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Air Quality Index and air quality awareness among adults in the United States

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Abstract

Background: Information about local air quality is reported across the United States using air quality alerts such as the Environmental Protection Agency's Air Quality Index. However, the role of such alerts in raising awareness of air quality is unknown. We conducted this study to evaluate associations between days with Air Quality Index ≥101, corresponding to a categorization of air quality as *unhealthy for sensitive groups, unhealthy, very unhealthy, or hazardous*, and air quality awareness among adults in the United States.

Methods: Data from 12,396 respondents to the 2016–2018 ConsumerStyles surveys were linked by geographic location and survey year to daily Air Quality Index data. We evaluated associations between the number of days in the past year with Air Quality Index ≥101 and responses to survey questions about awareness of air quality alerts, perception of air quality, and changes in behavior to reduce air pollution exposure using logistic regression.

Results: Awareness of air quality alerts (prevalence ratio [PR] = 1.23; 95% confidence interval [CI] = 1.15, 1.31), thinking/being informed air quality was bad (PR = 2.02; 95% CI = 1.81, 2.24), and changing behavior (PR = 2.27; 95% CI = 1.94, 2.67) were higher among respondents living in counties with ≥15 days with Air Quality Index ≥101 than those in counties with zero days in the past year with Air Quality Index ≥101. Each aspect of air quality awareness was higher among adults with than without asthma, but no differences were observed by heart disease status. Across quintiles of the number of days with Air Quality Index ≥101, air quality awareness increased among those with and without selected respiratory and cardiovascular diseases.

Conclusions: Among U.S. adults, air quality awareness increases with increasing days with alerts of unhealthy air. These findings improve our understanding of the extent to which air quality alerts prompt people to take actions to protect their health amidst poor air quality.

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Declaration of competing interest

The authors declare they have no competing financial interests.

Keywords

Adults; Air quality; Behavior; Environmental health; Epidemiology

1. Introduction

Poor ambient air quality is associated with exacerbations of asthma and chronic obstructive pulmonary disease (COPD) (Metzger et al., 2004; Meng et al., 2007; DeVries et al., 2017), respiratory and cardiovascular-related hospitalization (Bell et al., 2008; Belleudi et al., 2010), and death (Krewski et al., 2009). In fact, air pollution is estimated to have contributed to nearly 1 in every 10 deaths globally, leading it to be ranked fifth among global risk factors for mortality in 2017 (Health Effects Institute, 2019). Despite these well-documented associations, there is little evidence that our epidemiologic understanding of the hazards of exposure to poor air quality has translated widely into increased awareness or changes in behavior to reduce air pollution exposure among populations most at risk and their health care providers (Borbet et al., 2018; Mirabelli et al., 2018).

In 2018, we reported that 49% of U.S. adults were aware of air quality alerts where they live, 3% had discussed with a health professional strategies to reduce air pollution exposure, and 27% always or usually avoided busy roads to reduce air pollution exposure when walking, biking, or exercising outdoors (Mirabelli et al., 2018). Each of the three outcomes was more common among adults with than without existing respiratory disease. Variations in awareness of air quality alerts by sociodemographic characteristics, in particular, suggest that targeting messages about air quality might raise awareness about air quality alerts and motivate adults to change their behaviors to reduce air pollution exposure during periods of unhealthy air quality (Mirabelli et al., 2018). In 2019, Pennington et al. reported that television was the most common communication channel by which adults receive air quality alerts, regardless of their existing respiratory or heart disease status (Pennington et al., 2019). Together, these findings reveal opportunities for improving awareness of air quality alerts among adults during periods of poor air quality. However, the role of actual air quality, as indicated by the Environmental Protection Agency's (EPA's) Air Quality Index, in the observed differences in awareness of air quality alerts and changes in behavior to reduce air pollution exposures remains unknown.

Broadly speaking, ambient air quality and the Air Quality Index in the United States is driven largely by ambient concentrations of ground-level ozone and particle pollution (U.S. Environmental Protection Agency, 2016). Ground-level ozone is created by reactions between oxides of nitrogen and volatile organic compounds, in the presence of sunlight. Oxides of nitrogen and volatile organic compounds are emitted by vehicles, power plants, and other industrial processes (U.S. Environmental Protection Agency, 2018b). In contrast, particle pollution, which includes particulate matter ≤2.5 μm and ≤10 μm in diameter, can be emitted directly (e.g., from construction sites, smoke stacks, fires) or can form from pollutants emitted from power plants, industrial facilities, and vehicles (U.S. Environmental Protection Agency). Fires and emissions can also contribute to episodic and local or regional spikes in particle pollution. Additional information about sources and trends of ambient air pollution in the United States are publicly available from the U.S. Environmental Protection Agency's National Emissions Inventory (U.S. Environmental Protection Agency, 2018a).

In the United States, air quality alerts such as the EPA Air Quality Index are used to inform the public when air quality is likely to affect the health of sensitive individuals, including those with heart or lung disease (U.S. Environmental Protection Agency, 2016; U.S. Environmental Protection Agency, 2019). The Air Quality Index is a six-category index that translates daily air pollutant measurements into information to help people understand their local air quality, its associated health risks, and actions they can take to protect their health (U.S. Environmental Protection Agency, 2016; U.S. Environmental Protection Agency, 2019). To date, little information is available about the Air Quality Index alerts and the public's awareness of air quality. To address this gap, we evaluated associations between days with Air Quality Index ≥101, corresponding to a categorization of air quality as *unhealthy for sensitive groups, unhealthy, very unhealthy, or hazardous*, and three measures of air quality awareness, as indicated by responses to survey questions about awareness of air quality alerts, perception of air quality, and behavior change because of air quality, in a sample of U.S. adults, and describe the prevalences of air quality awareness among adults with and without respiratory and heart disease.

