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Asthma medication use among adults with current asthma by work-related asthma status, Asthma Call-back Survey, 29 states, 2012–2013

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Abstract

Objective—Asthma severity is defined as the intensity of treatment required to achieve good control of asthma symptoms. Studies have shown that work-related asthma (WRA) can be associated with poorer asthma control and more severe symptoms than non-WRA. Associations between asthma medications and WRA status were assessed using data from the 2012–2013 Asthma Call-back Survey among ever-employed adults (≥18 years) with current asthma from 29 states.

Methods—Persons with WRA had been told by a physician that their asthma was work-related. Persons with possible WRA had asthma caused or made worse by their current or previous job, but did not have physician-diagnosed WRA. Asthma medications were classified as controller (i.e., long-acting β-agonist, inhaled corticosteroid, oral corticosteroid, cromolyn/nedocromil, leukotriene pathway inhibitor, methylxanthine, anticholinergics) and rescue (i.e., short-acting β-agonist). Demographic and clinical characteristics were examined. Associations between asthma medications and WRA status were assessed using a multivariate logistic regression to calculate adjusted prevalence ratios (PRs).

Results—Among an estimated 15 million ever-employed adults with current asthma, 14.7% had WRA and an additional 40.4% had possible WRA. Compared with adults with non-WRA, those with WRA were more likely to have taken anti-cholinergics (PR=1.80), leukotriene pathway inhibitor (PR=1.59), and methylxanthine (PR=4.76), and those with possible WRA were more likely to have taken methylxanthine (PR = 2.85).

Conclusions—Results provide additional evidence of a higher proportion of severe asthma among adults with WRA compared to non-WRA. To achieve optimal asthma control, adults with

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Declaration of interest

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WRA may require additional intervention, such as environmental controls or removal from the workplace exposure.

Keywords

ACBS; BRFSS; WRA

Introduction

Asthma is a chronic airway disease that affected 18.7 million adults in the United States in 2010 [1]. Symptoms of asthma include shortness of breath, chest tightness, and wheezing caused by airflow obstruction due to reversible narrowing of bronchial airways and an increase in bronchial responsiveness to inhaled stimuli [1, 2]. In 2009, asthma was responsible for more than 1.3 million emergency department visits, 350 000 hospitalizations, and 3500 deaths among adults with current asthma [1]. Work-related asthma (WRA) is the asthma that is caused or made worse by workplace exposures, and has been associated with poorer asthma control, increased asthma attacks, more emergency department visits, greater asthma-related hospitalizations, and more frequent urgent treatment for worsening asthma [3, 4].

For most asthma patients, asthma symptoms can be controlled by implementing effective asthma treatment and environmental controls [5]. The National Asthma Education and Prevention Program's (NAEPP) *Expert Panel Report 3 (EPR-3): Guidelines for the Diagnosis and Management of Asthma* recommends rescue medications to treat acute symptoms and exacerbations, and long-term controller medications to achieve and maintain control of persistent asthma [2]. A stepwise approach to therapy, in which the number and frequency of medications are increased as asthma worsens and decreased as control is achieved, is recommended to maintain optimum control of asthma symptoms with the lowest possible dose of medications [2].

Early diagnosis and removal of asthma patients from workplace exposures have been shown to improve WRA symptoms [4, 6-8]. However, some adults elect to remain in their current workplace because they are unable to find alternative employment. In addition, others may have persistent symptoms despite removal [6]. A previous study estimated that 62% of the WRA patients have poorly controlled asthma [3]. Underutilization of available asthma treatments and poor management may be reflected in more frequent emergency department visits and hospitalizations, particularly as seen among adults with WRA [5, 9].

Previous studies using data from the Behavioral Risk Factor Surveillance System (BRFSS) Asthma Call-back Survey have assessed controller medications among adults with current asthma [10, 11]. Knoeller et al. [9] found that adults with WRA take significantly more prescription medications than those with non-WRA. However, a detailed analysis of medications taken by adults with WRA has not been performed [9-11]. Also, asthma severity in these studies has not been assessed using the 2009 European Respiratory Society (ERS) and the American Thoracic Society (ATS) guidelines that defined severity as the difficulty in controlling asthma with treatment [3, 12, 13]. Here, we report on asthma

medications and asthma severity among adults with WRA using data from the 2012–2013 Asthma Call-back Survey.

Methods

The BRFSS is a state-based, random-digit-dialed landline and cellular telephone survey of the non-institutionalized U.S. population aged ≥18 years that collects information on health risk factors, preventive health practices, and disease status [14]. BRFSS includes a standard set of core questions, optional modules, and state-added questions. BRFSS respondents who have ever been told by a health professional that they have asthma are invited to participate in the Asthma Call-back Survey, an optional module [15]. Those who agree to participate are interviewed within 2 weeks of the initial BRFSS interview and detailed information on asthma, including WRA, is collected. The Asthma Call-back Survey was administered among adults in 22 states in 2012 and 28 states in 2013. The median American Association for Public Opinion Research response rate in 2012 among the 22 states was 44.9% (range: 27.7–56.8%) for BRFSS and 47.2% (range: 38.5–60.6%) for Asthma Call-back Survey, and in 2013 among the 28 states was 43.9% (range: 31.1–57.2%) for BRFSS and 46.0% (range: 32.5–57.1%) for Asthma Call-back Survey. The Institutional Review Board at the Centers for Disease Control and Prevention has granted a surveillance exemption for BRFSS. Participating states are subject to state-specific Institutional Review Board requirements. Reports of selected statistical indicators of 2013 BRFSS data quality (outcome measures, selection biases, and missing values) are available at http://www.cdc.gov/brfss/annual_data/2013/pdf/2013_dqr.pdf.

