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Status of Childhood Asthma in the United States, 1980–2007

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ABSTRACT

Centers for Disease Control and Prevention data were used to describe 1980–2007 trends among children 0 to 17 years of age and recent patterns according to gender, race, and age. Asthma period prevalence increased by 4.6% per year from 1980 to 1996. New measures introduced in 1997 show a plateau at historically high levels; 9.1% of US children (6.7 million) currently had asthma in 2007. Ambulatory care visit rates fluctuated during the 1990s, whereas emergency department visits and hospitalization rates decreased slightly. Asthma-related death rates increased through the middle 1990s but decreased after 1999. Recent data showed higher prevalence among older children (11–17 years), but the highest rates of asthma-related health care use were among the youngest children (0–4 years). After controlling for racial differences in prevalence, disparities in adverse outcomes remained; among children with asthma, non-Hispanic black children had greater risks for emergency department visits and death, compared with non-Hispanic white children. For hospitalizations, for which Hispanic ethnicity data were not available, black children had greater risk than white children. However, nonemergency ambulatory care use was lower for non-Hispanic black children. Although the large increases in childhood asthma prevalence have abated, the burden remains large. Potentially avoidable adverse outcomes and racial disparities continue to present challenges. These findings suggest the need for sustained asthma prevention and control efforts for children. *Pediatrics* 2009;123:S131–S145

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Key Words

asthma, trends, epidemiology, data analysis

Abbreviations

BRFSS—Behavioral Risk Factor Surveillance System

CDC—Centers for Disease Control and Prevention

ED—emergency department

NAS—National Asthma Survey

NHIS—National Health Interview Survey

NSCH—National Survey of Children's Health

ICD—International Classification of Diseases

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THE REFRAIN HAS become familiar: “asthma is one of the most common chronic childhood conditions in the United States.” Asthma continues to present a major burden for affected children and their families, a challenge to public health organizations and health care providers, and a puzzle to researchers searching for its primary causes. Millions of children in the United States are affected by asthma, which is a major cause of childhood disability.¹ Asthma may limit a child's ability to play, learn, and sleep; it necessitates potentially complex and expensive interventions² and results in both direct medical costs and indirect costs (eg, missed school days and work days).^{3,4} Although scientific advances have greatly improved the understanding of the mechanisms that cause asthma attacks and have led to effective medical interventions,⁵ the majority of children with asthma still suffer from attacks,⁶ overall rates of adverse outcomes have remained relatively resistant to intervention efforts^{6,7} despite promising progress demonstrated for some innovative programs,^{8–10} large racial and income differences continue to widen,¹¹ and identification of the primary cause of asthma and the reasons for its increasing prevalence remains frustratingly complex.^{12,13}

One component of the response of the Centers for Disease Control and Prevention (CDC) to asthma is surveillance; asthma surveillance involves compiling asthma-specific data from multipurpose national data systems regarding prevalence, health care use, and mortality rates. On the basis of this data compilation, the CDC produced a series of 3 reports on asthma from 1960 through 2004.^{14–16} This report focuses specifically on childhood asthma since 1980; it updates a previous study of trends in childhood asthma,⁷ provides new details according to age and race/ethnicity, and adds data on the adoption of asthma control measures. Although estimates of prevalence, health care use, and mortality rates are major indicators of the impact of childhood asthma, symptoms that are not recognized or are not severe enough to warrant emergency care or hospitalization can still affect quality of life. Therefore, this report also addresses the broader context and responses to childhood asthma by reviewing CDC programs that track symptoms and disease management and that provide timely relevant data to health care professionals, policymakers, and child caretakers at the community level. High-priority CDC goals include improved tracking of asthma symptom severity and control, measurement of the magnitude of local asthma burdens, support for and evaluation of asthma intervention and treatment programs, and dissemination of interventions that have been demonstrated to be effective in reducing symptoms and adverse outcomes.¹⁷