2. Methods

2.1. Study population

We analyzed data from the summer 2016, 2017, and 2018 waves of the ConsumerStyles surveys, conducted by Porter Novelli Public Services (Washington, DC). Each year, ConsumerStyles surveys are conducted in the spring, summer, and fall to assess health-related knowledge and behaviors among adults in the United States. For each year included in our analysis, the spring wave of the ConsumerStyles survey (hereafter, "SpringStyles") was conducted as a cross-sectional survey of a random sample of adults registered with KnowledgePanel®, a panel of approximately 55,000 men and women aged 18 and older. Sampling was probability-based to be representative of the U.S. adult population. In 2016, 2017, and 2018, the summer waves of the ConsumerStyles surveys (hereafter, "SummerStyles") were conducted among individuals who responded to the SpringStyles surveys in 2016, 2017, and 2018, respectively.

In 2016, the SpringStyles survey was sent to 10,955 potential respondents and completed by 6490 (59%). Between June 24 and July 11, 2016, SummerStyles was completed by 4203 (68%) of 6166 SpringStyles respondents. In 2017, the SpringStyles survey was sent to 10,916 potential respondents and completed by 6622 (61%). Between June 7 and July 2, 2017, SummerStyles was completed by 4107 (74%) of 5586 SpringStyles respondents. In 2018, the SpringStyles survey was sent to 10,904 potential respondents and completed by 6427 (59%). Between June 12 and July 7, 2018, SummerStyles was completed by 4088 (73%) of 5584 respondents. In total, the 2016–2018 SummerStyles surveys were completed by 12,398 adults. We excluded from our analyses two respondents with unknown geographic locations and merged survey responses from the remaining 12,396 with location-specific Air Quality Index data, as described below.

2.2. Air Quality Index

For this analysis, we used publicly available, county-level daily Air Quality Index data (U.S. Environmental Protection Agency, 2018c). Briefly described, EPA's Air Quality Index is a six-category classification of the quality of the ambient air, as determined by a network of monitors sampling air for five major pollutants: carbon monoxide, ground-level ozone, nitrogen dioxide, particulate matter (≤2.5 μm and ≤10 μm in diameter), and sulfur dioxide (U.S. Environmental Protection Agency, 2016). For each pollutant, concentrations are assigned Air Quality Index values that are categorized based on existing evidence of documented health effects. Date- and location-specific Air Quality Index values are assigned as the maximum value among each of the five pollutants (U.S. Environmental Protection Agency, 2016; U.S. Environmental Protection Agency, 2019). Air Quality Index values range from 0 to 500, with values in the range of 0–50 indicating that air quality conditions are *good*, 51–100 indicating that air quality conditions are *moderate*, and 101–150 indicating air quality is *unhealthy for sensitive groups*, including persons with heart and lung disease, older adults, and children. Values in the ranges of 151–200, 201–300, and 301–500 indicate air quality is *unhealthy*, *very unhealthy*, and *hazardous*, respectively, for everyone (U.S. Environmental Protection Agency, 2016; U.S. Environmental Protection Agency, 2019).

For each U.S. county with available data, we aggregated the daily Air Quality Index data by year, with each year corresponding to the 12-month period leading up to each SummerStyles survey period. Specifically, responses from the 2016 survey were linked with Air Quality Index data aggregated over July 1, 2015 to June 30, 2016; responses from the 2017 survey were linked with Air Quality Index data aggregated over July 1, 2016 to June 30, 2017; and responses from the 2018 survey were linked with Air Quality Index data aggregated over July 1, 2017 to June 30, 2018. Ultimately, for each county and year, we calculated the number of days with Air Quality Index ≥101, corresponding to a categorization of air quality as *unhealthy for sensitive groups, unhealthy, very unhealthy, or hazardous* (U.S. Environmental Protection Agency, 2016). We linked each county- and year-level Air Quality Index metric to the survey data by respondents' residential location and survey year. The survey data included respondents' ZIP-codes, which were linked to county-level records of the Air Quality Index using the sashelp.zipcode crosswalk file in SAS version 9.4 (SAS Institute., Inc., Cary, North Carolina).

Air Quality Index data are not available for the entire United States (U.S. Environmental Protection Agency, 2016). For example, some localities, particularly those in rural areas, may not have local air monitors collecting air pollutant data with which to generate daily Air Quality Index values. Overall, 2306 (19%) respondents whose survey data were not linked with air quality data were categorized as having 0 days/year with Air Quality Index data. Responses from 10,090 (81%) SummerStyles respondents were linked with Air Quality Index data (median: 365 days/year; range: 16–366 days/year). For these individuals, we categorized the distribution of the number of days with Air Quality Index ≥101 into quintiles (0, 1–3, 4–6, 7–14, and 15–309 days).