Using previously established definitions, this study analyzed data on the ever-employed adults with current asthma [3, 9, 12]. Survey participants who responded “yes” to the questions “Have you ever been told by a doctor or other health professional that you have asthma?” and “Do you still have asthma?” had current asthma. Ever-employed participants were those who indicated that they were currently employed full-time, part-time, or had ever been employed. Participants who responded “yes” to the question “Have you ever been told by a doctor or other health professional that your asthma was caused by, or your symptoms made worse by, any job you ever had?” had WRA. Adults with possible WRA were those who did not have WRA and described their asthma as caused by or made worse by things like chemicals, smoke, dust, or mold in their current or previous job. Adults with current asthma who did not have WRA or possible WRA had non-WRA.

The Asthma Call-back Survey asked respondents about their prescription medication use during the 3 months preceding the interview. For this study, medications were classified as controller (i.e., long-acting β-agonist [LABA], inhaled corticosteroid, oral corticosteroid, cromolyn/nedocromil, leukotriene pathway inhibitor, methylxanthine, anti-cholinergics) or rescue (i.e., short-acting β-agonist [SABA]) and grouped into six treatment groups following EPR-3 guidelines (online Appendix 1) [2].

Smoking status was defined as current (i.e., smoked ≥100 cigarettes during lifetime and currently smoke every day or some days), former (i.e., smoked ≥100 cigarettes during lifetime and currently do not smoke at all), and never (i.e., never smoked or smoked <100

cigarettes during lifetime). Adverse asthma outcomes, including asthma attack, emergency room visit, hospital stay, and urgent treatment for worsening asthma in the last 12 months, were classified using previously developed definitions [3, 9]. Asthma control was defined according to EPR-3 guidelines and categorized into well controlled, not well controlled, and very poorly controlled based on the category with the most severe impairment using responses to questions on asthma symptoms, nighttime awakenings, and SABA medication use for symptom control [2, 3].

Asthma severity was defined, using EPR-3 and the ERS/ATS Severe Asthma Guidelines, as intermittent and persistent according to respondents' level of asthma control and use of asthma controller medications [2, 16]. Adults with well-controlled asthma not using long-term control medications had intermittent asthma. Adults using long-term control medications, regardless of their asthma control, and those with uncontrolled asthma not taking long-term control medications had persistent asthma.

The 2012–2013 Asthma Call-back Survey data collected from 29 states using landline and cellular telephone samples were weighted to account for non-coverage, unequal probability of sample selection, and survey non-response to produce estimates which are representative of these state populations. Analyses were performed using SAS software version 9.3 (SAS Institute Inc., Cary, NC) and SUDAAN release 11.0.1 software (Research Triangle Institute, Research Triangle Park, NC). Data from 2012 to 2013 were combined and re-weighted by multiplying the percentage of subjects in each state and survey year by the corresponding survey year's weight. Weights were unaltered for states with 1 year of data available. Estimates were not reported if the relative standard error was >30% or the estimate was based on a sample of <50 respondents [14].

We examined demographic and clinical characteristics of ever-employed adults with current asthma. The Rao–Scott chi-square test was used to assess associations between selected characteristics and a history of using asthma medications. A multivariate logistic regression was used to calculate adjusted prevalence ratios (PRs) for the associations among WRA status, asthma medications (drug class and treatment group), adverse asthma outcomes, and asthma control by asthma medication use. Age (continuous), sex, race/ethnicity, income, education, current employment status, smoking status, health insurance, chronic obstructive pulmonary disease (COPD), depression, and adverse asthma outcomes were all independently associated with WRA status and a history of taking asthma medication, and were simultaneously included in the multivariate logistic regression models. Using backward selection, non-significant covariates were removed from the model. Sex and race/ethnicity remained in the model regardless of significance because previous research has shown associations with either WRA status or asthma medication [17, 18]. Results were considered statistically significant at an alpha of <0.05.

Results

In the 29 states during 2012–2013, a sample of 20 823 adults participated in the Asthma Call-back Survey. Of these, 14 915 were ever-employed adults with current asthma. Participants with no current asthma (n = 5,123), who were never employed (n = 305), and

with missing information on employment or current asthma status (n = 480) were excluded from analyses.

Among an estimated 15 million ever-employed adults with current asthma in these 29 states, an estimated 14.7% had WRA and an additional 40.4% had possible WRA (Table 1). Overall, 64.9% (95% CI = 63.0–66.8) of the ever-employed adults with current asthma used any asthma medication in the 3 months preceding the interview; this proportion varied from 69.5% for adults with WRA to 67.3% for adults with possible WRA, and 61.2% for those with non-WRA. Age, sex, health insurance, and smoking status were significantly associated with a history of asthma medication use in the 3 months preceding the interview (Table 1).

Proportion of ever-employed adults with current asthma taking asthma controller medications by the number of medications and WRA status is shown in Table 2. Compared with adults with non-WRA, those with WRA and possible WRA were more likely to be taking ≥3 asthma controller medications (PR = 2.66, 95% CI = 1.67–4.26 and PR = 1.98, 95% CI = 1.34–2.93, respectively).

Proportion of ever-employed adults with current asthma taking specific asthma medications by asthma drug class and WRA status is shown in Table 3. Those with WRA were more likely to be taking anti-cholinergics (PR = 1.80, 95% CI = 1.05–3.06), leukotriene pathway inhibitor (PR = 1.59, 95% CI = 1.22–2.07), and methylxanthine (PR = 4.76, 95% CI = 2.06–11.0) than those without WRA (Table 3). Furthermore, an analysis by treatment regimen showed that, compared with non-WRA, adults with WRA were more likely to be taking a combination of inhaled corticosteroids and either a leukotriene pathway inhibitor or methylxanthine in addition to taking SABA as needed (PR = 2.21, 95% CI = 1.57–3.11) (Table 4). Those with possible WRA were more likely to be taking methylxanthine (PR = 2.85, 95% CI = 1.55–5.23) (Table 3), and were more likely to be taking a combination of inhaled corticosteroids and either a leukotriene pathway inhibitor or methylxanthine in addition to SABA (PR = 1.41, 95% CI = 1.05–1.89) (Table 4).

