questions: "Has a doctor or health professional ever told you that you have asthma?" and "Do you still have asthma?" Notes: Difference between children 6–11 years and adolescents 12–19 years in FEV1% ≤80 and FEV1/FVC ≤0.80 (P=0.568), FEV1/FVC ≤0.80 only (P=0.859), and FEV1% ≤80 only (P=0.709) were not statistically different. Prevalence estimates are weighted.

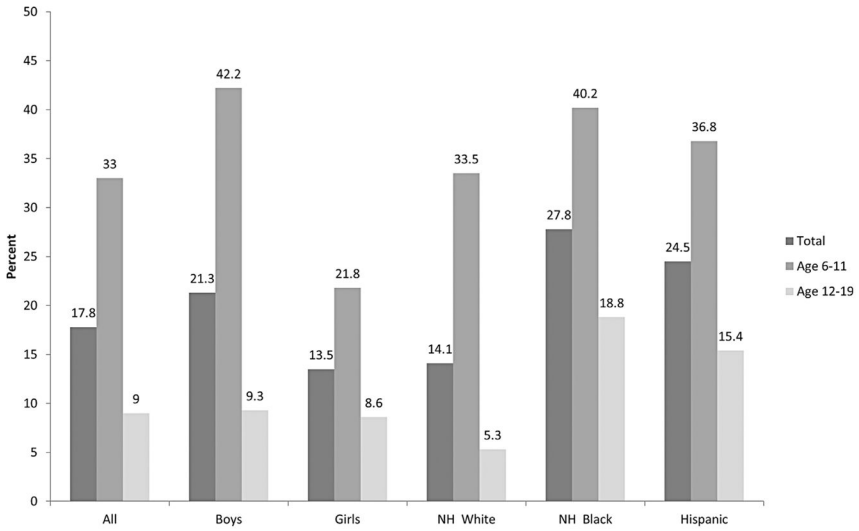

Fig. 3.

Prevalence of spirometry values consistent with uncontrolled asthma[1], by age, among children and adolescents age 6–19 years with current asthma[2], US, NHANES 2007–2010. Abbreviations: FEV1, forced expiratory volume at 1 sec; FEV1%, % predicted FEV1; FVC, forced vital capacity; NH, Non-Hispanic; NHANES, National Health and Nutrition Examination Survey. [1]Uncontrolled asthma defined by spirometry based on the NAEPP age-specific criteria for uncontrolled asthma: FEV1% ≤80 or FEV1/FVC ≤0.80 for children aged 6–11 years and FEV1% ≤80 for adolescents aged 12–19 years. [2]Current asthma defined as an affirmative response to both of the following questions: “Has a doctor or health professional ever told you that you have asthma?” and “Do you still have asthma?” Notes: For all (P<0.001), boys (P<0.001), non-Hispanic Whites (P <0.001), non-Hispanic Blacks (P=0.010), and Hispanics (P=0.004) the prevalence of spirometry values consistent with uncontrolled asthma between 6–11 and 12–19 year old were statistically different but it was not for girls (P=0.057). Participants with race/ Hispanic origin designated as “other” are included in totals and sex-specific analyses but not separately reported. Prevalence estimates are weighted.

TABLE 1

Sample Sizes and Mean FEV1% and FEV1/FVC Ratio, Children and Adolescents Age 6–19 years with current asthma[1], NHANES 2007–2010

	6–19 years		6–11 years		12–19 years	
	n	**% (SE)**	**n**	**% (SE)**	**n**	**% (SE)**
Total	453	100 (0.0)	207	36.8 (2.7)	246	63.2 (2.7)
Sex						
Boy	258	55.5 (2.7)	117	20.3 (2.1)	141	35.3 (2.4)
Girl	195	44.5 (2.7)	90	16.5 (2.1)	105	27.9 (2.2)
Race/Hispanic origin[2]						
Non-Hispanic White	136	56.0 (3.5)	54	17.5 (2.9)	82	38.5 (3.7)
Non-Hispanic Black	152	21.2 (2.6)	71	8.9 (1.6)	81	12.3 (1.6)
Hispanic	132	15.3 (2.3)	63	6.5 (1.0)	69	8.7 (1.7)
Mean (SE) Spirometry Values						
FEV1%	453	99.1(0.6)	207	100.3(1.1)	246	98.4(0.7)
FEV1/FVC[3]	453	83.0(0.5)	207	82.9(0.6)	246	83.1(0.7)

Abbreviations: FEV1- forced expiratory volume at 1 second; FEV1%- % predicted FEV1; FVC- forced vital capacity; NHANES- National Health and Nutrition Examination Survey; SE- standard error.

SOURCE: National Health and Nutrition Examination Survey.

NOTE: Sample sizes are unweighted and prevalence estimates are weighted.

[1]Current asthma defined as an affirmative response to both of the following questions: “Has a doctor or health professional ever told you that you have asthma?” and “Do you still have asthma?”

[2]Persons with race/Hispanic origin categorized as “other” are included in total but are not separately reported thus sample sizes and percentages do not sum to total.

[3]Mean Fev1/FVC expressed as a percentage.

TABLE 2

Prevalence of FEV1% ≤80 and FEV1/FVC ≤0.8, Children and Adolescents Age 6–19 Years With Current Asthma[1], NHANES 2007–2010

	FEV1% ≤80				FEV1/FVC ratio ≤0.80			
	% (SE)				% (SE)			
	6–19 years	6–11 years	12–19 years	*P*-value comparing 6–11 and 12–19 years	6–19 years	6–11 years	12–19 years	*P*-value comparing 6–11 and 12–19 years
Total	9.4(1.1)	10.1(2.0)	9.0(1.6)	0.695	30.1(3.7)	30.6(3.9)	29.8(4.3)	0.854
Sex								
Boy	10.4(1.9)	12.4(3.6)	9.3(2.4)	0.512	41.8(5.1)	40.2(5.5)	42.7(6.5)	0.721
Girl	8.1(1.7)	7.3(1.7)	8.6(2.6)*	0.681	15.5(3.0)	18.9(4.5)	13.5(4.0)	0.368
Race/Hispanic Origin[2]								
Non-Hispanic	5.5(1.7)[3]	*4*	*4*		29.5(5.6)	33.5(6.7)	27.6(6.4)	0.399
White Non-Hispanic	19.4(3.2)	20.3(4.7)	18.8(5.0)	0.837	39.7(3.9)	35.6(6.4)	42.7(5.7)	0.450
Black Hispanic	14.4(3.2)	13.1(3.9)	15.4(4.5)	0.685	25.9(4.7)	29.3(6.1)	23.4(5.7)	0.410

Abbreviations: FEV1, forced expiratory volume at 1 sec; FEV1%, % predicted FEV1; FVC, forced vital capacity; NHANES, National Health and Nutrition Examination Survey; SE, standard error.

SOURCE: National Health and Nutrition Examination Survey.

NOTE: Prevalence estimates are weighted.

[1] Current asthma defined as an affirmative response to both of the following questions: “Has a doctor or health professional ever told you that you have asthma?” and “Do you still have asthma?”

[2] Persons with race/Hispanic origin categorized as “other” are included in total but are not separately reported

[3] Relative standard error ≥30% but <40%;

[4] Relative standard error ≥40%