2.3. Measures of air quality awareness

Survey questions about air quality began with the following explanation, “The next few questions are about air quality. The government routinely collects and distributes information on air quality to help inform the public about air pollution levels.” Respondents then answered three questions to determine whether they: (1) were aware of air quality alerts (“Have you ever heard or read about the Air Quality Index or air quality alerts where you live?“, (2) thought or were informed that air quality was bad (“During the past 12 months, was there any time you thought or you were informed that air quality where you live was bad?“, and (3) changed behaviors because of air quality (“Did you do anything differently when you thought or were informed that air quality where you live was bad?). Respondents who reported changing their behaviors because of air quality were asked a follow-up question about whether they engaged in specific exposure reduction behaviors: spent less time outdoors, did less strenuous activity, closed windows, drove less, exercised indoors instead of outdoors, and exercised on a different day or at a different time. For all questions, negative (i.e., no) and uninformative responses (i.e., don’t know, missing) were categorized as negative. Hereafter, we collectively refer to awareness of air quality alerts, thinking or being informed that air quality was bad, and making changes when one thought or was informed that air quality was bad as three aspects of “air quality awareness.”

2.4. Statistical analysis

The SummerStyles survey was designed to be representative of the U.S. adult population. As such, Porter Novelli Public Services (Washington, DC) proportionally weighted the data to match U.S. Current Population Survey proportions of four individual-level characteristics (i.e., age, educational attainment, race/ethnicity, and sex) and five household characteristics (census region, household income, household size, metropolitan status, and prior internet access). Data from the three survey years were analyzed as a single, pooled sample. All analyses were weighted using the survey weights provided with the SummerStyles data. Univariate analyses were conducted using SAS version 9.4 (SAS Institute Inc., Cary, North Carolina) to generate unadjusted estimates of the prevalences of awareness of air quality alerts, thinking or being informed that air quality was bad, and making changes when one thought or was informed that air quality was bad across categories of the number of days with Air Quality Index ≥101. We estimated adjusted prevalences of the same values, as well as of the exposure reduction behavior responses, and adjusted prevalence ratios (PRs) with 95% confidence intervals (CIs) using predicted marginal probabilities from logistic regression models in SAS-callable SUDAAN (RTI International, Research Triangle Park, North Carolina). Unless otherwise noted, the regression models were adjusted for age (18–24, 25–34, 35–44, 45–54, 55–64, 65–74, and 75–94 years), educational attainment (less than high school, high school, some college, bachelor’s degree or higher), race/ethnicity (white, non-Hispanic; black, non-Hispanic; 2+ races, non-Hispanic; other, non-Hispanic; and Hispanic), sex, and survey year (2016, 2017, and 2018). This project was exempt from Institutional Review Board review at the Centers for Disease Control and Prevention.

3. Results

Characteristics of the 12,396 U.S. adults in our final study population are shown in Table 1. When survey responses were linked by county and survey year with publicly-available Air Quality Index data, we found that respondents spent an average of 238 days of the previous year with an Air Quality Index in the range of 0–50 (i.e., *good*), 98 days with an Air Quality Index in the range of 51–100 (i.e., *moderate*), and 15 days with an Air Quality Index ≥101 (i.e., *unhealthy for sensitive groups, unhealthy, very unhealthy,* and *hazardous*) (Table 2).

Overall, 53.9% of respondents were aware of air quality alerts, 29.2% reported thinking or being informed that air quality was bad where they live in the past 12 months, and 14.7% changed their behavior because they thought or were informed that air quality where they live was bad (Table 3). These percentages were lower among respondents without Air Quality Index data available where they live (n = 2306). Among respondents with Air Quality Index data (n = 10,090), percentages increased across categories of increasing numbers of days with Air Quality Index ≥101. When adjusted for age, educational attainment, race/ethnicity, sex, and survey year, adjusted percentages of each of the three aspects of air quality awareness were similar to unadjusted percentages and adjusted prevalence ratios increased monotonically across categories of number of days with Air Quality Index ≥101.

Over 7% of respondents self-reported asthma, 2% self-reported emphysema/COPD, and 3% self-reported heart disease. In adjusted analyses, all aspects of air quality awareness were higher among adults with than without asthma or emphysema/COPD. Among adults with and without heart disease, adjusted percentages were similar (Table 4). When stratified by health condition, adjusted percentages of each aspect of air quality awareness increased across quintiles of the number of days with Air Quality Index ≥101 (Fig. 1).

Overall, each of the specific exposure reduction behaviors were reported infrequently: 9% reported spending less time outdoors, 3% reported doing less strenuous activity, 6% reported closing windows, 2% reported driving less, 3% reported exercising indoors instead of outdoors, and 2% reported exercising on a different day or at a different time. Lowest adjusted percentages of all behaviors were observed among respondents without Air Quality Index data available where they live and percentages increased across quintiles of the number of days with Air Quality Index ≥101 (Fig. 2).

4. Discussion

Using data from a 2016–2018 survey of adults in the United States, we investigated whether ambient air quality, as indicated by the Air Quality Index, affects air quality awareness among adults in the United States and found that increasing numbers of days with poor air quality is associated with increasing awareness of air quality alerts, perception of air quality, and behavior change because of poor air quality. Furthermore, each aspect of air quality awareness was higher among in adults in geographic areas in which Air Quality Index values are available than among those in areas without Air Quality Index values, even when the Air Quality Index did not reach exceed a categorization of *moderate*. Taken together, these results suggest that air quality awareness increases not only in areas with increasing numbers of days of poor air quality, but also simply with the availability of a reported Air Quality Index.

