American Journal of
Preventive Medicine

RESEARCH ARTICLE

Cardiovascular Disease Among Adults With Work-Related Asthma, 2012–2017

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Introduction: Asthma is associated with an increased risk for cardiovascular disease, and adults with persistent, severe asthma have a significantly higher risk of cardiovascular disease than adults with intermittent or no asthma.

Methods: The objective of this cross-sectional study was to assess the association between work-related asthma status and cardiovascular disease among ever-employed adults (aged 18–64 years) with current asthma using data from the 2012–2017 Behavioral Risk Factor Surveillance System Asthma Call-Back Survey from 37 states and the District of Columbia. Weighted prevalence ratios and 95% CIs, adjusted for age, sex, race/ethnicity, education, household income, smoking status, chronic obstructive pulmonary disease, diabetes, and BMI, were calculated. In addition, the associations of cardiovascular disease with adverse asthma outcomes and asthma control among adults with work-related asthma were examined. Analyses were conducted in 2021.

Results: Among an estimated annualized 14.8 million ever-employed adults aged 18–64 years with current asthma, adults with work-related asthma (prevalence ratio=1.5; 95% CI=1.2, 1.8) and possible work-related asthma (prevalence ratio=1.2; 95% CI=1.0, 1.5) were significantly more likely to have cardiovascular disease than adults with non-work-related asthma. Among adults with work-related asthma, those with very poorly controlled asthma (prevalence ratio=1.8; 95% CI=1.3, 2.5) and an asthma-related emergency room visit (prevalence ratio=1.5; 95% CI=1.1, 2.0) were significantly more likely to have cardiovascular disease.

Conclusions: Adults with work-related asthma were more likely to have cardiovascular disease than those with non-work-related asthma. Primary prevention, early diagnosis, and implementation of optimal work-related asthma management are essential for workers' health. Cardiovascular disease should be considered where appropriate when diagnosing and recommending treatment and interventions for adults with work-related asthma.

Am J Prev Med 2023;64(2):194–203. Published by Elsevier Inc. on behalf of American Journal of Preventive Medicine.

INTRODUCTION

Asthma is a chronic airway disease that is characterized by chronic airway inflammation, variable airflow limitation, and tissue remodeling.[1] It can also be associated with chronic systemic inflammation beyond the airways.[1] Symptoms of asthma include wheeze, shortness of breath, chest tightness, and cough.[1,2] In 2019, asthma affected more than 20 million adults, resulting in more than 8 million asthma attacks, 860,000 emergency department visits, and 100,000 hospital inpatient stays in the U.S.[3] Annually, asthma is associated with an economic burden of more than $80 billion in the U.S. owing to medical costs, absenteeism, and deaths.[4]

A subset of asthma, work-related asthma (WRA), is comprised of new-onset asthma that is caused by

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0749-3797/$36.00
https://doi.org/10.1016/j.amepre.2022.09.010

exposures in the workplace (occupational asthma) or pre-existing asthma that is made worse by exposures in the workplace (work-exacerbated asthma).[5] An estimated 16% of incident adult asthma and 21.5% of pre-existing asthma are attributable to workplace exposures.[6,7] Adults with WRA who have uncontrolled asthma tend to have greater asthma medication use, more asthma symptoms, more frequent asthma attacks, increased emergency department visits, more frequent asthma-related hospitalizations, and more frequent urgent treatment for worsening asthma than those with non-WRA.[5,8,9] Moreover, WRA is associated with reduced quality of life and adverse socioeconomic outcomes such as unemployment and reduction or loss of income.[10–13]

Previous research has found that asthma is associated with an increased risk for cardiovascular disease (CVD).[14–19] CVD includes coronary heart disease, heart attack, and stroke and was the leading cause of death in the U.S. in 2017.[20] Inflammatory pathophysiology characteristic of both asthma and CVD may contribute to cardiovascular complications seen among individuals with asthma.[15,21–23] Moreover, adults with more severe and less controlled asthma have a significantly higher risk of developing CVD than adults with less severe and more controlled asthma.[14,24]

Because WRA is associated with more frequent and more severe asthma symptoms, adults with WRA may be at a greater risk for developing CVD than those with non-WRA.[5,8,9] In addition, there is evidence that certain workplace exposures, including welding fumes, pesticides, organic solvents, and engine exhaust, may be associated with both WRA and CVD.[7,25–28] Concurrent diagnosis of a comorbid condition, such as CVD, may make treatment of asthma symptoms and achieving control more difficult among adults with WRA than among those with no WRA.[8]

In this cross-sectional study, data from the Behavioral Risk Factor Surveillance System (BRFSS) Asthma Call-Back Survey (ACBS) were used to assess the association between WRA and CVD among ever-employed adults aged 18–64 years with current asthma. In addition, the association of asthma control and adverse asthma outcomes with CVD by WRA status was assessed.

