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Outdoor Air Quality Awareness, Perceptions, and Behaviors Among U.S. Children Aged 12–17 Years, 2015–2018

Katie M. Lynch, M.S.P.H.[a,b], **Maria C. Mirabelli, Ph.D., M.P.H.**[a,*]

[a]Asthma and Community Health Branch, National Center for Environmental Health, Centers for Disease Control and Prevention, Atlanta, Georgia

[b]Oak Ridge Institute for Science and Education, Oak Ridge, Tennessee

Abstract

Purpose: This study aimed to assess U.S. adolescents' perceptions and knowledge about air quality and their behaviors aimed to reduce air pollution exposure and whether they vary by demographic characteristics.

Methods: We analyzed data from the Porter Novelli Public Services *YouthStyles* survey, a nationally representative survey of U.S. adolescents aged 12–17 years. In survey years 2015–2018, a total of 3,547 adolescents self-reported awareness, perceptions, and behaviors related to air pollution. We calculated weighted percentages of respondents reporting each aspect of air quality awareness, perception, and behaviors overall and by categories of age, gender, parental education, metropolitan status, region, and survey year.

Results: Overall, an estimated 81% of U.S. adolescents thought outdoor air pollution could impact health, 52% thought there were things they could do to limit their or their family's exposure, 19% were aware of air quality alerts, 46% of those who thought or were informed air quality was bad did something differently, and 19% always or usually avoided busy roads to reduce air pollution exposure; differences were reported by some demographic variables.

Conclusions: Among U.S. adolescents, awareness that air pollution could impact health was relatively high. However, gaps were found in the awareness of the potential impacts and other aspects of awareness and perceptions related to air pollution and the engagement in behaviors to reduce exposure, some of which varied by demographic characteristics. These results can be used to inform interventions that increase awareness and behaviors to reduce air pollution exposures among U.S. adolescents.

[*]Address correspondence to: Maria C. Mirabelli, Ph.D., Asthma and Community Health Branch, National Center for Environmental Health, Centers for Disease Control and Prevention, 4770 Buford Highway, NE Mailstop S106-6, Atlanta, GA 30341., zif7@cdc.gov (M.C. Mirabelli).

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Supplementary Data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jadohealth.2020.07.040.

Keywords

Air pollution; Air quality alerts; Health education; Behavior change; Avoidance behaviors; Adolescents; Teenagers; Environmental health; Environmental exposure; Physical activity

Exposure to outdoor, or ambient, air pollution is associated with occurrence and exacerbations of respiratory and cardiovascular diseases [1–3], cancers [3,4], reproductive and developmental effects [5,6], childhood behavior and cognitive function [7,8], total (nonaccidental) mortality [3], and decreased life expectancy [9]. According to the World Health Organization, ambient air pollution causes an estimated 4.2 million premature deaths worldwide, per year [10]. Children are especially susceptible to air pollution because of physiology (e.g., higher minute ventilation), development (e.g., developing organs), and behavior (e.g., more time spent outside and more physical activity) [11]. In children, ambient air pollution has been linked to asthma exacerbations, school absences, decreased lung function, and detrimental effects on lung development [11,12]; recent studies also suggest associations with mental health [13,14].

To protect the health of individuals in the U.S., the U.S. Environmental Protection Agency (EPA) has established the National Ambient Air Quality Standards for six air pollutants known to be harmful to human health and the environment: carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter (PM) of two size ranges (<2.5 μm in diameter [$PM_{2.5}$] and <10 μm in diameter [PM_{10}]), and sulfur dioxide [15]. EPA's Air Quality Index (AQI), established in 1976, is an index based on the National Ambient Air Quality Standards, with values ranging from 0 to 500, divided into six categories [16,17]. Each category corresponds to a different level of health concern and has an associated color [17]. Categories include *Good, Moderate, Unhealthy for Sensitive Groups, Unhealthy, Very Unhealthy*, and *Hazardous* [17]. Different people are vulnerable at different levels, for example, at the level "Unhealthy for Sensitive Groups," members of sensitive groups, including children, older adults, people with heart and lung disease, and people of lower socioeconomic status (SES), are considered at risk from exposure to PM, whereas the rest of the public is considered less likely to experience health effects until the AQI reaches the "Unhealthy" level [17].