Each day, information about local air quality is reported for localities across the United States using air quality alerts such as the U.S. Environmental Protection Agency's Air Quality Index (U.S. Environmental Protection Agency, 2019). As an indicator of ambient air quality, we used the number of days in the past year with Air Quality Index ≥101, which corresponds to a categorization at which individuals with respiratory or heart disease are advised that the air quality may exacerbate their conditions. When we assessed the observed associations by respiratory and heart disease status, adjusted prevalences of awareness of air quality alerts were slightly higher among adults with than without each condition, though 95% CIs overlapped in nearly all categories of the number of days with Air Quality Index ≥101. In contrast, adjusted prevalences of thinking or being informed that air quality was bad and of changing behavior were generally higher among adults with than without respiratory disease and similar among adults with and without heart disease. These findings support and extend our previous findings that awareness of air quality alerts was higher among adults with than without asthma (PR: 1.11; 95% CI: 1.04, 1.20), but that no differences were observed by emphysema/COPD or heart disease status (Mirabelli et al., 2018) by reporting on differences observed across categories of air quality. Collectively, these findings clearly suggest that air quality influences air quality awareness, as indicated by awareness of air quality alerts, perception of air quality, and behavior change because of air quality. They also reveal that behavior change is because of poor air quality is relatively uncommon and suggest opportunities for increasing messages from public health, environmental health, and medical professionals about strategies to reduce exposure to ambient air pollution.

Because poor air quality negatively affects respiratory and cardiovascular health (Committee of the Environmental and Occupational Health Assembly of the American Thoracic Society, 1996; Brook et al., 2004; Dominici et al., 2006; HEI Panel on the Health Effects of Traffic-Related Air Pollution, 2010; Guarnieri and Balmes, 2014), our findings have important public health implications. Ambient air quality is a direct determinant of the Air Quality Index. The present results indicate that the Air Quality Index, and thus air quality, are associated with air quality awareness. However, while we observed positive associations between increasing numbers of days with poor air quality and air quality awareness, the low prevalence of each aspect of air quality awareness suggest a need for increasing awareness about air quality and heath among U.S. adults. Conceptually, if air quality awareness impacts health-related behaviors—specifically those behaviors that impact exposure to ambient air pollution—then increasing air quality awareness should directly affect health behaviors, exposures to ambient air pollution, and cardiorespiratory health. Again, conceptually, the only more direct routes to attenuating cardiorespiratory health impacts of air pollution are improving air quality and reducing air pollution exposure (Fig. 3). Even among respondents living in areas with ≥15 days with and Air Quality Index ≥101, only 43% thought or were informed that air quality was bad in their area, and just 23% changed their behavior as a result of poor air quality. These results suggest that improving messages about air quality alerts may be needed to raise air quality awareness among U.S. adult population. Indeed, raising awareness about air quality and its associated health impacts likely also have long-term public health benefits if such awareness leads to changes in behavior that reduce air pollution exposure.

Several limitations might affect the interpretation of our results. First, 2040 respondents lived in geographic areas in which the Air Quality Index is not available and for which we do not have any information about air quality. That awareness of air quality alerts is lowest in this population is unsurprising. More unexpected, however, is that among respondents in areas without the Air Quality Index, nearly 44% reported being aware of air quality alerts. Additional information about alerts of environmental conditions that affect general health, and breathing in particular (e.g., pollen reports, heat warnings), would further improve our understanding of air quality awareness, especially in areas that lack air quality alert systems. On a related note, we investigated the finding that over 22% of respondents with zero days with Air Quality Index ≥101 reported thinking or being informed that air quality was bad. In this population (n = 2721), we examined percentages reporting thinking or being informed that air quality was bad across quartiles of the maximum Air Quality Index and found only modest variation (maximum Air Quality Index = 22–77: 22%; 78–87: 22%; 88–93: 24%; 94–100: 22%). Similarly, nearly 22% of respondents with a maximum Air Quality Index in the 0–50 range (i.e., *good*) reported thinking or being informed that air quality was bad. Again, information about the occurrence of other environmental conditions that affect respiratory health would further help improve our understanding of how U.S. adults interpret air quality alerts. Comparison of environmental conditions, including pollen reports, heat alerts, and other factors that may vary across counties was beyond the scope of this analysis.

Second, we categorized air quality based on an Air Quality Index value of 101 or higher without any information about the extent to which the elevated Air Quality Index values were publicized in the geographic areas in which the respondents lived. Previous research indicating that television was the most common source of air quality alert information among U.S. adults was based on data collected in 2014 (Pennington et al., 2019) and may not reflect the ways in which the respondents in the present study received air quality alerts. Additional information about the extent to which air quality information is publicized, how air quality information on television or other communication channels varies when air quality changes, and how people receive and use information about air quality alerts would further improve our understanding of air quality awareness. Third, we have no information about how the aggregated measure of air quality that we used in this study corresponds with each respondent’s actual experience. However, we also have no reason to believe that categorizing exposure based on the number of days with an Air Quality Index value ≥ 101 would result in any systematic overestimation or underestimation of exposure. Nonetheless, because we have no information about indoor air quality, occupational exposures, or other potential sources of inhalation exposures that are similar to outdoor air pollution, our findings should be interpreted carefully. Finally, the air quality awareness and health status information in our study were self-reported and the ConsumerStyles survey does not include any validation processes. Validation of responses, particularly responses about health status, would provide additional information about the extent to which the associations we observed in our data might be impacted by misclassification.

Among U.S. adults, air quality awareness increases with increasing days with alerts of unhealthy air. These findings improve our understanding of the extent to which air quality alerts prompt U.S. adults to take actions to protect their health during periods of poor air quality. These findings may be especially useful to public health officials and others interested in increasing awareness of the hazards of poor air quality during air pollution events and attenuating the well-documented adverse health effects resulting from exposure to ambient air pollution.