Associations among WRA, adverse asthma outcomes, and asthma control by history of medication use are shown in Table 5. Adults with WRA were more likely than those with non-WRA to have adverse asthma outcomes in the last 12 months including an asthma attack (PR = 1.62, 95% CI = 1.47–1.79), urgent treatment for worsening asthma (PR = 1.51, 95% CI = 1.28–1.77), an asthma-related emergency room visit (PR = 1.65, 95% CI = 1.24–2.20), and to have very poorly controlled asthma (PR = 1.54, 95% CI = 1.28–1.86). By a history of asthma medication use in the last 3 months, the associations between WRA and having an asthma attack (PR = 2.16, 95% CI = 1.72–2.70), and unscheduled treatment (PR = 2.13, 95% CI = 1.38–3.30) were stronger among adults who did not take asthma medication compared with those who took asthma medication (PR = 1.42, 95% CI = 1.28–1.57 and PR = 1.18, 95% CI = 1.02–1.35, respectively). Also, very poorly controlled asthma remained associated with WRA among individuals who had taken medications in the last 3 months (Table 5).

By asthma severity, 75.2% of the adults with WRA had persistent asthma, compared to 57.9% of the adults with non-WRA (PR = 1.07, 95% CI = 0.98–1.18). Similarly, 69.8% of

the adults with possible WRA had persistent asthma, significantly greater than those with non-WRA (PR = 1.09, 95% CI = 1.02–1.16).

Discussion

This is the first study to use Asthma Call-back Survey data to evaluate the specific use of asthma medication among adults with WRA. Results indicate that adults with WRA were more likely than those with non-WRA to be taking less commonly prescribed medications, including anti-cholinergics, leukotriene pathway inhibitors, and methylxanthines. Those with possible WRA were more likely to be taking methylxanthines than those with non-WRA. Moreover, adults with WRA were significantly more likely than those with non-WRA to have used two or more controller medications, and to be taking medications recommended for controlling severe asthma symptoms (i.e., combination of inhaled corticosteroid and either a leukotriene pathway inhibitor or methylxanthine in addition to SABA, as needed). These findings are consistent with previous reports using data from Asthma Call-back Survey that persons with WRA used significantly more asthma medications in the past 3 months than individuals with non-WRA (1.5 vs 1.3; $p < 0.001$) and those with WRA had more severe asthma symptoms, higher healthcare utilization, and less well-controlled asthma than those with non-WRA [3, 9, 12].

Early diagnosis and elimination of exposures may resolve asthma symptoms and should be considered first in the management of asthma [4, 6-8]. In addition, the reduction of exposure may be considered when appropriate for some adults with irritant-induced asthma and asthma exacerbated by work [4, 6, 7, 19]. However, WRA is often under recognized and, if it is diagnosed, may be difficult to manage, resulting in delayed or inadequate medical care [4, 20]. A recent study showed as few as one in seven employed adults with asthma talk to their clinician about the possible relation between work and their asthma [21]. Moreover, some adults may choose to remain in their current workplace, and thus exposed, due to adverse social and financial consequences associated with job loss or job change [22]. The large proportion of adults taking medications in this study may represent a missed opportunity for control of exposures or removal, and the subsequent need for pharmaceutical intervention. Physicians should collect a thorough occupational history in all working adults with new-onset or exacerbated asthma. Establishing a WRA diagnosis and recommending appropriate management are necessary to improve health outcomes among these individuals [4, 6, 8].

In this study, adults with WRA were more likely than adults with non-WRA to be taking anti-cholinergic medications (i.e., ipratropium bromide, a bronchodilator indicated for the treatment of COPD) [23]. While ipratropium bromide has been used in addition to SABA to treat asthma attacks, its use among adults with WRA may suggest asthma–COPD overlap syndrome (ACOS) [24]. ACOS is characterized by overlapping clinical features of both asthma and COPD, and has been associated with more symptoms and worse outcomes than asthma or COPD alone [25-28]. Results from a previous report using the 2006–2008 Asthma Call-back Survey data indicated that 52% of the adults with WRA also have COPD [3]. An ACOS diagnosis among adults with WRA not responding to traditional asthma medication despite adherence to treatment guidelines may lead to better clinical characterization and

improved treatment among these patients [25]. Future studies should examine how overlap between COPD and WRA may impact WRA management.

Optimal control of asthma depends on the avoidance or reduction of exposures, correct inhaler technique, medication compliance, and appropriate recognition and response to an asthma episode [2, 4, 29, 30]. Lack of asthma control among adults with WRA may be explained, in part, by inadequate asthma management education in some patients (e.g., older adults, those with less formal education, and cigarette smokers) [31]. Moreover, asthma-related misconceptions (i.e., patients only have asthma when symptoms are present, asthma can be cured rather than symptoms controlled) and low health literacy may contribute to poor asthma medication compliance and adverse health outcomes [32].