DATA SOURCES AND ANALYSIS

Trend data from 1980 through the most recent year available were analyzed from the mortality component of the National Vital Statistics System and from 3 surveys conducted by the CDC National Center for Health Statistics, that is, the National Health Interview Survey (NHIS), the National Ambulatory Medical Care Survey, and the National Hospital Discharge Survey. Trend data from a fifth source, the National Hospital Ambulatory Medical Care Survey, were available beginning in 1992. The analysis included nationally representative samples of households "health care visits" and data compiled from death certificates for children 0 to 17 years of age. Analyses of recent data were stratified according to age group (0–4, 5–10, or 11–17 years), gender, and, when possible, race/ethnicity. Data for 2004–2005, the most recent period available for all data sets, were used to obtain stable estimates. Available race/ethnicity data ranged from broad categories of race (white or black) for the National Hospital Discharge Survey to detailed race and race/ethnicity categories (white, black, Alaska Native/American Indian, Asian, non-Hispanic white, non-Hispanic black, Hispanic, and 2 Hispanic subgroups, ie, Puerto Rican and Mexican) for the NHIS. Data from 2 additional data sources, the National Survey of Children's Health (NSCH) and the National Asthma Survey (NAS), were included to show recent geographic detail on prevalence and information on disease management.

Data on asthma prevalence were obtained from the NHIS, a cross-sectional, continuous, household interview survey of the US civilian noninstitutional population.¹⁸ A responsible adult (usually a parent) provides proxy responses for children included in the survey. NHIS data from 1980 to 1996 were used to estimate 12-month-period asthma prevalence on the basis of the question, "During the past 12 months, did anyone in the household have asthma?" In 1997, the NHIS was redesigned to improve data quality, to simplify the survey, and to reduce the questionnaire length.¹⁹ The redesigned survey included 2 new measures, that is, lifetime asthma diagnosis (assessed with the question, "Has a doctor or health professional ever told you that [child's name] had asthma?") and asthma attack prevalence (assessed on the basis of yes responses to the lifetime diagnosis question and to the follow-up question, "During the past 12 months, has [child's name] had an episode of asthma or an asthma attack?"). In 2001, a third new measure was added to assess the prevalence of asthma at the time of the survey; current asthma prevalence was estimated on the basis of yes responses to both the lifetime diagnosis question and the follow-up question "Does [child's name] still have asthma?". National estimates from the NHIS were calculated by using survey sample weights.

Asthma prevalence and disease management also were analyzed by using data from the NSCH²⁰ and NAS.²¹ Both surveys were administered through the State and Local Area Integrated Telephone Survey, a survey that uses the same random-digit-dial telephone design and sampling frame as the National Immunization Survey conducted by the CDC. Data were collected at telephone centers across the United States and were weighted to

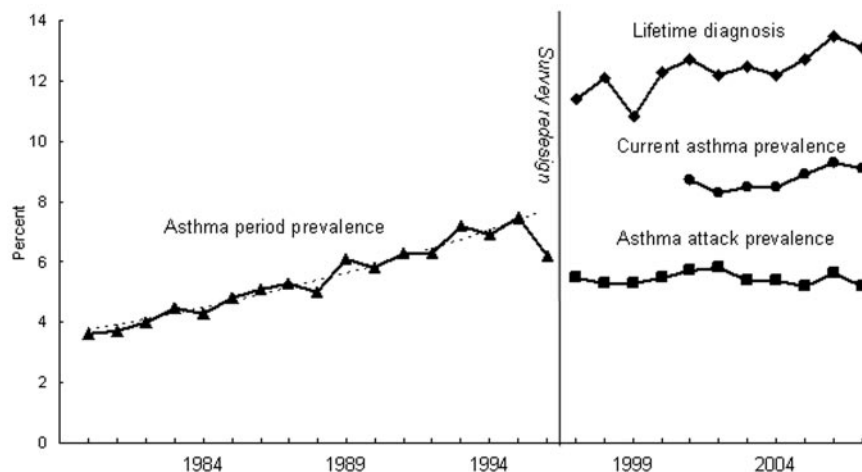
produce nationally representative estimates. Current asthma prevalence was determined by using the same questions as in the NHIS. NSCH data were used to create a map categorizing current asthma prevalence according to state. Disease management data from the NAS were based on the following questions: (1) "In the past 3 months, what medications did [child's name] take by inhaler?" (2) "Has a doctor or other health professional ever taught [child's name] how to use a peak flow meter, a device that measures how much air you can blow out of your lungs, to adjust daily medications?" (3) "Has a health professional ever advised you to change things in [child's name]'s home, school, or work to improve [child's name]'s asthma?" (4) "Has a doctor or other health professional ever given [child's name] an asthma management plan?" (5) "How many times did [child's name] see a doctor or other health professional for a routine checkup for [his/her] asthma?" (6) "Has a doctor or other health professional ever taught [child's name] how to recognize early signs or symptoms of an asthma episode?" (7) "Has a doctor or other health professional ever taught [child's name] what to do during an asthma episode or attack?" and (8) "Did a health professional teach [child's name] how to use the inhaler?"