METHODS

Study Sample

The BRFSS is a cross-sectional, population-based, random digit-dialed landline and cellular telephone survey of the non-institutionalized U.S. adult (aged ≥18 years) population.[29] The ACBS is an optional follow-up survey of BRFSS respondents with asthma conducted within 2 weeks after the initial interview and is designed to collect detailed information on respondents' asthma.[30] The IRB at the Centers for Disease Control and Prevention has granted a surveillance exemption for studies using BRFSS data; however, states participating in BRFSS are subject to the IRB requirements of their state.

Data were assessed from 37 states (Arizona, California, Connecticut, Florida, Georgia, Hawaii, Illinois, Indiana, Iowa, Kansas, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, Texas, Utah, Vermont, Washington, West Virginia, and Wisconsin) and the District of Columbia (DC) that conducted the ACBS during 2012–2017. The median response rate for these 37 states ranged from 44% in 2013 to 47% in 2014 for BRFSS and ranged from 43% in 2017 to 47% in 2012 for ACBS.[29,30] Despite recent declines in telephone survey response rates, the BRFSS produces prevalence rates comparable with those of other national and state population-level surveys.[31]

Measures

Adults with current asthma were identified by affirmative responses 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?* Respondents were considered ever employed if they described their current employment status as *employed full time* or *employed part-time* or answered *yes* to the question *Have you ever been employed?* Adults with current asthma were then classified as having either WRA, possible WRA, or non-WRA. Respondents had WRA if they 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?* Adults with possible WRA were those who did not have WRA as defined previously and responded *yes* to any of the following 4 questions: *Are your asthma symptoms made worse by things like chemicals, smoke, dust, or mold in your current job?, Was your asthma first caused by things like chemicals, smoke, dust, or mold in your current job?, Were your asthma symptoms made worse by things like chemicals, smoke, dust, or mold in any previous job you ever had?*, and *Was your asthma first caused by things like chemicals, smoke, dust, or mold in any previous job you ever had?* Ever-employed adults with current asthma who did not meet definitions for WRA or possible WRA were classified as non-WRA.

Respondents had CVD if they responded *yes* to any of the following questions: *Has a doctor, nurse, or other health professional ever told you that you had a heart attack also called a myocardial infarction?* or *Has a doctor, nurse, or other health professional EVER told you that you had angina or coronary heart disease?* or *Has a doctor, nurse, or other health professional EVER told you that you had a stroke?* Cigarette 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). Respondents had chronic obstructive pulmonary disease (COPD) if they responded *yes* to any of the following questions: *Have you ever been told by a doctor or health professional that you have chronic obstructive pulmonary disease also known as COPD?, Have you ever been told by a doctor or other health professional*

that you have emphysema?, or *Have you ever been told by a doctor or other health professional that you have chronic bronchitis?*

Respondents had diabetes if they responded *yes* to the question *Has a doctor, nurse, or other health professional ever told you that you have diabetes?* Female respondents who indicated that their diabetes only occurred during pregnancy were not considered to have diabetes. BMI was calculated from respondents' self-reported weight and height (weight in kilograms divided by height in meters squared) and categorized as underweight (<18.5), normal weight (18.5−24.9), overweight (25.0−29.9), and obese (≥30.0).

In accordance with the Expert Panel Report 3*: Guidelines for the Diagnosis and Management of Asthma*, asthma control was categorized into well controlled, not well controlled, and very poorly controlled on the basis of the category with the most severe impairment using responses to questions on asthma symptoms, nighttime awakenings, and short-acting β-agonist medication use for symptom control.[2,8] On the basis of previously developed definitions, adverse asthma outcomes, including asthma attacks, emergency room (ER) visits for asthma, hospital stays, and urgent treatment for worsening asthma in the last 12 months, were classified on the basis of responses to the following questions: *During the past 3 months, how many asthma episodes or attacks have you had?; During the past 12 months, how many times did you visit an emergency department or urgent care center because of your asthma?; During the past 12 months, how many different times did you stay in any hospital overnight or longer because of your asthma?*; and *During the past 12 months, how many times did you see a doctor or other health professional for urgent treatment of worsening asthma symptoms or for an asthma episode or attack?*.[8,32]

The ACBS asked respondents about their prescription medication use during the 3 months preceding the interview. For this study, respondents who indicated that they had taken pill or syrup corticosteroids were classified as using oral corticosteroids.