The AQI is used in the U.S. to inform the public about air quality and potential health effects [17]. When air quality is unhealthy, air quality alerts are issued to advise individuals about protective actions that they can take [17]. For example, they may recommend reducing or avoiding outdoor physical activity. Sensitive populations, such as children and individuals with asthma, are recommended to take precautions at lower levels of air pollution [17].

For adults, numerous epidemiologic studies provide information about the public's perceptions and knowledge of air pollution, its associated health effects, and behavioral responses to reduce air pollution exposure [18–22]. Despite the risks to children, little is known about the extent to which they are aware of the health effects of air pollution. We aimed to fill this gap using data collected in 2015–2018 from a nationally representative survey conducted annually among U.S. children 12–17 years of age. We conducted this analysis to assess and describe adolescents' perceptions and knowledge about ambient air quality and their behaviors intended to limit exposure to ambient air pollution.

Methods

Survey methods

We analyzed survey responses of adolescent respondents, aged 12–17 years, to the summer wave of *ConsumerStyles* for adolescents, known as *YouthStyles*, for years 2015–2018. *ConsumerStyles* is a survey conducted annually by Porter Novelli Public Services (Washington, DC) among respondents in the U.S. Participants were sampled from GfK's KnowledgePanel, an online database of eligible noninstitutionalized adults in the U.S. The panel is made up of members randomly recruited by mail using a probability-based sampling by address, maintains approximately 55,000 panelists, and is continuously replenished. For the spring wave of the survey, a random sample of adults, and a supplemental sample of adults with children aged 12–17 years, were included. The summer wave was then sent to individuals who previously completed the spring wave. The summer wave included two parts: [1] a survey for adults aged 18 years and older and [2] a survey for an adolescent in the adult's household, if there was a child of the correct age range and if the parent consented. If the household had more than one child in that age range, one of the children was randomly selected to complete the survey. The adult data were weighted by gender, age, household income, race/ethnicity, household size, education, U.S. Census region, and metropolitan statistical area status (as defined by the U.S. Office of Management and Budget). The adolescent data were weighted using weights from the adult spring wave data that were adjusted for adolescent gender, age, race/ethnicity, household income, number of adolescents in the household, U.S. Census region, and metropolitan statistical area status, to match U.S. Current Population Survey proportions. In 2015 and 2016, data were also weighted based on whether respondents reported having Internet access. Inclusion of Internet access in KnowledgePanel weighting was discontinued in 2017 based on widespread Internet access and the measurable error introduced with each weighting variable included. So that participants without Internet access could complete the survey, they were provided with a laptop or tablet and access to the Internet. The study protocol for our analysis was reviewed and determined to be exempt from full institutional review board review at the Centers for Disease Control and Prevention.

Study population

Overall, we included 3,547 *YouthStyles* survey respondents in our analysis. From June 11 to June 29, 2015, 888 youth (of 2,108 sampled parents) completed the survey for a response rate of 42%. From June 24 to July 11, 2016, 948 youth (of 2,112 sampled parents) completed the survey for a response rate of 45%. From June 7 to July 2, 2017, 866 youth (of 1,817 sampled parents) completed the survey for a response rate of 48%. From June 12, 2018, to July 7, 2018, 845 youth (of 1,759 sampled parents) completed the survey for a response rate of 48%.

Measures

Each adolescent's age, gender, location of residence, and the adult's level of education were reported by the adult *Summer-Styles* survey respondent in the household. Adolescent respondents answered five questions related to their perceptions and knowledge about ambient air quality, including (1) "*Do you think air pollution can impact a person's health in*

any way?" (2) "*Do you think there are things you can do to limit your or your family's exposure to air pollution?*" (3) "*Have you and your doctor, nurse, or other health professional ever talked about how to limit your exposure to air pollution?*" (4) "*Have you ever heard or read about the Air Quality Index or air quality alerts where you live?*", and for 2016–2018, but not 2015 (5) "*During the past 12 months, was there any time you thought or you were informed that air quality where you live was bad?*" Responses options to these five questions were "yes," "no," and either "don't know" or "don't know/not applicable."