Data on asthma-related visits to physicians' offices were obtained from the National Ambulatory Medical Care Survey, that provides information about the provision and use of medical care services in office-based physician practices in the United States.²² Data from this survey are available for 1980, 1981, 1985, and annually since 1989; before 1989, the survey excluded Alaska and Hawaii. Data on visits to hospital outpatient departments and emergency departments (EDs) were obtained from the National Hospital Ambulatory Medical Care Survey, which began to collect annual data on the provision and use of medical care services in these sites in 1992.^{22,23} Data on asthma-related hospital discharges were obtained from the National Hospital Discharge Survey, which has collected and produced national estimates on characteristics of inpatient stays in nonfederal, short-stay hospitals in the United States annually since 1965.²⁴

Data on deaths for which asthma was the underlying cause were obtained from the mortality component of the National Vital Statistics System, which collects national statistics on births, deaths, and fetal deaths based on US standard certificates of vital events.²⁵ Beginning in 1999, cause-of-death statistics were classified according to the *International Classification of Diseases, 10th Revision* (ICD-10) (codes J45 and J46 for asthma). The National Center for Health Statistics devised comparability ratios to assess discontinuities between *International Classification of Diseases, Ninth Revision* (ICD-9), and ICD-10 for selected causes of death.²⁶ For asthma, the comparability ratio in 1998 for the overall population was 0.89 (that is, 11% fewer deaths were attributed to asthma in 1998 by using ICD-10, compared with ICD-9), whereas the comparability ratio for asthma-related deaths among children 0 to 17 years of age was 1.02.²⁶ Because of the minimal impact of the coding change for children, asthma-related death rates among children for 1980

FIGURE 1

Asthma prevalence among children 0 to 17 years of age in the United States, in 1980–2007. The dashed line represents the optimal trend fitted by Joinpoint for 1980–1996 asthma period prevalence data. The optimal model included no joinpoints and yielded an estimated annual rate of change of 4.6% (statistically significant). The available data years for current asthma prevalence estimates (2001–2007) were insufficient for Joinpoint model fitting.



through 2005 were analyzed as a continuous trend, in addition to the more-conservative trend analysis limited to deaths from 1980 through 1998 (ICD-9 only).

National estimates of asthma-related ambulatory care visit rates and hospitalization rates were calculated by using weighted records for which asthma (ICD-9, Clinical Modification, code 493) was the first-listed diagnosis. To obtain ambulatory care visit rates for each age group, national estimates were divided by population estimates obtained from the US Census Bureau. Office visit estimates were divided by the civilian noninstitutionalized population. ED visit estimates and hospitalization estimates were divided by the civilian population. Death rates were calculated by dividing the number of asthma-related deaths by the resident population. Post-censal population estimates were used to calculate ambulatory care visit rates, hospitalization rates, and death rates for the years 2001 through 2005. More-accurate intercensal population estimates were used to calculate rates for the years 1980 through 1999. One exception was the death rate for Mexican children in the analysis of recent data (2004–2005); because population estimates for Hispanic subgroups are not available from the US Census, population estimates for Hispanic subgroups from the Current Population Survey²⁷ were used.