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References

Bell ML, Ebisu K, Peng RD, Walker J, Samet JM, Zeger SL, Dominici F, 2008 Seasonal and regional short-term effects of fine particles on hospital admissions in 202 US counties, 1999–2005. Am. J. Epidemiol 168 (11), 1301–1310. [PubMed: 18854492]

Belleudi V, Faustini A, Stafoggia M, Cattani G, Marconi A, Perucci CA, Forastiere F, 2010 Impact of fine and ultrafine particles on emergency hospital admissions for cardiac and respiratory diseases. Epidemiology 21 (3), 414–423. [PubMed: 20386174]

Borbet TC, Gladson LA, Cromar KR, 2018 Assessing air quality index awareness and use in Mexico City. BMC Publ. Health 18 (1), 538.

Brook RD, Franklin B, Cascio W, Hong Y, Howard G, Lipsett M, Luepker R, Mittleman M, Samet J, Smith SC Jr., Tager I, 2004 Air pollution and cardiovascular disease: a statement for healthcare professionals from the expert panel on population and prevention science of the American heart association. Circulation 109 (21), 2655–2671. [PubMed: 15173049]

Committee of the Environmental and Occupational Health Assembly of the American Thoracic Society, 1996 Health effects of outdoor air pollution. Am. J. Respir. Crit. Care Med 153 (1), 3–50. [PubMed: 8542133]

DeVries R, Kriebel D, Sama S, 2017 Outdoor air pollution and COPD-related emergency department visits, hospital admissions, and mortality: a meta-analysis. COPD 14 (1), 113–121. [PubMed: 27564008]

Dominici F, Peng RD, Bell ML, Pham L, McDermott A, Zeger SL, Samet JM, 2006 Fine particulate air pollution and hospital admission for cardiovascular and respiratory diseases. J. Am. Med. Assoc 295 (10), 1127–1134.

Guarnieri M, Balmes JR, 2014 Outdoor air pollution and asthma. Lancet 383 (9928), 1581–1592. [PubMed: 24792855]

Health Effects Institute, 2019 State of Global Air. Available at: www.stateofglobalair.org. 2019.

HEI Panel on the Health Effects of Traffic-Related Air Pollution, 2010 Traffic-related Air Pollution: a Critical Review of the Literature on Emissions, Exposure, and Health Effects. HEI Special Report 17 Health Effects Institute, Boston, MA.

Krewski D, Jerrett M, Burnett RT, Ma R, Hughes E, Shi Y, Turner MC, Pope CA 3rd, Thurston G, Calle EE, Thun MJ, Beckerman B, DeLuca P, Finkelstein N, Ito K, Moore DK, Newbold KB, Ramsay T, Ross Z, Shin H, Tempalski B, 2009 Extended follow-up and spatial analysis of the American Cancer Society study linking particulate air pollution and mortality. Res. Rep. Health Eff. Inst 140, 5–114 discussion 115–136.

Meng YY, Wilhelm M, Rull RP, English P, Ritz B, 2007 Traffic and outdoor air pollution levels near residences and poorly controlled asthma in adults. Ann. Allergy Asthma Immunol 98 (5), 455–463. [PubMed: 17521030]

Metzger KB, Tolbert PE, Klein M, Peel JL, Flanders WD, Todd K, Mulholland JA, Ryan PB, Frumkin H, 2004 Ambient air pollution and cardiovascular emergency department visits. Epidemiology 15 (1), 46–56. [PubMed: 14712146]

Mirabelli MC, Boehmer TK, Damon SA, Sircar KD, Wall HK, Yip FY, Zahran HS, Garbe PL, 2018 Air quality awareness among U.S. Adults with respiratory and heart disease. Am. J. Prev. Med 54 (5), 679–687. [PubMed: 29551329]

Pennington AF, Sircar K, Hsu J, Zahran HS, Damon SA, Mirabelli MC, 2019 Communication channels for air quality alerts in the United States. Prev. Med. Rep 14, 100860. [PubMed: 30989035]

U.S. Census Bureau, Census Bureau regions and divisions with state FIPS codes. Retrieved January 7, 2020 from. https://www2.census.gov/geo/pdfs/maps-data/maps/reference/us_regdiv.pdf.

U.S. Environmental Protection Agency, Particulate matter (PM) basics. Retrieved January 2, 2020 from. https://www.epa.gov/pm-pollution/particulate-matter-pm-basics.

U.S. Environmental Protection Agency, 2016 Technical Assistance Document for the Reporting of Daily Air Quality - The AIR Quality Index (AQI). Publication No, Research Triangle Park, NC EPA-454/B-16–002.

U.S. Environmental Protection Agency, 2018 2 2018. 2014 national emissions inventory report. Retrieved January 2, 2020 from. https://gispub.epa.gov/neireport/2014/.

U.S. Environmental Protection Agency, 2018 Ground-level ozone basics. Retrieved January 2, 2020 from. https://www.epa.gov/ground-level-ozone-pollution/ground-level-ozone-basics.

U.S. Environmental Protection Agency, 2018 Pre-generated data files. Retrieved. https://aqs.epa.gov/aqsweb/airdata/download_files.html, Accessed date: 13 July 2018.

U.S. Environmental Protection Agency, 2019 Air quality index (AQI) basics. Retrieved. https://airnow.gov/index.cfm?action=aqibasics.aqi, Accessed date: 29 August 2019.