Statistical Analysis

Analyses were performed in 2021 using SAS, Version 9.4, and SUDAAN, Release 11.0.1, using survey procedures to account for the complex survey design of the data. Data from 37 states and DC collected during 2012−2017 were combined and reweighted to increase the reliability and precision of estimates and produce estimates representative of the population of each participating state. Weights for analyses were established by multiplying the survey sample weight provided for each survey participant by the percentage of subjects in each state and survey year.[8] Estimates were considered unreliable if the relative SE (i.e., SE divided by the estimate) for the estimate was >30% or if the estimate was based on a sample of <50 respondents.[33]

Analyses were restricted to adults aged 18−64 years because 77% of the U.S. population aged ≥65 years were not in the labor force in 2014, the midpoint of the study.[34] In addition, age is an independent risk factor for CVD.[35] The demographic characteristics of the study population were described using weighted frequencies and proportions. Unadjusted prevalence ratios (PRs) to assess the association of WRA and CVD were calculated using bivariate logistic regression. Age, sex, race/ethnicity, education, household income, smoking status, COPD, diabetes, BMI, and oral corticosteroid use have been previously associated with WRA or CVD and were assessed for potential confounding.[8,35,36] The Rao-Scott chi-square test was used to assess for associations between potential confounders and CVD. Multivariable logistic regression, using the logistic regression predicted marginal risk ratio method, was used to calculate adjusted PRs. The multivariable model was adjusted for significant covariates in the model, including age, sex, race/ethnicity, education, household income, smoking status, COPD, diabetes, and BMI. In addition, multivariable logistic regression was used to calculate adjusted PRs to assess the association of CVD with adverse asthma outcomes and asthma control by WRA status. Observations with missing data were excluded from the multivariable logistic regression. Results were considered statistically significant at a $p<0.05$.

RESULTS

During 2012−2017, a sample of 70,454 adults in 37 states and DC participated in the BRFSS ACBS. Participants with no current asthma (n=18,180) or missing information on their asthma status (n=1,451), who were never employed (n=942) or had missing employment information (n=128), were aged ≥65 years (n=17,463) or had missing information on their age (n=203), or who had missing information on their WRA status (n=84) or CVD status (n=7) were excluded (Figure 1). The remaining 31,996 ever-employed adults aged 18−64 years with current asthma (representing a weighted estimate of 14.8 million adults) were included in the analyses.

Select characteristics of ever-employed adults aged 18−64 years with current asthma are illustrated in Table 1. Most of these adults were aged 18−44 years (54%), female (64%), and non-Hispanic White (54%). Among ever-employed adults, 9.4% (representing an estimated 1.4 million adults) had CVD, and 14.3% (representing an estimated 2.1 million adults) had WRA. Age, sex, race/ethnicity, education, household income, smoking status, COPD, diabetes, BMI, and WRA status were independently associated with CVD (Table 1).

The unadjusted PRs and 95% CIs for the associations between CVD and sociodemographic characteristics, comorbidities, and WRA are presented in Table 2. After adjusting for confounders, ever-employed adults with current asthma were more likely to have CVD among those aged 45−64 years (PR=2.7), with an annual household income <$15,000 (PR=2.1), with COPD (PR=1.8), and with diabetes (PR=2.0) and those overweight (PR=1.3) or obese (PR=1.3) and current (PR=1.3) and former (PR=1.2) smokers than among those aged 18−44 years, with an annual household income ≥$50,000, with no COPD, with no diabetes, of normal weight, and never smokers. Females (PR=0.7) and those of Hispanic ethnicity (PR=0.7) were significantly less likely to have CVD than males and those of non-Hispanic, White ethnicity. Adults with WRA (PR=1.5) and possible WRA