In addition to the traditional analysis of population-based rates, we also present an at-risk approach, in which we used the number of children estimated by the 2004–2005 NHIS to have current asthma as the denominator for health care use and mortality rates. This approach controls for the variation in asthma prevalence among subgroups. For these rates, the SE of the denominator is included in the SE of the rate.

For all survey estimates, SEs were calculated by using SUDAAN software (Research Triangle Institute, Research Triangle Park, NC), to account for the complex sampling design. For mortality data, SEs were calculated as the rate divided by the square root of the number of deaths, because mortality counts may be affected by random variation.²⁵ Survey estimates with relative SEs (calculated by dividing the SE by the estimate) of >30% were considered unreliable and are not shown in the

results. Death rates based on <20 deaths also were considered unreliable and are not included in the results.²⁵

Trends over time were assessed by using Joinpoint 3.0^{28,29} to test whether significant trends existed and to identify points (joinpoints) where trends changed during the time period examined. The software fits the simplest model with no joinpoints (a straight line) and tests whether ≥ 1 joinpoint is statistically significant and must be added to the model. Joinpoint selects the optimal model by using a series of permutation tests. The significance of a change in trend was assessed by using the weighted least-squares method as a test for trend.³⁰ Trends were assessed for asthma period prevalence (1980–1996), ambulatory care visit rates (1992–2006), ED visit rates (1992–2006), hospitalization rates (1980–2006), and death rates (1980–2005). The number of years of data available for the NHIS current asthma prevalence estimates (2001–2007) was insufficient for calculation of trends and annual percentage rate changes by using Joinpoint.

TRENDS AND CURRENT STATUS OF CHILDHOOD ASTHMA

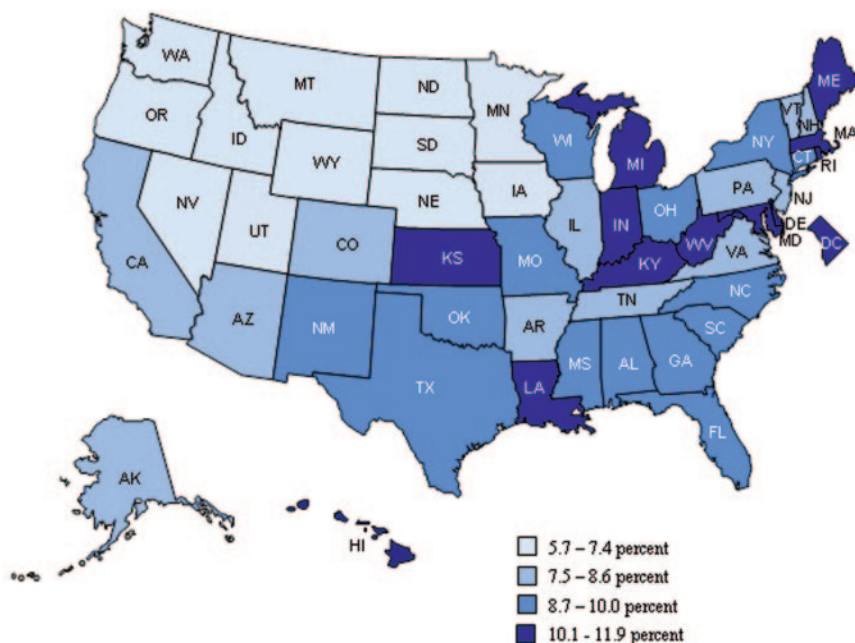
Asthma Prevalence Among Children Remains High

Asthma period prevalence among children 0 to 17 years of age increased from 3.6% in 1980 to a peak of 7.5% in 1995. The annual average increase between 1980 and 1996 (based on Joinpoint modeling) was 4.6% (Fig 1). Because the NHIS questionnaire was redesigned in 1997, asthma prevalence estimates from 1997 onward are not comparable to earlier estimates. All of the 3 new prevalence estimates (lifetime, current, and attack) show that asthma prevalence remained relatively level from 1997 to 2007.

