# Autism Spectrum Disorder Among US Children (2002–2010): Socioeconomic, Racial, and Ethnic Disparities

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*Objectives.* To describe the association between indicators of socioeconomic status (SES) and the prevalence of autism spectrum disorder (ASD) in the United States during the period 2002 to 2010, when overall ASD prevalence among children more than doubled, and to determine whether SES disparities account for ongoing racial and ethnic disparities in ASD prevalence.

*Methods.* We computed ASD prevalence and 95% confidence intervals (CIs) from population-based surveillance, census, and survey data. We defined SES categories by using area-level education, income, and poverty indicators. We ascertained ASD in 13 396 of 1 308 641 8-year-old children under surveillance.

*Results.* The prevalence of ASD increased with increasing SES during each surveillance year among White, Black, and Hispanic children. The prevalence difference between high- and low-SES groups was relatively constant over time (3.9/1000 [95% CI = 3.3, 4.5] in 2002 and 4.1/1000 [95% CI = 3.6, 4.6] in the period 2006–2010). Significant racial/ethnic differences in ASD prevalence remained after stratification by SES.

*Conclusions.* A positive SES gradient in ASD prevalence according to US surveillance data prevailed between 2002 and 2010, and racial and ethnic disparities in prevalence persisted during this time among low-SES children. (*Am J Public Health.* 2017;107:1818–1826. doi:10.2105/AJPH.2017.304032)

**See also Newschaffer, p. 1698.**

Population-based studies of the prevalence of autism spectrum disorder (ASD) in the United States have reported notable differences among selected racial and ethnic groups, with prevalence generally found to be higher among non-Hispanic White children relative to both non-Hispanic Black and Hispanic children.[1–7] Studies in the United States[8–10] and in some,[11,12] but not other,[13,14] countries have also found a positive socioeconomic status (SES) gradient in ASD prevalence, with prevalence increasing with indicators of increasing socioeconomic advantage. For example, in a previous analysis of public health surveillance data for children in communities included in the Centers for Disease Control and Prevention's Autism and Developmental Disabilities Monitoring (ADDM) Network in 2002 and 2004, we found a dose–response association between SES and ASD prevalence, and a prevalence nearly 70% higher among children in the highest relative to the lowest SES tertile of the population (prevalence ratio = 1.69; 95% confidence interval [CI] = 1.55, 1.83).[10]

The SES findings for ASD stand in sharp contrast to those for intellectual disability and childhood disabilities generally, which consistently show an excess prevalence among children of low SES.[15] Taken together, the US findings of racial/ethnic and socioeconomic variation in prevalence suggest potential underascertainment of ASD in economically disadvantaged groups, and raise the question of whether the ongoing racial and ethnic disparities in ASD prevalence are confounded by SES.

Since our earlier analysis of SES disparities in ASD prevalence based on ADDM Network findings,[10] the estimated prevalence of ASD overall has more than doubled, from 6.6 per 1000 8-year-old children in 2002[16] to 14.7 in 2010.[1] Whether the increase in prevalence occurred across all SES strata is not known. If the increase occurred disproportionally among children of low SES, perhaps because of expanded screening and improved access to ASD diagnostic and treatment services over time, we would expect to see a diminution of the SES gradient in ASD prevalence. The present study analyzed ADDM Network data for the period 2002 to 2010 to address 2 main questions: (1) Did the SES gradient in ASD prevalence persist in each surveillance year from 2002 through

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2010? and (2) Were the racial and ethnic differences in ASD prevalence that have been previously documented present within SES strata throughout the period? An affirmative answer to the second question would suggest that racial and ethnic disparities in ASD prevalence are not readily explained by racial/ethnic disparities in available indicators of SES.

Additional questions we sought to answer were whether a positive SES gradient was present over time among subgroups defined by race, ethnicity, sex, and co-occurrence of intellectual disability, and among ASD cases ascertained from different sources (health care, school, and both health care and school). In our previous study,[10] we had hypothesized that a positive SES gradient would not be found among cases ascertained from school sources because special education services for autism should be accessible to all school-aged children with ASD in the United States, whereas specialized health and autism therapeutic services are not universally available and accessible. However, in our previous study, based on surveillance years 2002 and 2004, we found the SES gradient to be similar for cases identified through health care and school sources.[10]

## METHODS

We performed stratified analyses of population-based, cross-sectional surveillance data from the ADDM Network and the US Census and American Community Survey (ACS) to determine the prevalence of ASD among 8-year-old children by SES strata in 4 surveillance years: 2002, 2006, 2008, and 2010, the latest year for which geocoded surveillance data were available.

### Autism and Developmental Disabilities Monitoring Network

The ADDM Network was established by the Centers for Disease Control and Prevention in 2000 as a population-based surveillance program at diverse geographic locations in the United States. It incorporates abstracted data from records of multiple educational and health care sources to determine the number of 8-year-old children who are determined to meet the ASD case definition, regardless of preexisting diagnoses. The ADDM Network clinician reviewers determine whether the ASD case definition is met by reviewing a composite record of all relevant abstracted data for a given child.