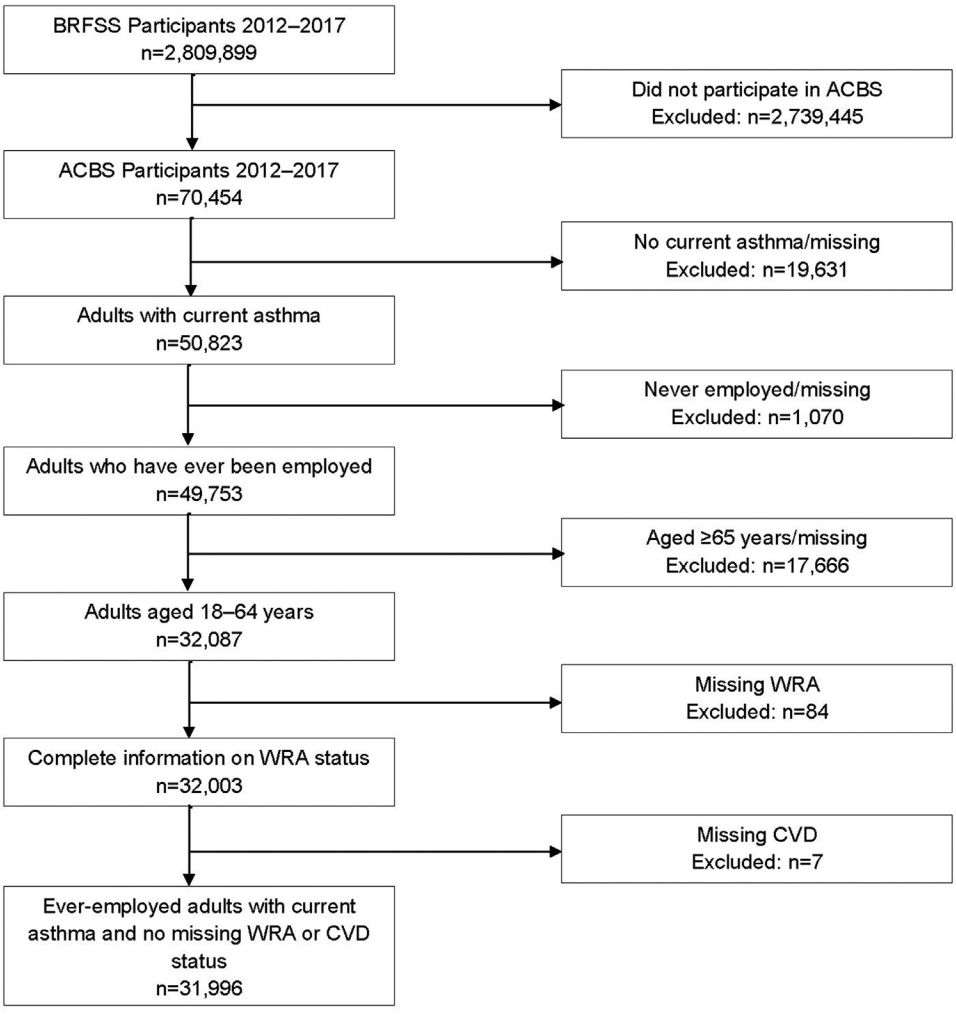

Figure 1. Flow diagram of participant selection, ACBS, 2012–2017.
ACBS, Asthma Call-back Survey; BRFSS, Behavioral Risk Factor Surveillance System; CVD, cardiovascular disease; WRA, work-related asthma.

(PR=1.2) were significantly more likely to have CVD than those with non-WRA.

Bivariate and multivariate associations between CVD and adverse asthma outcomes by WRA status are presented in Table 3. After adjusting for confounders, among adults with WRA, those with very poorly controlled asthma (PR=1.8) and an asthma-related ER visit (PR=1.5) were more likely to have CVD. Among adults with possible WRA and non-WRA, those with urgent treatment for worsening asthma (PR=1.3 and PR=1.3) and an overnight stay in the hospital because of asthma (PR=1.4 and PR=1.9) were more likely to have CVD.

DISCUSSION

The results of this study suggest that adults with WRA and those with very poorly controlled asthma were significantly more likely to have CVD than those with non-WRA and well-controlled asthma, respectively. An estimated 324,000 adults with WRA and 667,000 with possible WRA had CVD among these ever-employed adults (aged 18–64 years) with current asthma from 37 states and DC. Consistent with findings from previous research, Hispanic adults were less likely to have CVD than White, non-Hispanic adults.[37] Moreover, adults with a household income < $15,000, current and former smokers, adults with COPD and diabetes, and those with overweight and obese BMI were more likely to have CVD. To the authors' knowledge, this is the first study specifically assessing the association between WRA and CVD as well as the association between adverse asthma outcomes and asthma control with CVD among adults with WRA.

Studies have shown that 62% of adults with WRA have poorly controlled asthma.[8,38] Moreover, adults with WRA are significantly more likely to have more

Table 1. Characteristics of Ever-Employed Adults Aged 18–64 Years With Current Asthma, by CVD Status