Over one-third of the adults were not taking any asthma medications in the last 3 months, despite evidence of adverse asthma outcomes and uncontrolled asthma symptoms among some of these individuals. Moreover, over half of the adults with WRA and possible WRA were not taking any controller medications. This was similar to the findings by Zahran et al. [10] who found that only 53% of the adults with uncontrolled asthma were on long-term control medications. Adults may perceive taking asthma medication to have greater risks than benefits, or their asthma to be well controlled when it is not, and may not take asthma medications as prescribed [32-34]. Additionally, over a quarter of the adults with WRA experience financial barriers and may take less than the recommended dose or are unable to buy medications [9]. However, because the Asthma Call-back Survey is a cross-sectional survey, the temporal relationship of adverse asthma outcomes to a history of asthma medication use could not be established.

At least four asthma phenotypes (i.e., paucigranulocytic, eosinophil predominant, neutrophil predominant, and mixed granulocytic) have been identified through a cluster of analyses of clinical, physiological, and laboratory features [5, 35]. Available treatments may be less effective for some asthma phenotypes with more severe symptoms; thus, distinguishing asthma phenotypes among workers with WRA may provide the opportunity for more targeted treatment options for some patients with WRA [2, 5, 36]. Biological treatments have been developed to treat severe allergic asthma and include omalizumab, mepolizumab, and reslizumab [37-40]. In this study, only one respondent indicated using omalizumab in the 3 months preceding the interview. The American College of Chest Physicians concluded that immunotherapy may effectively manage sensitizer-induced occupational asthma when the causative agent cannot be avoided and the allergen extract is available [4, 6]. However, limited evidence exists on the efficacy of immunotherapy for adults with WRA. Exposure avoidance is the preferred primary strategy to reduce signs and symptoms of WRA. Removal of the workers with sensitizer-induced WRA from further exposure in addition to another asthma management may be necessary [4, 41].

This study is subject to additional limitations. Information on asthma and medications was self-reported and not validated by medical records or follow up with health care providers. Also, the survey did not collect information on the medication dose or duration of treatment; thus, it was necessary to combine some treatment groups (i.e., low-dose inhaled corticosteroid, medium-dose inhaled corticosteroid, and high-dose inhaled corticosteroid).

The Asthma Call-back Survey was not designed to collect information on the timing of WRA diagnosis or episodes of asthma worsening. Moreover, no data were available to categorize WRA cases as new-onset or work-exacerbated asthma. Small sample sizes for some subgroups resulted in unreliable estimates that were not reported. Finally, data used in this analysis were for adults living in 29 states; therefore, results may not be nationally representative or representative of non-participating states.

Conclusions

The results of this study provide additional evidence of severe asthma among individuals with WRA. Adults with WRA were taking more medications for their asthma and those less commonly prescribed medications typically recommended for more severe asthma symptoms; however, despite treatment, adults with WRA were still more likely to have adverse asthma outcomes and less well-controlled asthma than adults with non-WRA. Collection of detailed information on occupational exposures, asthma triggers, and determination of asthma phenotype is critical for accurate WRA diagnosis and implementation of targeted interventions to achieve optimal asthma symptom control [4, 20]. Physicians should focus on optimizing and intensifying guideline-directed treatment to improve asthma control, and may consider prescribing phenotype-specific treatments [2]. Physicians should also consider counseling patients to reduce or avoid workplace exposures, particularly for patients with difficult-to-control or sensitizer-induced asthma [4].

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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References

1. Moorman JE, Akinbami LJ, Bailey CM, Zahran HS, King ME, Johnson CA, et al. National surveillance of asthma: United States, 2001–2010. Vital Health Stat. 2012; 3(35):1–67.
2. Expert Panel Report 3 (EPR-3). Guidelines for the Diagnosis and Management of Asthma-Summary Report 2007. J Allergy Clin Immunol. 2007; 120(5 Suppl):S94–138. [PubMed: 17983880]
3. Knoeller GE, Mazurek JM, Moorman JE. Characteristics associated with health care professional diagnosis of work-related asthma among individuals who describe their asthma as being caused or made worse by workplace exposures. J Occup Environ Med. 2012; 54(4):485–490. [PubMed: 22453813]
4. Tarlo SM, Balmes J, Balkissoon R, Beach J, Beckett W, Bernstein D, et al. Diagnosis and management of work-related asthma: American College of Chest Physicians Consensus Statement. Chest. 2008; 134(3 Suppl):1S–41S. [PubMed: 18779187]
5. GalanterJ, , BousheyH. Chapter 20: Drugs Used in Asthma. In: KatzungB, , TrevorA, editorsBasic & clinical pharmacology13th ed. New York, NY: McGraw-Hill; 2015339357
6. Vandenplas O, Dressel H, Nowak D, Jamart J. What is the optimal management option for occupational asthma? Eur Respir Rev. 2012; 21(124):97–104. [PubMed: 22654081]