Respondents also answered questions about their behaviors aimed to reduce exposure to ambient air pollution (i.e., avoidance behaviors). In 2016–2018, respondents who answered yes to the question, "*During the past 12 months, was there any time you thought or you were informed that air quality where you live was bad?*" were then asked "*Did you do anything differently when you thought or were informed that air quality where you live was bad?* In 2015, respondents were asked, "*During the past 12 months, did you do anything differently when you thought or were informed air quality was bad?*" and were not asked a separate question about if they thought or were informed air quality was bad in the past 12 months. For all years, respondents who answered that they did something differently were asked which of the following activities they did differently: *spent less time outdoors, did less strenuous activity, closed windows of house, exercised indoors instead of outdoors, and exercised on a different day or at a different time.* Finally, respondents were asked, "*When walking, biking, or exercising outdoors how often do you avoid busy roads to reduce your exposure to air pollution?*" Response options included "always," "usually," "sometimes," "rarely," "never," and "don't know." Responses were categorized as always/usually, sometimes/rarely, and never. We categorized all "don't know," "don't know/not applicable," "never thought/informed air quality was bad," and missing responses as negative.

Statistical analysis

We conducted all prevalence analyses using procedures for weighted survey data to generate weighted percentages with 95% confidence intervals (CIs). Survey weights provided by Porter Novelli Public Services were used to generate results that are representative of the U.S. adolescent population. We conducted all analyses for the entire 2015–2018 study period and for each individual year, unless noted otherwise. In addition, analyses of responses to three questions were stratified by age group (12–13, 14–15, and 16–17 years), gender, the adult respondent's highest level of completed formal education (high school or less, some college, and bachelor's degree or higher), U.S. Census region of residence (Midwest, Northeast, South, and West), and metropolitan status. To assess for linear trends in survey responses for five questions across the 2015–2018 study period, we conducted linear regressions with each year's prevalence as the dependent variable, year as the independent variable, and weight specified as $1/(\text{standard error of the prevalence})^2$. We conducted all analyses using SAS version 9.4 (SAS Institute, Inc., Cary, NC).

Results

Overall, an estimated 80.7% (95% CI: 79.0–82.3) of U.S. adolescents aged 12–17 years reported thinking that air pollution could impact health (Table 1). This percentage ranged

from 72.9% (95% CI: 69.2–76.6) in 2015 to 85.7% (95% CI: 82.9–88.5) in 2017 (Table A1) increased monotonically across categories of parental education level and was higher among respondents in metropolitan than nonmetropolitan areas (Table 2). More than half of U.S. adolescents aged 12–17 year reported thinking there were things they could do to limit their own or their family's exposure to air pollution (51.5%; 95% CI: 49.6–53.5). This percentage was lowest in 2015 (44.4%; 95% CI: 40.4–48.5) and highest in 2018 (57.4%; 95% CI: 53.5–61.4) (Table A1), with a p_{trend} = .018 (Table A3), and increased with increasing parental educational level (Table 2).

For all survey years combined, an estimated 19.0% (95% CI: 17.5–20.4) of adolescents had ever heard or read about the AQI or air quality alerts where they live (Table 1). Percentages varied modestly by year (Table A1) and were higher among adolescents whose parent had a bachelor's degree or higher (22.5%; 95% CI: 20.1–24.9) than among those whose parent completed high school or less (15.3%; 95% CI: 12.4–18.1; Table 2). Percentages of adolescents who thought or were informed that air quality was bad in the past 12 months are shown in Table 1 (for all years combined) and Table A1 (separately by year). Among those who thought or were informed air quality was bad in the past 12 months, 46.1% (95% CI: 40.0–52.1) did something differently (Table 1). Among those who did something differently, spending less time outdoors (82.1%; 95% CI: 76.0–88.1) and closing windows of the house (49.3%; 95% CI: 41.5–57.1) were reported most frequently. Overall, 18.5% (95% CI = 17.0–20.1) always or usually avoided busy roads when walking, biking, or exercising outdoors. Table A2 shows the percentages of adolescents that think air pollution can impact health, think they can limit their or their family's exposure to air pollution, and are aware of air quality alerts where they live, by both demographic categories and across years. Broadly speaking, analyses both within demographic categories and by survey year were limited by small sample sizes for some strata; resulting estimates are imprecise.