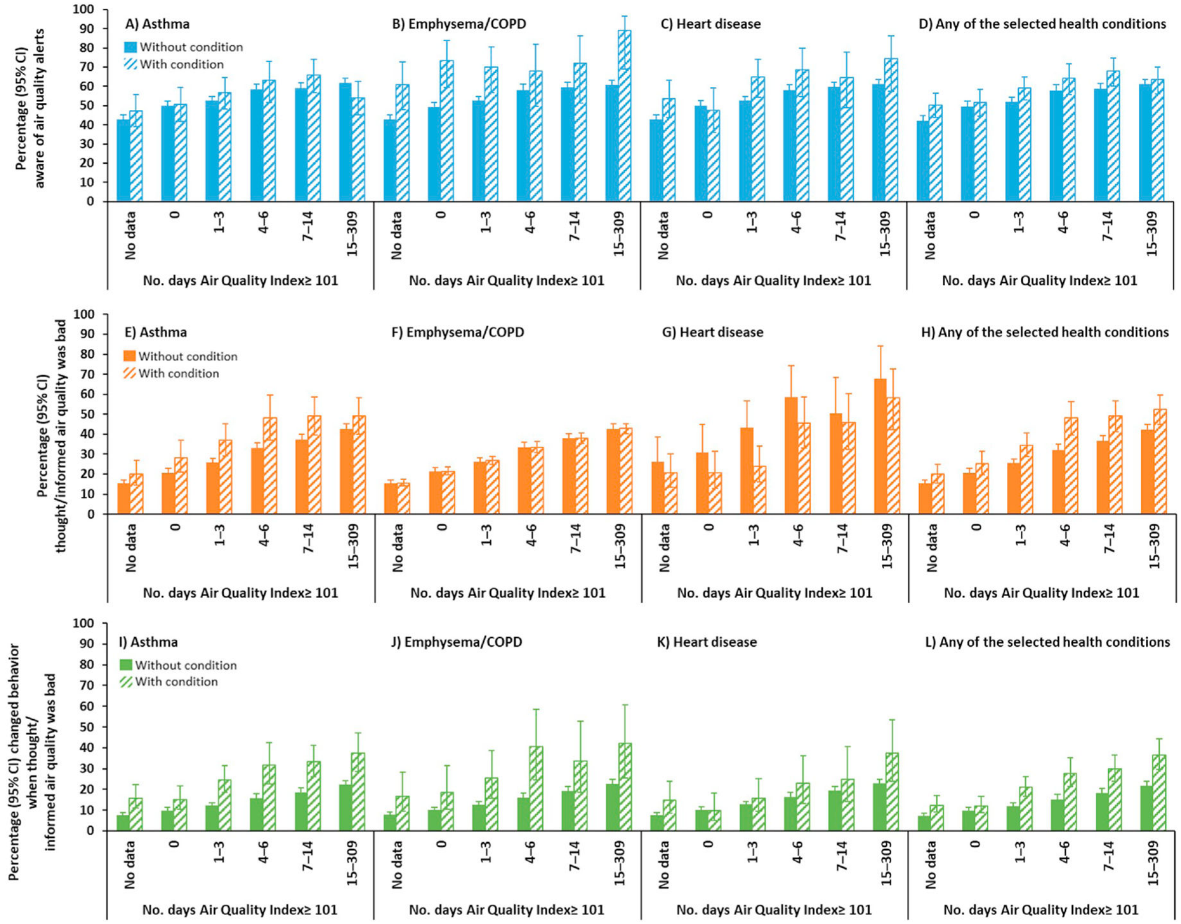

Fig. 1.

Adjusted percentages of each aspect of air quality awareness across quintiles of the distribution of number of days with Air Quality Index ≥101 in the past year among adults with and without selected respiratory and heart conditions. Percentages are adjusted for age, educational attainment, race/ethnicity, sex, and survey year.