Characteristics	Sample N	Weighted N[a]	%[a]	CVD (*n*=1,388,728)[a] %[a] (95% CI)	No CVD (*n*=13,397,669)[a] %[a] (95% CI)	*p*-value[b]
Age, years						
18–44	10,258	7,987,544	54.0	20.7 (17.2, 24.1)	57.5 (56.1, 58.8)	**<0.0001**
45–64	21,738	6,798,853	46.0	79.3 (75.9, 82.8)	42.5 (41.2, 43.9)	
Sex						
Male	9,940	5,257,988	35.6	40.5 (37.1, 44.0)	35.0 (33.7, 36.4)	**0.0031**
Female	22,056	9,528,409	64.4	59.5 (56.0, 62.9)	65.0 (63.6, 66.3)	
Race/ethnicity						
Non-Hispanic, White	20,361	8,011,282	54.2	51.4 (48.0, 54.9)	54.5 (53.1, 55.9)	**0.0004**
Non-Hispanic, black	2,010	1,520,175	10.3	14.2 (11.1, 17.2)	9.9 (9.0, 10.8)	
Hispanic	1,512	1,359,277	9.2	6.7 (4.9, 8.6)	9.4 (8.4, 10.5)	
Other	2,017	892,397	6.0	8.1 (5.7, 10.4)	5.8 (5.0, 6.6)	
Missing	6,096	3,003,266	20.3	19.6 (17.1, 22.0)	20.4 (19.4, 21.4)	
Education						
≤High school	10,170	5,366,463	36.3	54.4 (51.1, 57.8)	34.4 (33.0, 35.8)	**<0.0001**
Some college	9,990	5,295,410	35.8	30.8 (27.8, 33.9)	36.3 (34.9, 37.8)	
College graduate	11,804	4,114,413	27.8	14.7 (12.9, 16.6)	29.2 (28.0, 30.4)	
Missing	32	10,111	0.1	0.0 (0.0, 0.02)	0.1 (0.0, 0.1)	
Household income, $						
<15,000	5,249	2,250,799	15.2	31.3 (27.9, 34.6)	13.6 (12.6, 14.5)	**<0.0001**
15,000–24,999	5,039	2,243,453	15.2	21.8 (19.3, 24.3)	14.5 (13.5, 15.5)	
25,000–34,999	2,553	1,201,968	8.1	7.4 (5.9, 8.8)	8.2 (7.3, 9.1)	
35,000–49,999	3,490	1,411,956	9.5	7.5 (6.2, 8.9)	9.8 (9.0, 10.5)	
≥50,000	12,762	6,052,587	40.9	20.5 (17.5, 23.4)	43.1 (41.7, 44.5)	
Missing	2,903	1,625,634	11.0	11.6 (9.3, 13.9)	10.9 (10.0, 11.9)	
Smoking						
Current	6,550	3,098,152	21.0	35.5 (32.2, 38.7)	19.4 (18.3, 20.6)	**<0.0001**
Former	8,242	3,311,871	22.4	29.3 (26.2, 32.3)	21.7 (20.6, 22.8)	
Never	17,107	8,313,410	56.2	34.4 (31.1, 37.7)	58.5 (57.1, 59.9)	
Missing	97	62,964	0.4	0.9 (0.0, 1.9)	0.4 (0.1, 0.6)	
COPD						
Yes	11,197	4,314,521	29.2	62.7 (59.3, 66.2)	25.7 (24.5, 26.9)	**<0.0001**
No	20,769	10,458,434	70.7	37.0 (33.5, 40.4)	74.2 (73.0, 75.4)	
Missing	30	13,441	0.1	0.3 (0.0, 0.6)	0.1 (0.005, 0.1)	
Diabetes						
Yes	5,292	1,808,384	12.2	35.1 (32.0, 38.3)	9.9 (9.1, 10.7)	**<0.0001**
No	26,650	12,957,445	87.6	64.5 (61.3, 67.6)	90.0 (89.2, 90.8)	
Missing	54	20,568	0.1	0.4 (0.1, 0.8)	0.1 (0.04, 0.2)	
BMI						
Underweight	439	225,629	1.5	2.2 (1.1, 3.2)	1.5 (1.1, 1.8)	**<0.0001**
Normal weight	7,323	4,030,127	27.3	14.6 (12.7, 16.5)	28.6 (27.2, 29.9)	
Overweight	8,575	3,861,129	26.1	25.3 (22.6, 28.0)	26.2 (24.9, 27.4)	
Obese	14,135	6,005,345	40.6	54.6 (51.3, 57.9)	39.2 (37.8, 40.5)	
Missing	1,524	664,165	4.5	3.3 (2.2, 4.4)	4.6 (4.0, 5.2)	
Oral corticosteroid use[c]						
Yes	966	452,809	3.1	3.6 (2.5, 4.8)	3.0 (2.5, 3.5)	0.3167
No	30,960	14,304,726	96.7	96.2 (95.0, 97.3)	96.8 (96.3, 97.3)	
Missing	70	28,861	0.2	0.2 (0.1, 0.3)	0.2 (0.1, 0.3)	

(*continued on next page*)

Table 1. Characteristics of Ever-Employed Adults Aged 18–64 Years With Current Asthma, by CVD Status (*continued*)