7. Tarlo S. Clinical aspects of work-related asthma: past achievements, persistent challenges, and emerging triggers. J Occup Environ Med. 2014; 56(Suppl 10):S40–44.
8. Baur X, Sigsgaard T, Aasen TB, Burge PS, Heederik D, Henneberger P, et al. Guidelines for the management of work-related asthma. Eur Respir J. 2012; 39(3):529–545. [PubMed: 22379148]
9. Knoeller GE, Mazurek JM, Moorman JE. Work-related asthma, financial barriers to asthma care, and adverse asthma outcomes: Asthma Call-Back survey, 37 states and District of Columbia, 2006 to 2008. Med Care. 2011; 49(12):1097–1104. [PubMed: 22002642]
10. Zahran HS, Bailey CM, Qin X, Moorman JE. Assessing asthma control and associated risk factors among persons with current asthma - findings from the child and adult Asthma Call-back Survey. J Asthma. 2015; 52(3):318–326. [PubMed: 25144551]
11. Zahran HS, Bailey CM, Qin X, Johnson C. Long-term control medication use and asthma control status among children and adults with asthma. J Asthma. 2017 Epub.
12. Knoeller GE, Mazurek JM, Moorman JE. Asthma symptoms among adults with work-related asthma. J Asthma. 2013; 50(2):166–173. [PubMed: 23259750]
13. Reddel HK, Taylor DR, Bateman ED, Boulet LP, Boushey HA, Busse WW, et al. An official American Thoracic Society/European Respiratory Society statement: asthma control and exacerbations: standardizing endpoints for clinical asthma trials and clinical practice. Am J Respir Crit Care Med. 2009; 180(1):59–99. [PubMed: 19535666]
14. Centers for Disease Control and Prevention (CDC). [April 27, 2015] Behavioral Risk Factor Surveillance System. Updated March 19; Available from: http://www.cdc.gov/brfss/about/index.htm
15. Centers for Disease Control and Prevetion (CDC). BRFSS Asthma Call-back SurveyAccessed April 27, 2015. Updated June 9; Available from: http://www.cdc.gov/brfss/acbs/index.htm
16. Chung KF, Wenzel SE, Brozek JL, Bush A, Castro M, Sterk PJ, et al. International ERS/ATS guidelines on definition, evaluation and treatment of severe asthma. Eur Respir J. 2014; 43(2):343–373. [PubMed: 24337046]
17. Knoeller GE, Mazurek JM, Moorman JE. Work-related asthma among adults with current asthma in 33 states and DC: evidence from the Asthma Call-back Survey, 2006– 2007. Public Health Rep. 2011; 126(4):603–611. [PubMed: 21800756]
18. Deshpande M, Chewning B, Mott D, Thorpe JM, Young HN. Asthma medication use among late midlife US Adults. J Asthma. 2016; 53(3):261–268. [PubMed: 26365527]
19. Henneberger PK, Redlich CA, Callahan DB, Harber P, Lemiere C, Martin J, et al. An official American Thoracic Society statement: work-exacerbated asthma. Am J Respir Crit Care Med. 2011; 184(3):368–378. [PubMed: 21804122]
20. Legiest B, Nemery B. Management of work-related asthma: guidelines and challenges. Eur Respir Rev. 2012; 21(124):79–81. [PubMed: 22654078]
21. Mazurek JM, Storey E. Physician-patient communication regarding asthma and work. Am J Prev Med. 2012; 43(1):72–75. [PubMed: 22704750]
22. Vandenplas O, Toren K, Blanc PD. Health and socioeconomic impact of work-related asthma. Eur Respir J. 2003; 22(4):689–697. [PubMed: 14582924]
23. Alvarado-Gonzalez A, Arce I. Tiotropium Bromide in chronic obstructive pulmonary disease and bronchial asthma. J Clin Med Res. 2015; 7(11):831–839. [PubMed: 26491494]
24. Global Initiative for Asthma GIfCOLD. Diagnosis of Diseases of Chronic Airflow Limitation: Asthma COPD and Asthma-COPD Overlap Syndrome (ACOS). 2015
25. van den Berge M, Aalbers R. The asthma-COPD overlap syndrome: how is it defined and what are its clinical implications? J Asthma Allergy. 2016; 9:27–35. [PubMed: 26929652]
26. Nielsen M, Barnes CB, Ulrik CS. Clinical characteristics of the asthma-COPD overlap syndrome–a systematic review. Int J Chron Obstruct Pulmon Dis. 2015; 10:1443–1454. [PubMed: 26251584]
27. Alshabanat A, Zafari Z, Albanyan O, Dairi M, FitzGerald JM. Asthma and COPD overlap syndrome (ACOS): A systematic review and meta analysis. PLoS One. 2015; 10(9):e0136065. [PubMed: 26336076]
28. Malo JL, Tarlo SM, Sastre J, Martin J, Jeebhay MF, Le Moual N, et al. An official American Thoracic Society Workshop Report: presentations and discussion of the fifth Jack Pepys Workshop

on Asthma in the Workplace. Comparisons between asthma in the workplace and non-work-related asthma. Ann Am Thoracic Soc. 2015; 12(7):S99–s110.