Discussion

Based on the results, awareness among adolescents that air pollution can impact health was relatively high during the 2015–2018 study period and was higher in 2018 than in 2015. Similarly, the percentage of U.S. adolescents who thought there were things they could do to limit their or their family's exposure to air pollution increased from 2015 to 2018. In contrast, only 19% of U.S. adolescents were aware of the AQI or air quality alerts during the 2015–2018 study period, with little variation over time. Each of these metrics of air quality awareness and perceptions was highest among adolescents with parental educational levels of bachelor's degrees or higher.

Few other data are available with which to compare our findings. One study of adolescents surveyed 13- to 17-year-olds in Mexico City and found that 75% of respondents thought air pollution affected health a lot and only 1% believed that it did not affect health at all [23]. Other qualitative studies found that adolescents identified air pollution as a main environmental concern [24,25]. Awareness of air quality alerts among U.S. adults has ranged from one-third in a 2005–2006 study of adults from Portland, Oregon, and Houston, Texas, to nearly half in a 2014–2016 study of adults from across the U.S. [18,19]. Among adults with children 4 years of age and older surveyed in Utah in 2003, 88% were aware of air

quality alerts with higher awareness reported among parents of children with asthma than among parents of children without asthma [26]. These findings indicate considerably less awareness of air quality alerts among U.S. adolescents than among adults, suggesting an opportunity for educating adolescents about their use.

The percentage of adolescents who were aware of air quality alerts was lower than both the percentage who thought that air pollution could impact health and the percentage who thought that there were ways to limit exposure. Because knowing when to take action to reduce exposure may depend on accurate knowledge of the ambient air quality, increasing awareness of air quality alerts could be important for exposure reduction. Air quality alerts based on the AQI contain information about potential health effects of air pollution and ways to limit exposure [27], so learning about the AQI could provide a way to increase knowledge of these topics, too. One way adolescents might learn about the AQI is in school, including through educational materials [28,29] developed by the EPA. However, these study results raise questions about whether this information, in fact, reaches adolescents.

By age group, 12- to 13-year-olds showed the greatest and most consistent increases over time in both the percentage who thought that air pollution could impact health and the percentage who thought that they could limit exposure to air pollution. If there were increased coverage of the topic in schools or by the media or increased awareness among the public in general, this could, speculatively, have contributed to changes in knowledge over time. However, perceiving that there are ways to limit exposure to air pollution does not necessarily indicate accurate knowledge of the effective ways to reduce exposure. For 2015–2018 combined, approximately 29% fewer 12- to 17-year-olds thought there were things they could do to limit exposure than thought that air pollution could impact health. This difference could represent a lack of knowledge of ways to reduce exposures or an actual or perceived inability to implement those methods.

Overall, the percentage of adolescents who reported that they talked to a health care professional about ways to limit air pollution exposure was low (3%) with minimal variation seen over the survey years (data not shown). This finding is consistent with a previous finding that only 3% of U.S. adults surveyed in 2014–2016 reported discussing ways to limit exposure with a health care professional [18]. Together, these findings suggest that health care professionals could be another channel to inform adolescents, as well as adults, about the health effects of air pollution and ways to limit exposure.

For years 2016–2018 combined, a little less than half of U.S. adolescents did something differently when they thought or were informed air quality was bad in the preceding 12 months. In another study, 10%–15% of respondents reported changing an activity during an air quality advisory; however, change was related to their perception of air quality, not the actual advisory [19]. In a study of young adult students in Singapore, attention to media, interpersonal discussion, knowledge, and risk perception were factors found to be associated with intention to take self-protective measures related to haze [30]. Behaviors may also be influenced by parents who might restrict certain activities during an episode of poor ambient air quality or take actions to reduce pollution [26]. Together, these findings suggest that addressing behavior change related to ambient air pollution exposure may involve more than

just increasing awareness of ambient air quality, and there might exist other important barriers to exposure reduction.

Among U.S. adolescents who did something differently when they thought or were informed air quality was bad, the most frequently reported activities were spending less time outdoors and closing windows of the house. Although limiting outdoor activity is sometimes a recommendation to reduce exposure to air pollution [17], this assumes better indoor than outdoor air quality. Indoor air pollution is also associated with health effects such as respiratory effects among children with asthma [31]. In addition to sources that originated inside, indoor air pollution can contain outdoor pollution that penetrated the building envelope [32,33]. U.S. adolescents also reported exercising indoors instead of outdoors or on a different day or time and doing less strenuous activity when they thought or were informed air quality was bad. Ambient air quality has been found to influence outdoor activity [22] and overall levels of physical activity [21] in other studies of adults. Behaviors may be different for adolescents, though, and findings from studies of adults might not be applicable.