Autism spectrum disorder refers to a group of neurodevelopmental disorders involving impairments in social communication and interaction, as well as the presence of repetitive or stereotyped behaviors.[17,18] In the ADDM Network surveillance database for 2002 to 2010, which preceded the publication of *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition*,[18] children with ASD included those who were 8 years of age, resided in the surveillance areas during surveillance years, and met *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition–Text Revision* (*DSM-IV-TR*)[17] diagnostic criteria for autistic disorder, Asperger's syndrome, or a pervasive developmental disorder not otherwise specified. Trained abstractors systematically reviewed health and educational records of children with a documented developmental delay or concern, regardless of the presence of a documented ASD classification. Children's records were reviewed by experienced clinicians who applied *DSM-IV-TR* criteria to classify ASD. Further details regarding the ADDM Network methodology have been reported previously.[1,16,19,20]

### Study Sample

This study was restricted to sites participating in the ADDM Network for surveillance years 2002, 2006, 2008, and 2010 that contributed geocoded data allowing classification of ASD cases by census indicators of SES. The included sites were located in 11 states: Alabama, Arizona, Arkansas, Colorado, Georgia, Maryland, Missouri, New Jersey, North Carolina, Utah, and Wisconsin.[1,16] Of the 11 sites, 8 participated in all 4 surveillance years and all participated in at least 3 of the surveillance years included in this report. A total of 13 396 8-year-old children with ASD were ascertained at the participating sites across the 4 surveillance years. Of the 13 396 children with ASD, 10 172 (75.9%) had a previous ASD diagnosis. Information from standardized intelligence tests was available for 77.7% of the children with ASD. On the basis of this information, children with ASD were classified as having co-occurring intellectual disability if their IQ was 70 or less.

The population denominator comprised all 8-year-old children residing in census tracts within the respective study areas and surveillance years according to US Census and National Center for Health Statistics bridged-race decennial and intercensal population estimates for 2002 to 2010. Across the 4 surveillance years, a total of 1 308 641 8-year-old children were under surveillance. Characteristics of this population are shown in Table 1.

### Socioeconomic Status Indicators and Computation of Prevalence

Although intercensal and 2010 US Census data provide population counts, they do not include socioeconomic information at the census tract level. To obtain census tract–level SES indicators, for surveillance year 2002, we used 2000 Census data, and for surveillance years 2006, 2008, and 2010, we used 2006–2010 ACS data. To allow assessment of the comparability of SES indicators based on 2000 Census data and 2006–2010 ACS data, for the 2006 surveillance year we computed SES indicators based on 2000 Census data in addition to 2006–2010 ACS data.

Our primary SES indicator for this analysis is educational attainment, based on the percentage of adults aged 25 years or older who attained a bachelor's degree or higher. At census area levels, this indicator is highly correlated with other indicators of SES, such as median household income and poverty, and such educational indicators are widely used measures of SES in health research.[10,27] To define SES tertiles, we ranked all census tracts included in a given surveillance year by educational attainment and created cut-points so that each tertile contained approximately one third of the 8-year-old population. For surveillance year 2002, with the 2000 Census data, the low educational attainment SES tertile included census tracts with percentage of those aged 25 years or older with bachelor's degrees of 14.4% or less and the high educational attainment SES included those with percentage of those with bachelor's degrees of 30.1% or more. For surveillance year 2010, with the ACS data, the corresponding cut-offs were 19.1% or less for low and 37.1% or more for high educational attainment.

**TABLE 1—Distribution of the Population of 8-Year-Old Children in the Surveillance Areas, by Period and Percentage Living in Poverty Areas: United States, 2002–2010**