Characteristics	Sample N	Weighted N[a]	%[a]	CVD (*n*=1,388,728)[a] %[a] (95% CI)	No CVD (*n*=13,397,669)[a] %[a] (95% CI)	*p*-value[b]
WRA status						
WRA	5,172	2,109,441	14.3	23.4 (20.6, 26.1)	13.3 (12.4, 14.2)	**<0.0001**
Possible WRA	13,062	5,834,329	39.5	48.0 (44.7, 51.4)	38.6 (37.2, 39.9)	
Non-WRA	13,762	6,842,626	46.3	28.6 (25.4, 31.7)	48.1 (46.7, 49.5)	

Note: Boldface indicates statistical significance ($p<0.05$).
COPD, chronic obstructive pulmonary disease; CVD, cardiovascular disease; WRA, work-related asthma.
[a]Weighted to the state populations using the survey sample weights for each survey participant.
[b]Characteristic associated with CVD; Rao-Scott chi-square test.
[c]During the 3 months before the interview.

Table 2. Associations of CVD With Sociodemographic Characteristics, Comorbidities, and WRA

Characteristics	CVD, P[a] (95% CI)	Bivariate, PR (95% CI)	Multivariate, PR[b] (95% CI)
Age, years			
18–44	3.6 (2.9, 4.3)	1.0	1.0
45–64	16.2 (15.2, 17.2)	**4.5 (3.7, 5.6)**	**2.7 (2.1, 3.4)**
Sex			
Male	10.7 (9.5, 11.9)	1.0	1.0
Female	8.7 (8.0, 9.3)	**0.8 (0.7, 0.9)**	**0.7 (0.6, 0.9)**
Race/ethnicity			
Non-Hispanic, White	8.9 (8.2, 9.6)	1.0	1.0
Non-Hispanic, black	13.0 (10.1, 15.8)	**1.5 (1.1, 1.8)**	1.2 (0.9, 1.5)
Hispanic	6.9 (4.9, 8.9)	0.8 (0.6, 1.0)	**0.7 (0.5, 0.9)**
Other	12.5 (8.8, 16.3)	**1.4 (1.0, 1.9)**	1.3 (0.9, 1.7)
Education			
≤High school	14.1 (12.7, 15.5)	**2.8 (2.4, 3.3)**	1.2 (0.9, 1.5)
Some college	8.1 (7.2, 9.0)	**1.6 (1.4, 1.9)**	1.0 (0.8, 1.2)
College graduate	5.0 (4.4, 5.6)	1.0	1.0
Household income, $			
<15,000	19.3 (16.8, 21.7)	**4.1 (3.3, 5.1)**	**2.1 (1.6, 2.7)**
15,000–24,999	13.5 (11.9, 15.0)	**2.9 (2.3, 3.5)**	**1.5 (1.2, 2.0)**
25,000–34,999	8.5 (6.7, 10.3)	**1.8 (1.4, 2.4)**	1.1 (0.8, 1.4)
35,000–49,999	7.4 (6.2, 8.7)	**1.6 (1.2, 2.0)**	1.2 (0.9, 1.6)
≥50,000	4.7 (3.9, 5.4)	1.0	1.0
Smoking			
Current	15.9 (14.2, 17.6)	**2.8 (2.4, 3.3)**	**1.3 (1.0, 1.6)**
Former	12.3 (10.8, 13.7)	**2.1 (1.8, 2.5)**	**1.2 (1.0, 1.5)**
Never	5.7 (5.1, 6.4)	1.0	1.0
COPD			
Yes	20.2 (18.7, 21.7)	**4.1 (3.6, 4.8)**	**1.8 (1.5, 2.2)**
No	4.9 (4.3, 5.5)	1.0	1.0
Diabetes			
Yes	27.0 (24.4, 29.6)	**3.9 (3.4, 4.5)**	**2.0 (1.6, 2.3)**
No	6.9 (6.3, 7.5)	1.0	1.0
BMI			
Underweight	13.3 (7.0, 19.6)	**2.6 (1.6, 4.3)**	1.9 (0.9, 3.7)
Normal weight	5.0 (4.4, 5.7)	1.0	1.0
Overweight	9.1 (8.1, 10.1)	**1.8 (1.5, 2.2)**	**1.3 (1.1, 1.5)**
Obese	12.6 (11.4, 13.9)	**2.5 (2.1, 3.0)**	**1.3 (1.1, 1.6)**

(*continued on next page*)

Table 2. Associations of CVD With Sociodemographic Characteristics, Comorbidities, and WRA (*continued*)