29. Scichilone N. Asthma control: the right inhaler for the right patient. Adv Ther. 2015; 32(4):285–292. [PubMed: 25845769]
30. Price D, Harrow B, Small M, Pike J, Higgins V. Establishing the relationship of inhaler satisfaction, treatment adherence, and patient outcomes: a prospective, real-world, cross-sectional survey of US adult asthma patients and physicians. World Allergy Org J. 2015; 8(1):26.
31. Zahran HS, Person CJ, Bailey C, Moorman JE. Predictors of asthma self-management education among children and adults–2006–2007 Behavioral Risk Factor Surveillance System Asthma Call-back Survey. J Asthma. 2012; 49(1):98–106. [PubMed: 22216949]
32. Federman AD, Wolf M, Sofianou A, Wilson EA, Martynenko M, Halm EA, Leventhal H, et al. The association of health literacy with illness and medication beliefs among older adults with asthma. Patient Educ Couns. 2013; 92(2):273–278. [PubMed: 23523196]
33. Ponieman D, Wisnivesky JP, Leventhal H, Musumeci-Szabo TJ, Halm EA. Impact of positive and negative beliefs about inhaled corticosteroids on adherence in innercity asthmatic patients. Ann Allergy Asthma Immunol. 2009; 103(1):38–42. [PubMed: 19663125]
34. Barnes PJ. Achieving asthma control. Curr Med Res Opin. 2005; 21(Suppl 4):S5–9.
35. Moore WC, Hastie AT, Li X, Li H, Busse WW, Jarjour NN, Wenzel SE, et al. Sputum neutrophil counts are associated with more severe asthma phenotypes using cluster analysis. J Allergy Clin Immunol. 2014; 133(6):1557–1563. [PubMed: 24332216]
36. de Nijs SB, Venekamp LN, Bel EH. Adult-onset asthma: is it really different? Eur Respir Rev. 2013; 22(127):44–52. [PubMed: 23457164]
37. U.S. Food and Drug Administration. Omalizumab Product Approval Information - Licensing ActionAccessed August 1, 2016. Updated May 6, 2016; Available from: http://www.fda.gov/drugs/developmentapprovalprocess/howdrugsaredevelopedandapproved/approvalapplications/therapeuticbiologicapplications/ucm093373.htm
38. Omalizumab [package insert]Genentech, Inc.; South San Francisco, CA: Accessed August 1, 2016. Available from: http://www.fda.gov/downloads/drugs/developmentapprovalprocess/howdrugsaredevelopedandapproved/approvalapplications/therapeuticbiologicapplications/ucm113454.pdf
39. U.S. Food and Drug Administration. Cinqair (reslizumab)Accessed 22 August, 2016. Updated 5 May 2016. Available from: http://www.accessdata.fda.gov/drugsatfda_docs/nda/2016/761033Orig1s000TOC.cfm
40. U.S. Food and Drug Administration. Nucala (mepolizumab) Lyophilized Powder for Subcutaneous InjectionAccessed 22 August, 2016. Updated 11 December 2015. Available from: http://www.accessdata.fda.gov/drugsatfda_docs/nda/2015/125526Orig1s000TOC.cfm
41. Heederik D, Henneberger PK, Redlich CA. Primary prevention: exposure reduction, skin exposure and respiratory protection. Eur Respir Rev. 2012; 21(124):112–124. [PubMed: 22654083]

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Table 1

Characteristics of ever-employed adults with current asthma by history of medication use in the last 3 months.

		Weighted		Medication use in last 3 months	No medication use in last 3 months
	No. in Sample[a]	No.[a]	%[b] (95% CI)	%[b] (95% CI)	%[b] (95% CI)
Total	14 915	15 120 762		100.0	100.0
Age[c]					
18–44	3099	6 841 498	45.4 (43.4–47.4)	40.4 (37.9–42.8)	54.7 (51.4–58.1)
45–64	6824	5 591 020	37.1 (35.4–38.8)	39.5 (37.3–41.6)	32.8 (29.8–35.7)
≥65	4929	2 634 581	17.5 (16.4–18.6)	20.2 (18.7–21.6)	12.5 (11.0–14.0)
Sex[c]					
Male	4307	5 206 981	34.4. (32.6–36.3)	32.7 (30.5–34.8)	37.7 (34.3–41.2)
Female	10 608	9 913 780	65.6 (63.7–67.4)	67.3 (65.2–69.5)	62.3 (58.8–65.7)
Race/ethnicity					
Non-Hispanic, white	11 794	10 517 631	70.5 (68.6–72.5)	71.0 (68.5–73.4)	69.8 (66.3–73.3)
Non-Hispanic, black	1124	1 840 601	12.3 (10.9–13.8)	12.8 (11.0–14.5)	11.6 (9.2–14.0)
Hispanic	695	1 547 548	10.4 (8.9–11.9)	9.1 (7.3–10.9)	12.7 (9.9–15.6)
Other	1108	1 005 121	6.7 (5.6–7.9)	7.2 (5.6–8.7)	5.9 (4.2–7.7)
Education					
≤High school	5356	5 558 676	36.8 (34.9–38.7)	37.2 (35.0–39.5)	36.0 (32.7–39.3)
Some college	4540	5 607 025	37.1 (35.2–39.1)	36.4 (34.1–38.7)	38.5 (34.9–42.0)
College graduate	5003	3 942 694	26. 1 (24.6–27.6)	26.4 (24.6–28.2)	25.6 (22.8–28.4)
Household income					
<$15,000	2586	2 299 211	17.1 (15.6–18.6)	18.0 (16.2–19.8)	15.4 (12.7–18.1)
$15,000–$24,999	2779	2 470 877	18.4 (16.9–19.9)	17.7 (15.9–19.5)	19.6 (17.0–22.2)
$25,000–$34,999	1482	1 363 071	10.1 (8.9–11.4)	10.3 (8.9–11.6)	9.9 (7.5–12.3)
$35,000–$49,999	1757	1 654 115	12.3 (11.1–13.5)	12.3 (10.8–13.7)	12.3 (10.1–14.5)
≥$50,000	4834	5 664 151	42.1 (40.1–44.1)	41.7 (39.4–44.1)	42.8 (39.2–46.4)
Health insurance[c]					
Yes	13 493	13 069 439	86.6 (85.2–88.0)	88.3 (86.6–90.0)	83.6 (81.1–86.1)
No	1390	2 016 308	13.4 (12.0–14.8)	11.7 (10.0–13.4)	16.4 (13.9–18.9)
Smoking status[c]					