Our study described percentages of air quality awareness and perceptions by parental education level. Understanding air quality awareness and perceptions of adolescents by parental education level, an indicator of SES [34], is important because children of parents with lower levels of educational attainment may be at increased risk of asthma [35] and children with asthma are at risk of acute exacerbations from air pollution [11]. In addition, some studies, including a study of respiratory health among elementary school children in Canada, suggest that effect modification might exist between ambient air pollution exposure and health effects, by SES, with greater effects for those of lower SES [36,37]. Finally, differences in exposure to ambient air pollution based on SES have been found in parts of the U.S. [38]. These findings suggest that individuals of lower SES may be at increased risk of the health effects from ambient air pollution because of both greater exposure and susceptibility to air pollution. Increasing awareness related to ambient air pollution may not be sufficient if individuals do not have resources to avoid air pollution exposure, though, and this is a factor to consider when developing interventions.

One notable limitation of this study is the lack of data available on health status. In particular, respiratory health status, such as asthma, was not available for *YouthStyles* respondents. Another limitation is that we analyzed responses by only four regions. Differences in perceptions that might exist within regions are not captured by our analyses. In addition, although the aim of the survey was to focus on outdoor air pollution, the survey questions did not explicitly exclude indoor air pollution, and we could not assess the extent to which respondents may have been referring to indoor air quality in their responses. Furthermore, *YouthStyles* respondents were recruited via an adult survey respondent in the home, and while response rates for adults ranged from 67% in 2015 to 74% in 2017, *YouthStyles* survey response rates were lower than 50% each year. We cannot determine if the adult or adolescent nonresponders differed from adult or adolescent responders, respectively, in terms of unmeasured variables. For example, homeownership versus renter status was not reported in the *YouthStyles* survey and was not accounted for in our analyses; however, the weighting of the data take into account age and household income, and we do

not anticipate that our results insufficiently represent any category of occupancy status. Also, participants were provided with Internet access and a web-based device, as needed. Although this could create an incentive to participate in the survey among people without Internet access or devices, and theoretically make the sample less representative of the U.S. population, the results are weighted by household income, and for 2015 and 2016, by Internet access, to make them representative by these variables.

A strength of this study is that we analyzed data from a survey that was weighted to make it representative of adolescents in the U.S. based on several demographic variables. This makes the results useful for considering awareness, perceptions, and behaviors of adolescents across the U.S. Other strengths of our analysis include the large sample of adolescents on which our results are based and the inclusion of identical survey questions over several years, which allowed us to pool survey responses for a robust description of U.S. adolescents' awareness, perceptions, and behaviors related to ambient air quality.

In summary, U.S. adolescents were found in this study to have a relatively high awareness that air pollution could impact health, with increased percentages over time in both this awareness and the perception that there were things they could do to limit exposure. However, gaps were found between the awareness of the potential impacts and the perception that they could limit exposure, the engagement in behaviors to reduce exposure, and the awareness of air quality alerts. Furthermore, differences by some demographic variables were seen. These results can be used to inform interventions to increase awareness related to ambient air quality and engagement in behaviors aimed at reducing air pollution exposures among U.S. adolescents.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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IMPLICATIONS AND CONTRIBUTION

This study adds to the understanding of U.S. adolescents' perceptions and knowledge about outdoor air quality and their behaviors to reduce outdoor air pollution exposure. The findings can be used to inform interventions related to air pollution exposure reduction among adolescents.