Characteristics	CVD, P[a] (95% CI)	Bivariate, PR (95% CI)	Multivariate, PR[b] (95% CI)
Oral corticosteroid use[c]			
Yes	11.1 (7.5, 14.6)	1.2 (0.8, 1.6)	0.9 (0.7, 1.3)
No	9.3 (8.7, 10.0)	1.0	1.0
WRA status			
WRA	15.4 (13.5, 17.3)	**2.7 (2.2, 3.2)**	**1.5 (1.2, 1.8)**
Possible WRA	11.4 (10.4, 12.5)	**2.0 (1.7, 2.3)**	**1.2 (1.0, 1.5)**
Non-WRA	5.8 (5.0, 6.6)	1.0	1.0

Note: Boldface indicates statistical significance ($p<0.05$).
COPD, chronic obstructive pulmonary disease; CVD, cardiovascular disease; P, prevalence; PR, prevalence ratio; WRA, work-related asthma.
[a]Weighted to the state population using the survey sample weights for each survey participant.
[b]Adjusted for age, sex, race/ethnicity, education, household income, smoking, COPD, diabetes, and BMI.
[c]During the 3 months before the interview.

frequent asthma symptoms, greater risk of asthma attacks, and increased healthcare utilization than those with non-WRA.[5,8,38] Consistent with findings from previous research, the results of this study suggest that poorly controlled and more severe asthma is associated with CVD.[14,24] Research has suggested that allergic asthma is a risk factor for CVD, and inflammatory pathogenesis similar to both asthma and CVD, such as increased leukotriene and eosinophil production, may lead to atherosclerotic plaques and the development of CVD.[21–23] Conversely, other studies have found no significant association between asthma and CVD.[39,40] Future research may elucidate the potential causal relationships between WRA and CVD and examine the pathology of disease progression.

Cigarette smoking is the leading risk factor for CVD; however, evidence suggests that certain workplace exposures associated with WRA may also contribute to the development of CVD, including welding fumes, pesticides, organic solvents, and engine exhaust, which may contribute to the development of both diseases.[7,25–28,41] In a review of 16 studies, Leachi et al. found that exposure to polycyclic aromatic hydrocarbons was associated with cardiovascular and respiratory diseases, including asthma and COPD, among coke oven workers, asphalt workers, and aluminum smelter workers.[42] Exposure to certain hazardous materials may explain the development of both WRA and CVD in some workers, and workplace interventions, such as reduction or elimination of exposures, should be considered in managing patients with both conditions.

Primary prevention of WRA, including the elimination of exposures or removal of the worker from exposures, is the most effective intervention for WRA symptoms and should be considered first in the management of asthma.[5,43–45] For some adults with work-exacerbated or irritant-induced asthma, reduction of exposure may be considered, when appropriate.[5,7,43,46] WRA is often underdiagnosed and may be challenging to manage when it is diagnosed, resulting in delayed or inadequate medical care.[5,47] Moreover, recent research has shown that only 15% of employed adults with asthma discuss the possible relationship between their asthma and exposures in the workplace with their healthcare provider.[48] Owing to the potential for significant adverse social and financial consequences associated with job loss or job change, some adults with WRA may choose to remain in their current position.[11] WRA and CVD may develop or worsen among adults who remain exposed.[7,25–28,42] In clinical practice, a thorough occupational history should be collected for all working adults with new-onset or exacerbated asthma. Following current expert guidance, early diagnosis of WRA and implementation of appropriate treatment and disease management are necessary to improve health outcomes among working adults.[5,43,45]

This study had several strengths. In the U.S., there is currently no nationwide surveillance system for occupational lung diseases, such as WRA.[49] For many states, the ACBS provides the only data source for WRA estimates. An additional strength of this study is the inclusion of individuals reporting possible WRA. WRA is often under-recognized in clinical practice, therefore, including adults with possible WRA captures individuals that may have undiagnosed WRA.[5,47]

Limitations

This study was also subject to some limitations. Information on asthma, CVD, and potential confounders was self-reported and was not validated by medical records or follow-up with a healthcare provider, so estimates might be subject to misclassification. However, previous research has found that adult asthma can be reliably estimated using self-reported data compared with medical

Table 3. Associations Between CVD and Adverse Asthma Outcomes Among Ever-Employed Adults by WRA Status