		Weighted			
	No. in Sample[a]	**No.[a]**	**%[b] (95% CI)**	**Medication use in last 3 months %[b] (95% CI)**	**No medication use in last 3 months %[b] (95% CI)**
Current	2568	3 017 332	20.0 (18.4–21.6)	20.7 (18.8–22.6)	18.7 (15.8–21.6)
Former	5068	4 152 733	27.5 (25.9–29.1)	30.4 (28.4–32.4)	22.2 (19.6–24.8)
Never	7237	7 910 921	52.5 (50.5–54.4)	48.9 (46.6–51.2)	59.1 (55.7–62.5)
Asthma status					
WRA	2338	2 224 263	14.7 (13.4–16.0)	15.8 (14.1–17.4)	12.8 (10.6–15.0)
Possible WRA	6209	6 094 064	40.4 (38.5–42.2)	41.8 (39.6–44.1)	37.6 (34.2–40.9)
Non-WRA	6338	6 784 072	44.9 (43.0–46.9)	42.4 (40.1–44.7)	49.6 (46.1–53.1)
Asthma control					
Well controlled	6743	7 554 008	50.0 (48.0–51.9)	47.4 (36.1–58.6)	96.3 (95.0–97.5)
Not well controlled	3959	3 855 751	25.5 (23.9–27.1)	21.0 (11.6–30.4)	3.0 (1.8–4.1)
Very poorly controlled	4210	3 710 704	24.5 (23.0–26.1)	31.6 (20.8–42.4)	—
Adverse asthma outcomes					
Asthma attack in past 12 months[c]	7705	7 807 696	51.9 (50.0–53.9)	60.6 (58.3–62.8)	35.9 (32.7–39.1)
Urgent treatment for worsening asthma[c]	3528	3 466 275	43.5 (40.9–46.1)	64.0 (60.6–67.4)	17.4 (14.3–20.5)
Asthma-related emergency room visit[c]	1845	2 041 792	13.5 (12.2–14.9)	17.7 (15.8–19.6)	5.8 (4.3–7.3)
Overnight stay in hospital because of asthma[c]	555	549 438	3.6 (2.9–4.4)	4.8 (3.8–5.8)	1.5 (0.7–2.4)

[a]Categories do not sum to total due to item non-response.

[b]Results presented as weighted annual average.

[c]Rao–Scott chi-square test $p < 0.05$.

Table 2

Number of controller medications[a] taken by ever-employed adults with current asthma by WRA status.

	WRA (N =2 224 263)[b] %[b] (95% CI)	Possible WRA (N = 6 094 064)[b] %[b] (95% CI)	Non-WRA (N = 6 784 072)[b] %[b] (95% CI)	WRA vs Non-WRA PR[c] (95% CI)	Possible WRA vs Non-WRA PR[c] (95% CI)
0	50.5 (45.7–55.2)	55.2 (52.3–58.1)	60.0 (57.1–62.8)	0.97 (0.88–1.07)	0.96 (0.89–1.03)
1	27.9 (24.1–31.7)	31.5 (28.7–34.4)	30.3 (27.7–33.0)	**0.80 (0.67–0.95)**	0.98 (0.86–1.11)
2	16.7 (12.5–20.8)	10.8 (9.3–12.2)	8.4 (7.0–9.7)	**1.63 (1.18–2.24)**	1.18 (0.95–1.47)
≥3	5.0 (3.5–6.4)	2.5 (1.9–3.1)	1.3 (1.0–1.6)	**2.66 (1.67–4.26)**	**1.98 (1.34–2.93)**

[a] In 3 months preceding the survey interview.

[b] Results presented as weighted annual average.

[c] Consists of model where the outcome variable was the number of controller medications taken and the predictor variable was WRA status, adjusted for age, sex, race/ethnicity, income, health insurance, current employment status, chronic obstructive pulmonary disease (COPD), and adverse asthma outcomes.

WRA, work-related asthma; PR, prevalence ratio; CI, confidence interval; **Bold** text indicates significance.

Table 3

Proportion of ever-employed adults with current asthma by asthma drug class and WRA status.

Drug Class [a]	WRA (N =2 224 263)[b] %[b] (95% CI)	Possible WRA (N =6 094 064)[b] %[b] (95% CI)	Non-WRA (N = 6 784 072)[b] %[b] 95% CI	WRA vs non-WRA PR[c] (95% CI)	Possible WRA vs non-WRA PR[c] (95% CI)
Controller					
Long-acting β-agonist	28.2 (24.3–32.1)	23.7 (21.5–26.0)	21.2 (19.1–23.3)	1.15 (0.95–1.39)	1.05 (0.92–1.21)
Inhaled corticosteroid	38.3 (33.8–42.9)	36.0 (33.2–38.7)	32.2 (29.6–34.8)	1.04 (0.89–1.21)	1.06 (0.95–1.18)
Oral corticosteroid	5.5 (3.8–7.3)	3.0 (1.8–4.2)	2.5 (1.7–3.4)	1.29 (0.83–1.99)	0.95 (0.62–1.45)
Cromolyn/nedocromil	—	—	—	—	—
Leukotriene pathway inhibitor	16.0 (12.7–19.3)	10.9 (9.4–12.4)	10.5 (8.7–12.2)	**1.59 (1.22–2.07)**	1.22 (0.97–1.52)
Methylxanthine	1.8 (0.8–2.8)	1.1 (0.7–1.6)	0.3 (0.2–0.5)	**4.76 (2.06–11.0)**	**2.85 (1.55–5.23)**
Anti-cholinergic	9.9 (6.3–13.4)	5.3 (4.3–6.3)	3.5 (2.8–4.2)	**1.80 (1.05–3.06)**	1.18 (0.90–1.56)
Rescue					
Short-acting β-agonist	61.2 (56.6–65.9)	57.5 (54.5–60.4)	50.2 (47.2–53.2)	0.99 (0.88–1.10)	1.02 (0.95–1.10)

[a] Medications used in 3 months preceding the survey interview.

[b] Results presented as weighted annual average.

[c] Consists of eight models where the outcome variables were drug class and the predictor variable was WRA status, adjusted for age, sex, race/ethnicity, income, health insurance, current employment status, chronic obstructive pulmonary disease (COPD), and adverse asthma outcomes.

CI, confidence interval; PR, prevalence ratio; WRA, work-related asthma; **Bold** text indicates significance; "–" indicates relative standard error >30%, estimate not reportable.