| | Surveillance Year 2002 | | Surveillance Years 2006, 2008, and 2010 | | Total | |
|---|---|---|---|---|---|---|
| Population Strata | No. (%) | % in Poverty Area | No. (%) | % in Poverty Area | No. (%) | % in Poverty Area |
| Total | 379 459 (100) | 22.4 | 929 182 (100) | 36.0 | 1 308 641 (100) | 32.0 |
| Sex | | | | | | |
| Male | 194 407 (51.2) | 23.7 | 474 168 (51.0) | 36.0 | 668 575 (51.1) | 32.4 |
| Female | 185 052 (48.8) | 24.1 | 455 014 (49.0) | 36.0 | 640 066 (48.9) | 32.6 |
| Race/ethnicity | | | | | | |
| Non-Hispanic White | 226 134 (59.6) | 9.6 | 503 812 (54.2) | 20.8 | 729 946 (55.8) | 17.3 |
| Non-Hispanic Black | 81 402 (21.5) | 50.3 | 185 648 (19.9) | 60.2 | 267 050 (20.4) | 57.2 |
| Hispanic | 49 696 (13.1) | 36.1 | 166 898 (18.0) | 57.5 | 216 594 (16.6) | 48.8 |
| Other | 22 227 (5.8) | 19.4 | 72 824 (7.9) | 30.8 | 95 051 (7.2) | 28.1 |
| Site | | | | | | |
| Alabama | 37 495 (9.9) | 28.8 | 93 778 (10.1) | 46.5 | 131 274 (10.0) | 41.7 |
| Arizona | 42 618 (11.2) | 23.4 | 106 768 (11.5) | 41.1 | 149 386 (11.4) | 36.1 |
| Arkansas | 39 157 (10.3) | 37.9 | 44 136 (4.7) | 59.4 | 83 293 (6.4) | 49.3 |
| Colorado | 35 848 (9.4) | 11.6 | 114 375 (12.3) | 33.2 | 150 223 (11.5) | 28.1 |
| Georgia | 45 501 (12.0) | 16.2 | 140 906 (15.2) | 40.3 | 186 407 (14.3) | 36.3 |
| Maryland | 31 830 (8.4) | 21.6 | 81 923 (8.8) | 11.6 | 113 753 (8.7) | 14.4 |
| Missouri | 29 186 (7.7) | 20.3 | 78 981 (8.5) | 29.3 | 108 167 (8.3) | 26.9 |
| New Jersey | 30 807 (8.1) | 32.4 | 38 806 (4.2) | 37.6 | 69 613 (5.3) | 35.3 |
| North Carolina | 21 691 (5.7) | 20.6 | 96 293 (10.4) | 38.3 | 117 984 (9.0) | 35.1 |
| Utah | 27 921 (7.4) | 6.9 | 26 092 (2.8) | 21.3 | 54 012 (4.1) | 13.9 |
| Wisconsin | 37 405 (9.9) | 22.1 | 107 124 (11.5) | 34.0 | 144 529 (11.0) | 30.9 |
| Low EA, total[a] | 125 937 (100) | 50.1 | 308 572 (100) | 69.7 | 434 509 (100) | 64.0 |
| Non-Hispanic White | 56 037 (44.5) | 26.5 | 121 503 (39.4) | 51.3 | 177 540 (40.9) | 43.5 |
| Non-Hispanic Black | 48 492 (32.2) | 77.1 | 85 247 (27.6) | 86.0 | 125 739 (28.9) | 83.1 |
| Hispanic | 23 318 (18.5) | 59.3 | 84 337 (27.3) | 79.3 | 107 655 (24.9) | 75.0 |
| Middle EA, total[a] | 126 997 (100) | 14.4 | 311 721 (100) | 29.7 | 438 718 (100) | 25.3 |
| Non-Hispanic White | 75 889 (59.8) | 7.2 | 167 442 (53.7) | 18.0 | 243 331 (55.5) | 14.6 |
| Non-Hispanic Black | 27 202 (21.4) | 30.7 | 67 997 (21.8) | 46.6 | 68 269 (15.6) | 40.3 |
| Hispanic | 16 614 (13.1) | 20.0 | 53 824 (17.3) | 44.3 | 70 438 (16.1) | 38.6 |
| High EA, total[a] | 126 402 (100) | 2.8 | 308 455 (100) | 8.7 | 434 857 (100) | 7.0 |
| Non-Hispanic White | 94 126 (74.5) | 1.5 | 214 530 (69.6) | 5.7 | 308 656 (71.0) | 4.4 |
| Non-Hispanic Black | 13 241 (10.5) | 7.6 | 32 352 (10.5) | 20.6 | 45 593 (10.5) | 16.8 |
| Hispanic | 9 729 (7.7) | 8.2 | 28 706 (9.3) | 17.9 | 38 435 (8.8) | 15.5 |

*Note.* EA = educational attainment. Poverty areas include census tracts where at least 20% of people have incomes below the poverty level, US Census Bureau.[21,22]

*Source.* Population data sources: US Census Bureau,[23] Centers for Disease Control and Prevention,[24] US Census Bureau.[25, 26]

[a]Educational attainment socioeconomic status tertiles based on percentage of adults aged 25 years or older with a bachelor's degree or higher per census tract, based on 2000 Census data for surveillance year 2002, and on 2006–2010 ACS data for surveillance years 2006, 2008 and 2010. Total includes population classified as other or unknown race and ethnicity.

To confirm the robustness of the findings across SES indicators, we computed separate SES tertiles on the basis of median household income. The results of analyses using these tertiles were similar to those based on educational attainment and are not included in this report. We also created a dichotomous variable indicating census tracts that meet the US Census definition of "poverty area," defined as those in which at least 20% of children lived in households with incomes below the federal poverty line.[21] Although by design, with the use of tertile cut-offs, the proportion of children in the surveillance areas who were classified as low, middle, and high SES was approximately equal within each surveillance year, the proportion classified as living in poverty areas increased over time, from 22.4% in 2002 for which 2000 Census data were used to 36.0% in the later 3 surveillance years based on data from the 2006–2010 ACS (Table 1). This increase is indicative of the population impact of the 2008–2009 economic recession.[28]

For children with ASD, we assigned values for SES indicator tertiles and poverty area residence based on their census tract of residence at age 8 years, similar to the approach described by Krieger et al.[29]

## Statistical Analysis

We computed the SES-specific prevalence of ASD per 1000 by dividing the number of children with ASD in each SES category and study year by the general population of 8-year-old children in the same category and study year. We computed 95% confidence intervals (CIs) based on the B distribution, by using SPSS version 22 (IBM, Somers, NY). We examined associations between SES indicators and ASD prevalence after stratifying by site, and found the results were generally in the same direction each study year in all sites. The results presented here are pooled across sites within surveillance years or sets of surveillance years. To evaluate the association between ASD prevalence and both SES indicators and race/ethnicity, we computed prevalence ratios with 95% CIs. To evaluate whether the associations between educational attainment tertiles and ASD varied by race or ethnicity, sex, and other characteristics, we evaluated the educational attainment–ASD association after stratifying by these characteristics. We also computed prevalence differences with 95% CIs to estimate the differences in ASD prevalence between high and low educational attainment tertiles.