Table 1

Prevalence of air quality awareness, perceptions, and behaviors among U.S. adolescents from 2015 to 2018

	All years		
	N[a]	Total N[a]	Weighted % (95% CI)
Thinks air pollution can impact health	2,923	3,547	80.7 (79.0–82.3)
Thinks they can limit exposure to air pollution	1,878	3,547	51.5 (49.6–53.5)
Aware of air quality alerts	723	3,547	19.0 (17.5–20.4)
Thought/informed air quality was bad[b]	370	2,659	13.2 (11.7–14.7)
Did something differently when thought/informed air quality was bad[b]	165	370	46.1 (40.0–52.1)
Did the following differently when thought/informed air quality was bad[c]			
Spent less time outdoors	187	231	82.1 (76.0–88.1)
Closed windows of house	114	231	49.3 (41.5–57.1)
Did less strenuous activity	72	231	34.9 (27.2–42.6)
Exercised indoors instead of outdoors	72	231	33.7 (26.2–41.2)
Exercised on a different day/time	38	231	21.8 (14.5–29.0)
Avoids busy roads to reduce exposure to air pollution when walking, biking, or exercising outdoors			
Always/usually	646	3,547	18.5 (17.0–20.1)
Sometimes/rarely	900	3,547	25.0 (23.4–26.7)

[a]Number (N) from unweighted survey sample.

[b]Data shown include 2016–2018 data only because of changes in the phrasing of questions between year 2015 and 2016–2018.

[c]Among respondents who reported they did something differently when thought/informed air quality was bad.

Table 2

Prevalence of air quality awareness and perceptions among 3,547 U.S. adolescents from 2015 to 2018, by demographic characteristics

	All years		
	N[a]	Total N[a]	Weighted % (95% CI)
Thinks air pollution can impact health			
Age (years)			
12–13	944	1,183	79.6 (76.9–82.3)
14–15	956	1,137	81.3 (78.4–84.2)
16–17	1,023	1,227	81.0 (78.2–83.8)
Gender			
Female	1,473	1,754	82.0 (79.8–84.3)
Male	1,450	1,793	79.3 (77.0–81.6)
Parental education level			
High school or less	597	798	72.4 (68.7–76.2)
Some college	953	1,160	81.2 (78.5–84.0)
Bachelor's or higher	1,373	1,589	86.2 (84.2–88.2)
Region			
Midwest	773	947	79.8 (76.6–83.1)
Northeast	552	656	83.1 (79.7–86.6)
South	994	1,235	78.5 (75.7–81.3)
West	604	709	83.0 (79.6–86.4)
Metropolitan status			
Metropolitan	2,567	3,088	81.7 (80.0–83.4)
Nonmetropolitan	356	459	74.7 (69.8–79.6)
Thinks they can limit exposure to air pollution			
Age (years)			
12–13	614	1,183	51.4 (48.0–54.7)
14–15	610	1,137	51.4 (48.0–54.9)
16–17	654	1,227	51.7 (48.3–55.1)
Gender			
Female	949	1,793	52.3 (49.5–55.1)
Male	929	1,754	50.7 (48.0–53.5)
Parental education level			
High school or less	364	798	43.1 (39.1–47.2)
Some college	596	1,160	51.0 (47.6–54.4)
Bachelor's or higher	918	1,589	58.0 (55.2–60.8)
Region			
Midwest	490	947	50.0 (46.2–53.8)
Northeast	331	656	48.3 (43.8–52.8)
South	666	1,235	51.8 (48.5–55.0)
West	391	709	54.8 (50.5–59.0)

	All years		
	N[a]	Total N[a]	Weighted % (95% CI)
Metropolitan status			
Metropolitan	1,655	3,088	52.0 (49.9–54.1)
Nonmetropolitan	223	459	48.7 (43.4–54.1)
Aware of air quality alerts			
Age (years)			
12–13	207	1,183	17.2 (14.7–19.8)
14–15	232	1,137	18.9 (16.4–21.5)
16–17	284	1,227	20.6 (17.9–23.2)
Gender			
Female	362	1,793	19.8 (17.6–22.0)
Male	361	1,754	18.2 (16.1–20.2)
Parental education level			
High school or less	136	798	15.3 (12.4–18.1)
Some college	223	1,160	17.8 (15.3–20.3)
Bachelor’s or higher	364	1,589	22.5 (20.1–24.9)
Region			
Midwest	186	947	18.3 (15.4–21.1)
Northeast	115	656	15.5 (12.4–18.5)
South	253	1,235	18.5 (16.0–20.9)
West	169	709	22.8 (19.3–26.4)
Metropolitan status			
Metropolitan	672	3,088	20.6 (18.9–22.2)
Nonmetropolitan	51	459	9.6 (6.7–12.5)

[a]Number (N) from unweighted survey sample.