Table 4

Proportion of ever-employed adults with current asthma by asthma treatment group[a] and WRA status.

Treatment group[b]	WRA (N =2 224 263)[c] %[c] (95% CI)	Possible WRA (N =6 094 064)[c] %[c] (95% CI)	Non-WRA (N = 6 784 072)[c] %[c] (95% CI)	WRA vs non-WRA PR[d] (95% CI)	Possible WRA vs non-WRA PR[d] (95% CI)
Short-acting β-agonist (SABA)	35.8 (30.3–41.3)	38.3 (35.0–41.7)	38.3 (34.5–42.0)	0.90 (0.75–1.08)	0.91 (0.81–1.04)
Inhaled corticosteroid (ICS) + SABA	12.3 (7.4–17.1)	15.9 (12.9–18.8)	16.1 (13.5–18.8)	0.74 (0.47–1.17)	0.99 (0.77–1.28)
Cromolyn/nedocromil, leukotriene receptor agonist (LTRA), or theophylline + SABA	8.6 (5.8–11.3)	7.1 (5.3–8.8)	9.0 (6.7–11.3)	1.11 (0.74–1.66)	1.03 (0.72–1.46)
ICS + long-acting β-agonist (LABA) + SABA	24.0 (19.8–28.1)	26.1 (23.2–29.1)	26.1 (23.2–29.0)	0.90 (0.72–1.12)	1.01 (0.86–1.18)
ICS + LTRA, theophylline, or zileuton + SABA	16.2 (12.1–20.2)	10.2 (8.6–11.8)	8.2 (6.6–9.9)	**2.21 (1.57–3.11)**	**1.41 (1.05–1.89)**
ICS + LABA + oral corticosteroid + SABA	2.8 (1.7–3.9)	1.2 (0.7–1.7)	2.0 (1.0–3.1)	1.34 (0.78–2.30)	0.68 (0.39–1.19)

[a] In 3 months preceding the Asthma Call-back Survey interview.

[b] Treatment groups based on NAEPP Expert Panel Report 3: Guidelines for the Diagnosis and Management of Asthma.

[c] Results presented as weighted annual average.

[d] Consists of model where the outcome variable was the treatment group and the predictor variable was the WRA status, adjusted for age, sex, race/ethnicity, income, health insurance, current employment status, chronic obstructive pulmonary disease, and adverse asthma outcomes.

CI, confidence interval; PR, prevalence ratio; WRA, work-related asthma; **Bold** text indicates significance.

Table 5

Adverse asthma outcomes and asthma control by history of medication use and work-related asthma (WRA) status.

Adverse asthma outcomes	Total PR[a] (95% CI)	Medication use in last 3 months PR[a] (95% CI)	No medication use in last 3 months PR[a] (95% CI)
Asthma attack[b]			
WRA	**1.62 (1.47–1.79)**	**1.42 (1.28–1.57)**	**2.16 (1.72–2.70)**
Possible WRA	**1.32 (1.20–1.44)**	**1.24 (1.13–1.35)**	**1.44 (1.14–1.78)**
Non-WRA	1.00	1.00	1.00
Urgent treatment[b]			
WRA	**1.51 (1.28–1.77)**	**1.18 (1.02–1.35)**	**2.13 (1.38–3.30)**
Possible WRA	**1.22 (1.06–1.40)**	1.11 (0.98–1.24)	0.91 (0.60–1.40)
Non-WRA	1.00	1.00	1.00
ER visit[b]			
WRA	**1.65 (1.24–2.20)**	**1.40 (1.05–1.84)**	—
Possible WRA	1.26 (0.99–1.61)	1.17 (0.92–1.49)	1.33 (0.73–2.42)
Non-WRA	1.00	1.00	1.00
Overnight hospital stay[b]			
WRA	1.18 (0.72–1.93)	1.10 (0.65–1.84)	—
Possible WRA	1.27 (0.79–2.05)	1.33 (0.82–2.17)	—
Non-WRA	1.00	1.00	—
Well-controlled asthma[c]			
WRA	**0.74 (0.64–0.85)**	**0.68 (0.54–0.85)**	**0.87 (0.77–0.98)**
Possible WRA	**0.81 (0.75–0.88)**	**0.80 (0.70–0.92)**	**0.89 (0.81–0.96)**
Non-WRA	1.00	1.00	1.00
Not well-controlled asthma[c]			
WRA	1.16 (0.95–1.41)	0.99 (0.80–1.23)	**1.69 (1.05–2.74)**
Possible WRA	**1.19 (1.03–1.38)**	1.06 (0.91–1.23)	**1.65 (1.11–2.47)**
Non-WRA	1.00	1.00	1.00
Very poorly controlled asthma[c]			
WRA	**1.54 (1.28–1.86)**	**1.47 (1.22–1.76)**	1.49 (0.89–2.49)
Possible WRA	**1.31 (1.14–1.50)**	**1.22 (1.07–1.39)**	1.36 (0.86–2.16)
Non-WRA	1.00	1.00	1.00

[a]Consists of five models where the outcome variables were adverse asthma outcomes and asthma control and the predictor variable was WRA status, adjusted for age, sex, race/ethnicity, income, health insurance, current employment status, and chronic obstructive pulmonary disease among the total population and those reporting medication use in last 3 months.

[b]In the last 12 months.

[c]Based on NAEPP Expert Panel Report 3: Guidelines for the Diagnosis and Management of Asthma, using information on the number of days with any asthma symptoms and nighttime awakenings in the last 30 days, and the frequency of inhaler SABA use in the last 3 months.

CI, confidence interval; PR, prevalence ratio; WRA, work-related asthma; **Bold** text indicates significance; "–" indicates relative standard error >30%, estimate not reportable.