## RESULTS

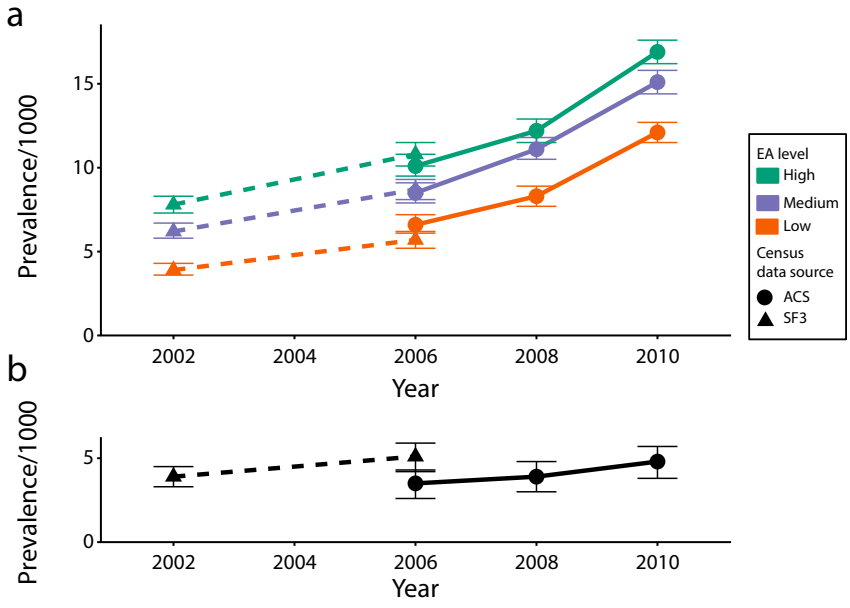
Among children overall, ASD prevalence rose over time in each educational attainment tertile of the population. In each surveillance year, prevalence was lowest in the low educational attainment tertile and highest in the high educational attainment tertile, consistent with a dose–response association between census tract educational attainment and ASD prevalence (Figure 1). A positive gradient in ASD prevalence by educational attainment categories was also seen in each surveillance year within each racial/ethnic group examined (Table 2).

Among children overall and among non-Hispanic children (both White and Black), the ratio of ASD prevalence in high versus low educational attainment tertiles appeared to decrease over time as the prevalence increased. For example, in 2002, when the overall ASD prevalence was 6.2 per 1000, the high to low educational attainment prevalence ratio was 1.99 (95% CI = 1.78, 2.21). In the 2006-to-2010 period, when the prevalence had increased to 11.9 per 1000, the high-to low-prevalence ratio was 1.44 (95% CI = 1.37, 1.51). Among Hispanic children, ASD prevalence increased over time, from 3.9 per 1000 in 2002 to 8.0 in the later period, while the high to low educational attainment prevalence ratios did not decrease (1.28 [95% CI = 0.87, 1.88] in 2002 and 1.35 [95% CI = 1.17, 1.56] in 2006–2010; Table 2).

In contrast to the prevalence ratios, ASD prevalence differences between high and low educational attainment tertiles showed no decrease over time among children overall (Figure 1 and Table 2) or among non-Hispanic Black children or Hispanic children (Table 2). Among non-Hispanic White children, the prevalence differences between high and low educational attainment tertiles narrowed from 3.7 per 1000 (95% CI = 2.9, 4.5) in 2002 to 2.4 per 1000 (95% CI = 1.7, 3.2) in 2006 to 2010 (Table 2).

Additional stratified results in Table 2 show that the educational attainment gradient in ASD prevalence was present among both boys and girls, among children without co-occurring intellectual disability, and among ASD cases ascertained from health care or both school and health care records. Among cases ascertained only from school records, ASD prevalence was lowest among children in the lowest educational attainment tertile during both periods, but the educational attainment gradient was present only in the earlier period (Table 2).

Evidence of the educational attainment gradient was present among children meeting surveillance criteria for ASD who had a previous ASD diagnosis or determination in their records, and among those with no previous ASD diagnosis, though in both periods the gradient was steeper for children with a previous ASD diagnosis (Table 2).




*Note.* 95% confidence intervals provided around the point estimates. Educational attainment tertiles based on percentage of adults aged ≥ 25 years with a bachelor's degree or higher per census tract, based on 2000 Census data for surveillance year 2002, and on 2006–2010 ACS data for surveillance years 2006, 2008, and 2010.

*Source.* Based on 2000 US Census data (SF3) for surveillance years 2002 and 2006, and on 2006–2010 American Community Survey (ACS) data for surveillance years 2006, 2008, and 2010.

**FIGURE 1—Autism Spectrum Disorder Among 8-Year-Old Children Indicating (a) Prevalence by Educational Attainment (EA) Tertiles and (b) Prevalence Differences Between High and Low EA Tertiles: United States, 2002–2010**

**TABLE 2—Autism Spectrum Disorder Prevalence and Prevalence Ratios and Differences by Educational Attainment Tertiles and Surveillance Period, Overall and Stratified by Sociodemographic Characteristics: United States, 2002–2010**