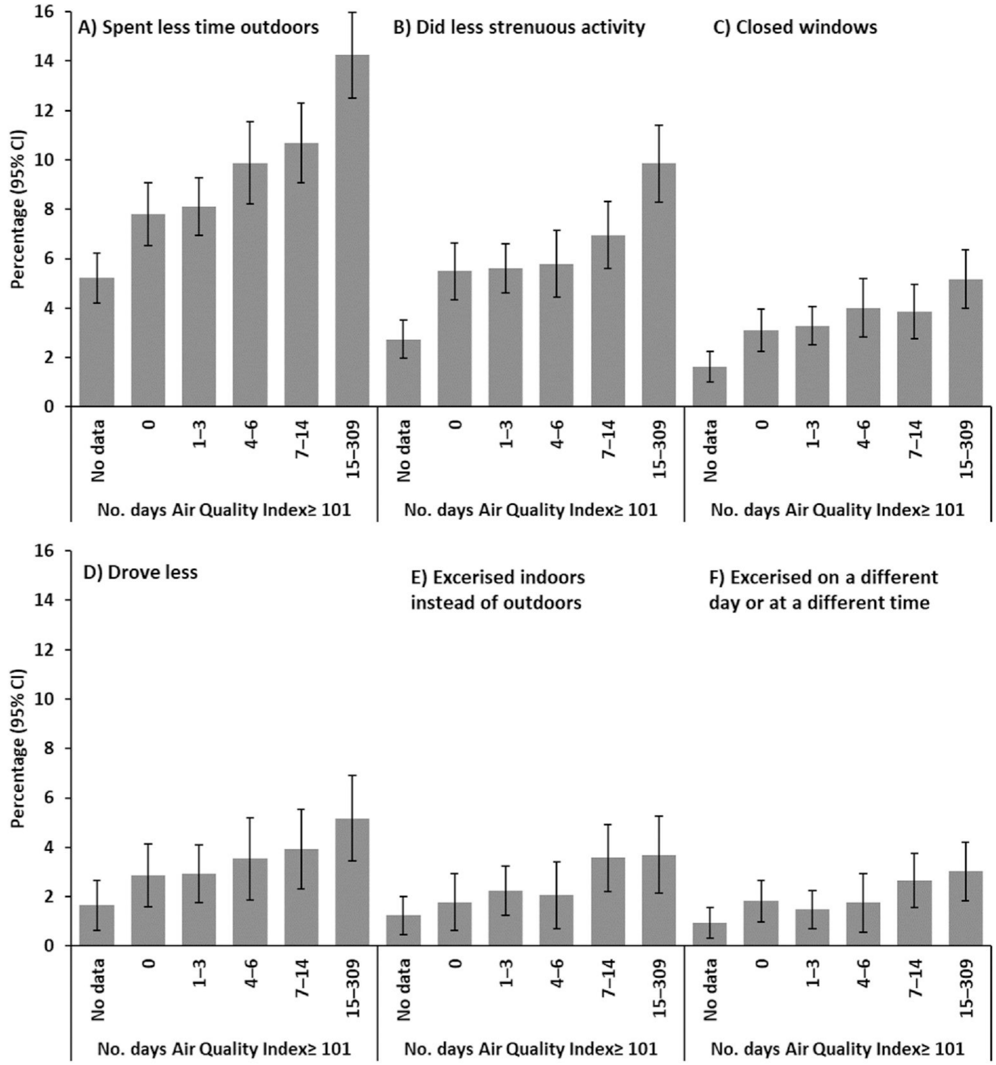

Fig. 2.

Adjusted percentages of adults reporting specific exposure reduction behaviors (panels A–F), across quintiles of the distribution of number of days with Air Quality Index ≥101 in the past year. Percentages and 95% CIs are adjusted for age, educational attainment, race/ethnicity, and sex; models also adjusted for survey year failed to generate valid estimates.

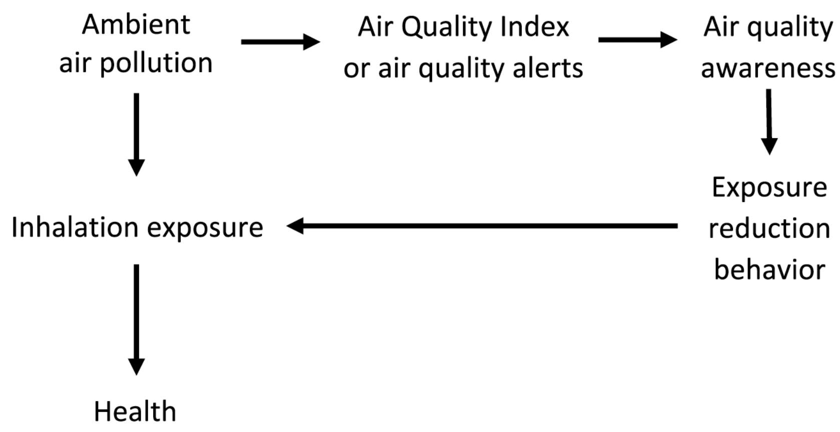

Fig. 3.

Relationships between air pollution and health may be modified by air quality awareness and resulting changes in air quality exposure reduction behaviors.

Table 1

Characteristics of 2016–2018 SummerStyles respondents.

Characteristics	No[a]	Weighted % (95% CI)[b]
Total	12,396	100.
Age, in years		
18–24	701	12.0 (11.1, 12.9)
25–34	1732	17.8 (16.9, 18.6)
35–44	2132	16.4 (15.6, 17.1)
45–54	2542	17.4 (16.7, 18.2)
55–64	2628	16.9 (16.2, 17.5)
65–74	1840	13.8 (13.1, 14.4)
75–94	821	5.8 (5.4, 6.3)
Educational attainment		
Less than high school	784	11.6 (10.8, 12.4)
High school	3684	29.2 (28.3, 30.1)
Some college	3677	28.5 (27.6, 29.4)
Bachelor's degree or higher	4251	30.7 (29.8, 31.6)
Race/ethnicity		
White, non-Hispanic	9133	64.5 (63.5, 65.6)
Black, non-Hispanic	1158	11.8 (11.0, 12.5)
2+ races, non-Hispanic	289	1.3 (1.1, 1.4)
Other, non-Hispanic	461	6.8 (6.1, 7.4)
Hispanic	1355	15.7 (14.8, 16.5)
Sex		
Female	6370	51.7 (50.7, 52.8)
Male	6026	48.3 (47.2, 49.3)
Survey year		
2016	4203	33.9 (32.9, 34.9)
2017	4106	33.1 (32.2, 34.1)
2018	4087	33.0 (32.0, 33.9)
U.S. Census region[c]		
Northwest	2333	18.0 (17.2, 18.7)
Midwest	2829	21.1 (20.3, 21.9)
South	4496	37.4 (36.4, 38.4)
West	2738	23.5 (22.7, 24.4)

[a]Unweighted number of respondents.

[b]Column percent.

[c]Defined by the U.S. Census Bureau (U.S. Census Bureau): Northwest: Connecticut, Massachusetts, Maine, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont; Midwest: Iowa, Illinois, Indiana, Kansas, Michigan, Minnesota, Michigan, North Dakota, Nebraska, Ohio, South Dakota, Wisconsin; South: Alabama, Arkansas, Delaware, Florida, Georgia, Kentucky, Louisiana, Maryland, Missouri, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, West Virginia, Washington DC; West: Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, New Mexico, Nevada, Oregon, Utah, Washington, Wyoming.