	WRA			Possible WRA			Non-WRA		
Adverse asthma outcomes	**CVD, P[a]**	**Bivariate, PR (95% CI)**	**Multivariate, PR[b] (95% CI)**	**CVD P[a]**	**Bivariate, PR (95% CI)**	**Multivariate, PR[b] (95% CI)**	**CVD, P[a]**	**Bivariate, PR (95% CI)**	**Multivariate, PR[b] (95% CI)**
Asthma control									
Well controlled	9.2	1.0	1.0	7.7	1.0	1.0	4.0	1.0	1.0
Not well controlled	11.9	1.3 (0.9, 1.9)	1.3 (0.9, 2.0)	11.0	**1.4 (1.1, 1.9)**	1.3 (0.9, 1.8)	6.8	**1.7 (1.2, 2.4)**	**1.5 (1.1, 2.0)**
Very poorly controlled	24.4	**2.6 (1.9, 3.6)**	**1.8 (1.3, 2.5)**	17.7	**2.3 (1.8, 2.9)**	**1.3 (1.0, 1.7)**	12.2	**3.1 (2.3, 4.1)**	1.3 (0.9, 1.9)
Adverse asthma outcomes									
Asthma attack in the past 12 months									
No	12.0	1.0	1.0	9.5	1.0	1.0	4.9	1.0	1.0
Yes	16.7	**1.4 (1.0, 1.9)**	1.1 (0.8, 1.4)	12.8	**1.3 (1.1, 1.7)**	1.1 (0.9, 1.5)	6.8	**1.4 (1.1, 1.8)**	**1.3 (1.0, 1.7)**
Urgent treatment for worsening asthma									
No	12.3	1.0	1.0	9.8	1.0	1.0	5.3	1.0	1.0
Yes	19.8	**1.6 (1.2, 2.1)**	1.2 (0.9, 1.6)	16.4	**1.7 (1.4, 2.0)**	**1.3 (1.0, 1.7)**	8.4	**1.6 (1.2, 2.0)**	**1.3 (1.0, 1.6)**
Asthma-related emergency room visit									
No	12.1	1.0	1.0	11.0	1.0	1.0	5.4	1.0	1.0
Yes	25.0	**2.1 (1.6, 2.7)**	**1.5 (1.1, 2.0)**	14.1	**1.3 (1.0, 1.6)**	1.1 (0.8, 1.4)	8.8	**1.6 (1.2, 2.2)**	1.2 (0.9, 1.6)
Overnight stay in hospital owing to asthma									
No	14.2	1.0	1.0	10.8	1.0	1.0	5.4	1.0	1.0
Yes	31.8	**2.2 (1.5, 3.3)**	1.3 (0.9, 2.0)	27.6	**2.6 (1.9, 3.5)**	**1.4 (1.0, 2.2)**	22.7	**4.2 (2.9, 6.1)**	**1.9 (1.3, 2.9)**

Note: Boldface indicates statistical significance ($p<0.05$).
COPD, chronic obstructive pulmonary disease; CVD, cardiovascular disease; P, prevalence; PR, prevalence ratio; WRA, work-related asthma.
[a]Weighted to the state population using the survey sample weights for each survey participant.
[b]Adjusted for age, sex, race/ethnicity, education, household income, smoking, COPD, diabetes, and BMI.

records review.[50] In addition, the use of self-reported myocardial infarction, angina, and stroke combined as an indicator of CVD reduced the potential for misclassification.[51] Moreover, a previous study has shown that occupational exposures were documented by healthcare professionals in only 7% of adult-onset asthma cases, suggesting potential underdiagnosis of WRA in the medical record.[52] The data are cross-sectional, and no information was available to determine the temporal sequence of asthma and CVD diagnoses; therefore, causality cannot be inferred. Finally, data used in this analysis were for adults living in 37 states and DC; therefore, the results may not be representative nationally.

CONCLUSIONS

Adults with WRA and possible WRA were significantly more likely to have CVD than those with non-WRA. Moreover, among adults with WRA, those with very poorly controlled asthma and an asthma-related ER visit were significantly more likely to have CVD. Primary prevention (including elimination or substitution of the offending agent), early diagnosis, and implementation of individualized WRA and CVD management (including removal of the worker from exposure, smoking cessation, and phenotype-specific asthma treatment) are essential for workers' health. Cardiovascular comorbidities should be considered, where appropriate, when diagnosing and recommending treatment and interventions for adults with WRA. Continued surveillance is needed to better characterize cardiovascular risk among adults with WRA.

ACKNOWLEDGMENTS

The authors thank the Behavioral Risk Factor Surveillance System state coordinators for their assistance in collecting the data used in this analysis. The authors also thank Dr. Hatice Zahran, National Center for Environmental Health, Centers for Disease Control and Prevention (CDC) and Dr. Taylor Shockey, National Institute for Occupational Safety and Health, CDC for their helpful comments.

The findings and conclusions in this report are those of the authors and do not necessarily represent the official views of the National Institute for Occupational Safety and Health, CDC.

No financial disclosures were reported by the authors of this paper.

CREDIT AUTHOR STATEMENT

Katelynn E. Dodd: Conceptualization, Formal analysis, Methodology, Visualization, Writing — original draft. David Blackley: Writing — review and editing. Jacek M. Mazurek: Writing — review and editing.

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