| Characteristics | ASD Cases | | ASD Prevalence per 1 000 (95% CI) | | | | Prevalence Ratio[b] (95% CI) | | High–Low EA Prevalence Difference (95% CI) |
|---|---|---|---|---|---|---|---|---|---|
| | No. | % in Poverty[a] | Overall | Low EA | Middle EA | High EA | Medium EA | High EA | |
| **2002 surveillance year** | | | | | | | | | |
| Overall | 2 338 | 19.0 | 6.2 (6.0, 6.5) | 3.9 (3.6, 4.3) | 6.2 (5.8, 6.7) | 7.9 (7.4, 8.4) | 1.58 (1.41, 1.77) | 1.99 (1.78, 2.21) | 3.9 (3.3, 4.5) |
| Race/ethnicity | | | | | | | | | |
| Non-Hispanic White | 1 522 | 10.0 | 6.7 (6.4, 7.0) | 4.3 (3.8, 4.9) | 6.5 (5.9, 7.1) | 8.0 (7.4, 8.6) | 1.51 (1.30, 1.76) | 1.86 (1.61, 2.15) | 3.7 (2.9, 4.5) |
| Non-Hispanic Black | 476 | 42.6 | 5.9 (5.4, 6.5) | 4.2 (3.6, 4.9) | 6.7 (5.8, 7.8) | 8.9 (7.4, 10.7) | 1.59 (1.29, 1.96) | 2.11 (1.67, 2.66) | 4.6 (3.0, 6.5) |
| Hispanic | 192 | 36.5 | 3.9 (3.4, 4.5) | 3.2 (2.5, 4.0) | 4.0 (3.1, 5.1) | 4.1 (3.0, 5.6) | 1.25 (0.90, 1.74) | 1.28 (0.87, 1.88) | 0.9 (–0.5, 2.5) |
| Sex | | | | | | | | | |
| Boys | 1 910 | 18.4 | 9.8 (9.4, 10.3) | 6.2 (5.6, 6.8) | 10.0 (9.3, 10.8) | 12.5 (11.7, 13.4) | 1.62 (1.43, 1.86) | 2.03 (1.80, 2.29) | 6.3 (5.3, 7.4) |
| Girls | 428 | 21.7 | 2.3 (2.1, 2.5) | 1.6 (1.3, 2.0) | 2.3 (1.8, 2.7) | 2.9 (2.5, 3.4) | 1.41 (1.09, 1.82) | 1.79 (1.41, 2.29) | 1.3 (0.8, 1.8) |
| Co-occurring intellectual disability[c] | | | | | | | | | |
| Present | 749 | 25.4 | 2.0 (1.9, 2.1) | 1.6 (1.4, 1.8) | 2.2 (2.0, 2.5) | 2.1 (1.9, 2.3) | 1.42 (1.19, 1.71) | 1.25 (1.03, 1.51) | 0.4 (0.1, 0.7) |
| Absent | 1 031 | 13.9 | 2.7 (2.5, 2.9) | 1.4 (1.2, 1.6) | 2.6 (2.3, 2.9) | 4.1 (3.8, 4.5) | 1.87 (1.55, 2.24) | 2.90 (2.44, 3.44) | 2.6 (2.2, 3.0) |
| Unknown | 558 | 20.1 | 1.5 (1.4, 1.6) | 1.0 (0.8, 1.2) | 1.4 (1.2, 1.6) | 1.9 (1.7, 2.2) | 1.45 (1.15, 1.82) | 1.89 (1.52, 2.34) | 0.9 (0.6, 1.2) |
| Previous diagnosis[d] | | | | | | | | | |
| No | 671 | 22.8 | 1.8 (1.7, 1.9) | 1.4 (1.2, 1.6) | 1.7 (1.5, 1.9) | 2.0 (1.8, 2.3) | 1.21 (0.99, 1.47) | 1.42 (1.18, 1.72) | 0.6 (0.3, 0.9) |
| Yes | 1 667 | 17.5 | 4.4 (4.2, 4.6) | 2.5 (2.2, 2.8) | 4.5 (4.1, 4.9) | 5.9 (5.5, 6.3) | 1.79 (1.56, 2.06) | 2.30 (2.02, 2.63) | 3.3 (2.8, 4.8) |
| Ascertainment source[e] | | | | | | | | | |
| Health and school | 763 | 18.1 | 2.0 (1.9, 2.1) | 1.4 (1.2, 1.6) | 1.9 (1.7, 2.2) | 2.7 (2.4, 3.0) | 1.40 (1.16, 1.71) | 2.00 (1.66, 2.40) | 1.3 (0.9, 1.6) |
| Health only | 793 | 19.0 | 2.1 (2.0, 2.3) | 1.4 (1.2, 1.6) | 2.0 (1.8, 2.3) | 2.6 (2.3, 2.9) | 1.42 (1.17, 1.73) | 1.85 (1.54, 2.22) | 1.2 (0.8, 1.5) |
| School only | 782 | 20.0 | 2.21(2.0, 2.3) | 1.2 (1.0, 1.4) | 2.4 (2.1, 2.7) | 2.6 (2.3, 2.9) | 1.97 (1.62, 2.40) | 2.14 (1.77, 2.60) | 1.4 (1.0, 1.7) |
| **2006, 2008, and 2010 surveillance years combined** | | | | | | | | | |
| Overall | 11 058 | 28.6 | 11.9 (11.7, 12.1) | 9.3 (9.0, 9.8) | 11.6 (11.2, 12.0) | 13.4 (13.0, 13.8) | 1.25 (1.19, 1.31) | 1.44 (1.37, 1.51) | 4.1 (3.6, 4.6) |
| Race/ethnicity | | | | | | | | | |
| Non-Hispanic White | 6 660 | 18.8 | 13.2 (12.9, 13.5) | 11.1 (10.5, 11.7) | 12.9 (12.4, 13.5) | 13.5 (13.0, 14.0) | 1.17 (1.09, 1.25) | 1.22 (1.15, 1.30) | 2.4 (1.7, 3.2) |
| Non-Hispanic Black | 2 055 | 49.6 | 11.1 (10.6, 11.6) | 9.0 (8.4, 9.7) | 11.8 (11.0, 12.6) | 14.3 (13.0, 15.7) | 1.30 (1.18, 1.44) | 1.58 (1.41, 1.77) | 5.3 (3.8, 6.8) |
| Hispanic | 1 341 | 49.6 | 8.0 (7.6, 8.4) | 6.9 (6.4, 7.5) | 7.9 (7.2, 8.7) | 9.3 (8.2, 10.5) | 1.15 (1.02, 1.30) | 1.35 (1.17, 1.56) | 2.4 (1.2, 3.9) |
| Sex | | | | | | | | | |
| Boys | 9 123 | 28.4 | 19.2 (18.8, 19.6) | 14.8 (14.2, 15.4) | 19.2 (18.5, 19.9) | 21.8 (21.1, 22.5) | 1.30 (1.24, 1.37) | 1.48 (1.40, 1.56) | 7.0 (6.1, 8.0) |
| Girls | 1 935 | 29.9 | 4.3 (4.1, 4.5) | 3.5 (3.2, 3.8) | 4.3 (4.0, 4.6) | 4.7 (4.4, 5.1) | 1.22 (1.09, 1.37) | 1.33 (1.19, 1.49) | 1.2 (0.7, 1.6) |
| Co-occurring intellectual disability[c] | | | | | | | | | |
| Present | 2 923 | 38.1 | 3.1 (3.0, 3.2) | 3.1 (2.9, 3.3) | 3.3 (3.1, 3.5) | 2.8 (2.6, 3.0) | 1.06 (0.97, 1.15) | 0.88 (0.81, 0.97) | –0.4 (–0.6, –0.2) |
| Absent | 5 711 | 25.2 | 6.1 (5.9, 6.3) | 4.1 (3.9, 4.3) | 6.0 (5.7, 6.3) | 7.7 (7.4, 8.0) | 1.46 (1.36, 1.57) | 1.87 (1.74, 2.00) | 3.6 (3.2, 4.0) |
| Unknown | 2 424 | 25.2 | 2.6 (2.5, 2.7) | 2.0 (1.8, 2.2) | 2.5 (2.3, 2.7) | 2.9 (2.7, 3.1) | 1.25 (1.12, 1.38) | 1.42 (1.28, 1.57) | 0.8 (0.6, 1.1) |