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Table 2

Days in each Air Quality Index Level of Health Concern category among 10,090 SummerStyles respondents with linked Air Quality Index data.

Air Quality Index values	**Air Quality Index Level of Health Concern**	**No. days**[a]	
		Mean (95% CI)	**Range**
0–50	Good	237.8 (235.8, 239.7)	0–366
51–100	Moderate	98.4 (97.0, 99.9)	0–274
101–150	Unhealthy for sensitive groups	12.1 (11.6, 12.6)	0–132
151–200	Unhealthy	2.8 (2.6, 3.0)	0–180
201–300	Very unhealthy	0.4 (0.3, 0.4)	0–17
300–500	Hazardous	0.03 (0.02, 0.03)	0–18

[a]Days in the past year, where past year is defined as July 1st of the previous year through June 30th of the year in which the respondent completed the survey.

Table 3

Adjusted prevalences of air quality awareness across categories of the number of days with Air Quality Index ≥101 and adjusted associations between days with Air Quality Index ≥101 and air quality awareness.

	Aware of air quality alerts		Thought/informed; air quality was bad		Changed behavior when thought/informed air quality was bad	
	Weighted % (95% CI)[a]	**PR (95% CI)[a]**	**Weighted % (95% CI)[a]**	**PR (95% CI)[a]**	**Weighted % (95% CI)[a]**	**PR (95% CI)[a]**
Total	53.9 (52.9, 54.9)[b]	-	29.2 (28.3, 30.1)[b]	-	14.7 (14.0, 15.4)[b]	-
No Air Quality Index data	43.2 (40.9, 45.5)	0.87 (0.81,0.93)	15.8 (14.2, 17.4)	0.74 (0.65, 0.84)	7.9 (6.9, 9.2)	0.78 (0.64, 0.95)
No. days Air Quality Index ≥101						
0[c]	49.9 (47.5, 52.3)	1.00	21.4 (19.5, 23.3)	1.00	10.2 (8.9, 11.6)	1.00
1–3	53.0 (50.9, 55.1)	1.06 (1.00,1.13)	26.7 (24.9, 28.6)	1.25 (1.12, 1.40)	12.9 (11.6, 14.3)	1.27 (1.07, 1.51)
4–6	58.4 (55.6, 61.2)	1.17 (1.09,1.25)	33.9 (31.4, 36.6)	1.59 (1.41, 1.79)	16.6 (14.6, 18.7)	1.63 (1.36, 1.95)
7–14	59.9 (57.3, 62.4)	1.20 (1.12,1.28)	38.2 (35.7, 40.7)	1.79 (1.60, 2.00)	19.6 (17.6, 21.6)	1.93 (1.63, 2.28)
15–309	61.3 (58.9, 63.7)	1.23 (1.15,1.31)	43.1 (40.6, 45.5)	2.02 (1.81, 2.24)	23.1 (21.1, 25.2)	2.27 (1.94, 2.67)

[a] Adjusted for age, educational attainment, race/ethnicity, sex, and survey year.

[b] Unadjusted.

[c] Referent category.

Table 4

Adjusted percentages of adults who reported each aspect of air quality awareness and adjusted associations with respiratory and heart disease status.

Respiratory and heart disease status	Aware of air quality alerts			Though/informed air quality was bad			Changed behavior when thought/informed air quality was bad		
	No[a]	Weighted % (95% CI)[b,c]	PR (95% CI)[c]	No.[a]	Weighted % (95% CI)[b,c]	PR (95% CI)[c]	No.[a]	Weighted % (95% CI)[b,c]	PR (95% CI)[c]
Asthma									
Yes	506	58.7 (55.0, 62.4)	1.10 (1.03, 1.17)	344	39.1 (35.5, 42.9)	1.37 (1.24, 1.52)	228	24.6 (21.6, 27.7)	1.76 (1.54, 2.01)
No[d]	6709	53.5 (52.4, 54.6)	1.00	3543	28.5 (27.5, 29.4)	1.00	1750	14.0 (13.3, 14.7)	1.00
Emphysema/COPD									
Yes	199	64.0 (57.5, 70.0)	1.19 (1.08, 1.32)	121	37.6 (31.8, 43.8)	1.30 (1.10, 1.53)	74	22.7 (18.0, 28.1)	1.56 (1.24, 1.96)
No[d]	7016	53.7 (52.6, 54.7)	1.00	3766	29.0 (28.1, 29.9)	1.00	1904	14.5 (13.8, 15.2)	1.00
Heart disease									
Yes	284	53.1 (48.0, 58.1)	0.98 (0.89, 1.15)	152	26.9 (22.8, 31.4)	0.92 (0.78, 1.08)	90	15.8 (12.6, 19.6)	1.08 (0.86, 1.35)
No[d]	6931	53.9 (52.9, 55.0)	1.00	3735	29.3 (28.4, 30.2)	1.00	1888	14.7 (14.0, 15.4)	1.00
Any of the above									
Yes	887	58.0 (55.1, 60.9)	1.09 (1.03, 1.15)	552	35.5 (32.8, 38.4)	1.25 (1.15, 1.36)	346	21.3 (19.2, 23.7)	1.54 (1.37, 1.73)
No[d]	6328	53.4 (52.3, 54.5)	1.00	3335	28.4 (27.4, 29.3)	1.00	1632	13.9 (13.1, 14.6)	1.00

[a] Unweighted number of respondents.

[b] Row percent.

[c] Adjusted for age, educational attainment, race/ethnicity, sex, and survey year.

[d] Referent category.