*Continued*

TABLE 2—*Continued*

| Characteristics | ASD Cases | | ASD Prevalence per 1 000 (95% CI) | | | | Prevalence Ratio[b] (95% CI) | | High–Low EA Prevalence Difference (95% CI) |
|---|---|---|---|---|---|---|---|---|---|
| | No. | % in Poverty[a] | Overall | Low EA | Middle EA | High EA | Medium EA | High EA | |
| Previous diagnosis[d] | | | | | | | | | |
| No | 1 553 | 49.5 | 1.7 (1.6, 1.8) | 2.4 (2.2, 2.6) | 2.7 (2.5, 2.9) | 2.9 (2.7, 3.1) | 1.12 (1.02, 1.24) | 1.21 (1.10, 1.33) | 0.5 (0.2, 0.7) |
| Yes | 8 504 | 28.1 | 9.2 (9.0, 9.4) | 6.9 (6.6, 7.2) | 9.2 (8.9, 9.5) | 10.5 (10.1, 10.9) | 1.33 (1.26, 1.41) | 1.52 (1.44, 1.60) | 3.6 (3.1, 4.1) |
| Ascertainment source[e] | | | | | | | | | |
| Health and school | 3 484 | 31.6 | 3.7 (3.6, 3.8) | 3.0 (2.8, 3.2) | 3.8 (3.6, 4.0) | 4.4 (4.2, 4.6) | 1.23 (1.13, 1.34) | 1.43 (1.32, 1.56) | 1.3 (0.1, 1.6) |
| Health only | 4 206 | 23.1 | 4.5 (4.4, 4.6) | 3.3 (3.1, 3.5) | 3.9 (3.7, 4.1) | 5.3 (5.0, 5.6) | 1.20 (1.10, 1.30) | 1.60 (1.48, 1.73) | 2.0 (1.7, 2.3) |
| School only | 3 368 | 39.9 | 3.6 (3.5, 3.7) | 2.9 (2.7, 3.1) | 4.2 (4.0, 4.4) | 3.7 (3.5, 3.9) | 1.45 (1.33, 1.57) | 1.28 (1.18, 1.40) | 0.8 (0.5, 1.1) |

*Note.* ASD = autism spectrum disorder; CI = confidence interval; EA = educational attainment (indicator of socioeconomic status [SES], tertiles based on percentage of adults aged 25 or older with a bachelor's degree or higher per census tract, based on 2000 Census data for surveillance year 2002, and on 2006–2010 American Community Survey data for surveillance years 2006, 2008 and 2010).

[a]% in poverty refers to residence in census tracts where at least 20% of people have incomes below the poverty level: US Census Bureau.[21,22]

[b]Reference = low EA.

[c]Co-occurring intellectual disability considered present if IQ ≤ 70.

[d]Previous autism diagnosis documented in health or educational records.

[e]Sources of records reviewed for autism spectrum disorder case ascertainment.

The educational attainment–ASD prevalence gradient was absent in both periods in 1 subgroup of children with ASD—namely, those with co-occurring intellectual disability. In the earlier period, the prevalence of co-occurring ASD and intellectual disability was lowest among children in low educational attainment tertile and highest among those in the middle educational attainment tertile. In the later period, the prevalence of co-occurring ASD and intellectual disability was lowest in the high educational attainment tertile (Table 2).

The results in Table 2 also show that in both periods, children with ASD and co-occurring intellectual disability and those with no previous ASD diagnosis were more likely to live in poverty areas than were those without intellectual disability and those with a previous ASD diagnosis, respectively. In addition, the percentage of children with ASD living in poverty areas varied substantially by race and ethnicity (Table 2). Overall, in both periods, children with ASD were less likely to live in poverty areas than were all 8-year-old children in the surveillance areas. In 2002, 19.0% of ASD cases (Table 2) and 22.4% of the children in the surveillance areas overall lived in poverty areas (Table 1). For the 2006 to 2010 surveillance years combined, 28.6% of ASD cases (Table 2) and 36.0% of the children in the surveillance areas overall lived in poverty areas (Table 1).

The prevalence ratios in Table 3 are presented to allow evaluation of the extent to which racial and ethnic disparities in ASD prevalence are explained by the association between SES and ASD prevalence, by using 2 indicators of SES–educational attainment and residence in poverty areas. The prevalence ratios for non-Hispanic White relative to non-Hispanic Black children were elevated in both periods before stratification by SES indicators, but not consistently so after stratification. In the low educational attainment tertile, the White–Black prevalence ratio was elevated only in the latter period whereas in poverty areas this ratio was elevated in both periods. In contrast, in the high educational attainment tertile and among children not residing in poverty areas, there was no racial disparity in ASD prevalence in either period (Table 3). The prevalence ratios comparing ASD prevalence in non-Hispanic White to Hispanic children were significantly elevated during both periods, both overall and within each SES stratum.

## DISCUSSION

These results confirm, on the basis of ADDM Network data and using educational attainment or poverty as indicators of SES, that a positive SES gradient in ASD prevalence was present over time between 2002 and 2010. Although the ratio indicating the relative prevalence in high- compared with low-SES children decreased over this time as overall prevalence more than doubled, the ASD prevalence difference between high and low SES was relatively constant, showing no evidence of convergence over time.

The results also show that the rise in ASD prevalence between 2002 and 2010 was similar in absolute terms in all 3 SES groups—low, middle, and high educational attainment—with an absolute change in prevalence between 2002 and 2010 of approximately 8 per 1000 children in each group (Figure 1). This finding along with the persistent SES disparity in prevalence is consistent with a recent National Academies of Science, Engineering, and Medicine study that found steady increases in ASD prevalence among children in poverty and receiving Supplemental Security Income and Medicaid between 2000 and 2012, but also found that even after the increase, the proportion of children in poverty receiving services or supplementary income because of ASD was lower than the proportion expected on the basis of estimates of the prevalence of ASD in the general population.[30]

The persistence of SES disparities in ASD prevalence in the United States has important public health implications. Early clinical

TABLE 3—Autism Spectrum Disorder Prevalence in Non-Hispanic White to Non-Hispanic Black and Non-Hispanic White to Hispanic Children, by Surveillance Period and Socioeconomic Strata: United States, 2002–2010

| Population Strata | Surveillance Period, PR (95% CI), 2002 | 2006, 2008, and 2010 |
|---|---|---|
| Overall | | |
| Non-Hispanic White/Non-Hispanic Black | 1.15 (1.04, 1.38) | 1.19 (1.14, 1.25) |
| Non-Hispanic White/Hispanic | 1.74 (1.50, 2.02) | 1.65 (1.56, 1.74) |
| Low EA[a] | | |
| Non-Hispanic White/Non-Hispanic Black | 1.02 (0.84, 1.25) | 1.23 (1.12, 1.34) |
| Non-Hispanic White/Hispanic | 1.34 (1.03, 1.73) | 1.61 (1.46, 1.77) |
| Middle EA[a] | | |
| Non-Hispanic White/Non-Hispanic Black | 0.97 (0.82, 1.15) | 1.11 (1.03, 1.21) |
| Non-Hispanic White/Hispanic | 1.61 (1.25, 2.08) | 1.65 (1.49, 1.83) |
| High EA[a] | | |
| Non-Hispanic White/Non-Hispanic Black | 0.91 (0.75, 1.10) | 0.95 (0.86, 1.04) |
| Non-Hispanic White/Hispanic | 1.95 (1.42, 2.67) | 1.46 (1.29, 1.65) |
| Poverty area[b] | | |
| Non-Hispanic White/Non-Hispanic Black | 1.41 (1.15, 1.74) | 1.31 (1.21, 1.42) |
| Non-Hispanic White/Hispanic | 1.80 (1.35, 2.38) | 1.72 (1.57, 1.89) |
| Non-poverty area[b] | | |
| Non-Hispanic White/Non-Hispanic Black | 0.93 (0.82, 1.00) | 0.95 (0.89, 1.00) |
| Non-Hispanic White/Hispanic | 1.85 (1.53, 2.24) | 1.51 (1.39, 1.64) |

*Note.* CI = confidence interval; EA = educational attainment; PR = prevalence ratio.

[a]EA socioeconomic tertiles based on percentage of adults aged 25 years or older with a bachelor's degree or higher per census tract, based on 2000 Census data for surveillance year 2002, and on 2006–2010 American Community Survey data for surveillance years 2006, 2008, and 2010.

[b]Poverty areas include census tracts where at least 20% of people have incomes below the poverty level: US Census Bureau.[21,22]

descriptions of autism suggested that it was a disorder seen primarily among children of highly educated and accomplished parents,[31] and a number of epidemiological studies have found positive associations between SES and autism prevalence.[8–12,32,33] However, as early as 1980, Lorna Wing argued that studies based on data for children receiving clinical diagnoses and services for autism were affected by biased case ascertainment, and that even in the United Kingdom, where access to health and educational services was universal, relatively high levels of parental education and resources were necessary to ensure that a child with autism was able to get an accurate diagnosis.[34] Recent large, epidemiological studies in Sweden[13] and France[14] that were designed to evaluate the association between SES and ASD found no evidence of a positive SES gradient in ASD prevalence. Both studies concluded that in countries with universal access and no economic barriers to obtaining autism diagnoses and services, ASD is not found to be associated with socioeconomic advantage and may be associated with socioeconomic disadvantage.[13]

## Limitations and Other Considerations

A limitation of the present study is that the surveillance data were available only for children receiving comprehensive developmental assessments or special education services. For this reason, we cannot confirm that ASD was underidentified in children of low SES, contributing to the positive SES gradient observed. It is possible that even if comprehensive assessments were available for all children, ASD would be found to be less frequent in some groups. If, however, the SES gradient in ASD prevalence found in this study is attributable to persisting disparities in access to or use of autism services in the United States, one implication of the findings is that the prevalence of ASD based on surveillance is underestimated and that the actual overall prevalence is similar to that observed for children of high SES. In 2010, ASD prevalence in the high educational attainment tertile was 16.9 per 1000, compared with 14.7 overall.

Another limitation of this study was our reliance on aggregate Census data for the denominator and comparison group data. Because of this, we were unable to perform multivariable analyses to evaluate and control for confounding effects of a broad set of variables. We were, however, able to perform stratified analyses to evaluate potential confounding of demographic variables.

Our finding that racial and ethnic disparities in ASD prevalence persisted over time, especially among children in low-SES communities, suggests that the relatively low ASD prevalence among Black and Hispanic children is not fully explained by racial and ethnic disparities in SES. Moreover, if low prevalence is indicative of underascertainment of ASD, this finding suggests that the negative impacts of poverty and being Black or Hispanic on ASD ascertainment are additive rather than confounded.

One potential strategy to enhance the completeness and equity of case ascertainment, though perhaps requiring more evidence,[35] is universal screening for ASD, as recommended by the American Academy of Pediatrics.[36] If all children received periodic screening for ASD during routine pediatric care and follow-up services as needed, we could be more confident in the use of administrative data to estimate ASD prevalence for low- and middle-SES children. In addition to potentially improving surveillance and prevalence estimation, universal routine screening for ASD could help ensure equitable access to and use of autism services.

Diagnostic and treatment services for ASD are among the most expensive of all forms of neurodevelopmental and behavioral services.[37] If the disparities found in this study are a result of services being preferentially accessed by socioeconomically advantaged children, these disparities would point to the need for strategies to help ensure that ASD services are reaching those in greatest need. As the proportion of resources for developmental disabilities that are dedicated to ASD grows, it is important that these resources

are distributed equitably. In addition to low income and education, some of the barriers to equitable access to ASD services identified in previous studies include language and transportation barriers, cultural differences, and scheduling difficulties.[38,39]

The SES gradient and racial disparities in ASD prevalence found in this study contrast with those for cerebral palsy identified in a previous analysis of ADDM Network data[40]; for cerebral palsy, a negative SES gradient and higher prevalence among Black relative to White children were found. These contrasting patterns for cerebral palsy and ASD do not suggest the coverage of the ADDM Network surveillance system is differential by SES, but may instead point to disparities in referral for or access to autism diagnostic and treatment services.

Consistent with our earlier analysis of data for surveillance years 2002 and 2004,[10] the positive SES gradient in ASD prevalence persisted in the latter half of the decade in each demographic group examined, with the exception of children with co-occurring ASD and intellectual disability. The lack of an association during both periods between ASD and SES in the subgroup with co-occurring intellectual disability might result from the existence of competing associations, as the prevalence of intellectual disability is consistently found to be elevated among children of low SES.[10] The absence of an SES gradient in ASD prevalence among children with co-occurring intellectual disability could also result from these children being more likely than those with ASD alone to be referred and evaluated for developmental disorders including autism and thus less subject to ascertainment bias.

## Conclusions

In conclusion, the SES disparity in ASD prevalence based on US surveillance data persisted between 2002 and 2010, and this disparity, according to SES measures available for this study, does not appear to fully explain the observed racial and ethnic disparities in ASD prevalence in the United States. AJPH

### CONTRIBUTORS

M. S. Durkin and M. J. Maenner conceptualized and designed the study. All of the authors acquired the data. M. S. Durkin and M. J. Maenner analyzed and interpreted the data. M. S. Durkin drafted the article. M. J. Maenner, J. Daniels, R. Fitzgerald, P. Imm, and M. Yeargin-Allsopp made critical revisions.

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**Note.** The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

### HUMAN PARTICIPANT PROTECTION

This project was approved by the University of Wisconsin Health Sciences institutional review board. All participating sites met applicable institutional review board and privacy/confidentiality requirements under 45 CFR 46.

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