The post-1997 measure most similar to the pre-1997 asthma 12-month-period prevalence measure is current asthma prevalence, which is defined as the proportion of children reported to have ever been diagnosed as having asthma and to still have asthma. Data on this measure are available beginning in 2001. An analysis of NHIS data for children before and after the 1997 questionnaire redesign indicated that much of the difference between

FIGURE 2

Current asthma prevalence among children 0 to 17 years of age in the United States in 2003. The states were divided into approximate quartiles to construct categories of current asthma prevalence.



the pre-1997 period prevalence estimates and the current asthma prevalence estimates available in 2001 was attributable to changes in the NHIS questionnaire and not to a dramatic change in prevalence.³¹ That is, the stability of current asthma prevalence noted from 2001 to 2007 probably began in 1997. Prevalence, as estimated in the 2007 NHIS, remains at historically high levels. That is, 9.1% of children (6.7 million) were estimated to have asthma currently, 5.2% of children (3.8 million), or nearly 60% of children with current asthma, had experienced ≥ 1 asthma attack in the previous year, and 13.1% of children (9.6 million) had been diagnosed as having asthma during their lifetimes. Of this group, 70% were reported to have asthma currently.

Asthma prevalence data on the state level for 2003 were available from the NSCH (Fig 2). Current asthma prevalence estimates were generally higher in eastern and southern parts of the United States, whereas the lowest levels were concentrated in the northwestern quadrant.

Data from 2003 from the NAS showed that among

children with current asthma, 31% reported using an inhaled corticosteroid in the past 3 months, 39% reported using any kind of controller medication, 57% reported being taught how to use a peak flow meter, 51% reported being instructed to change their home environment to minimize trigger exposures, and 37% had received an asthma management plan. More encouraging findings included the following: 74% reported visiting a physician for routine medical care for asthma ≥ 1 time per year, 85% reported being taught how to recognize early signs of an attack, 88% reported receiving explicit instructions on what to do to manage an attack, and 98% reported being instructed in the proper use of an inhaler.

Ambulatory Care Use for Asthma Followed an Increasing Trend, Whereas Emergency Care Use Decreased

The majority of nonurgent, ambulatory care visits attributable to asthma occurred in physicians' offices (Fig 3). Since 1992, rates of visits to physicians' offices fluctuated from year to year but the overall trend was increasing,

FIGURE 3

Numbers of asthma-related ambulatory care visits per 1000 children 0 to 17 years of age in the United States in 1980–2006, according to site. The dashed line represents the optimal trend fitted by Joinpoint for 1992–2006 total ambulatory care visit rates. The optimal model included no joinpoints and yielded an estimated annual rate of change of 2.1% for the period 1992–2006 (statistically significant).

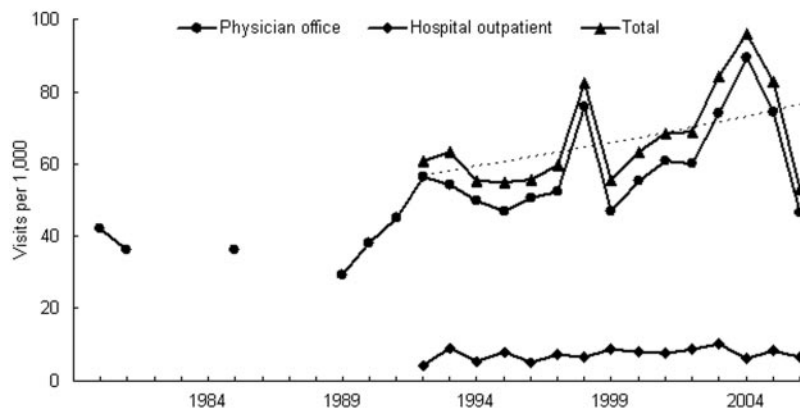
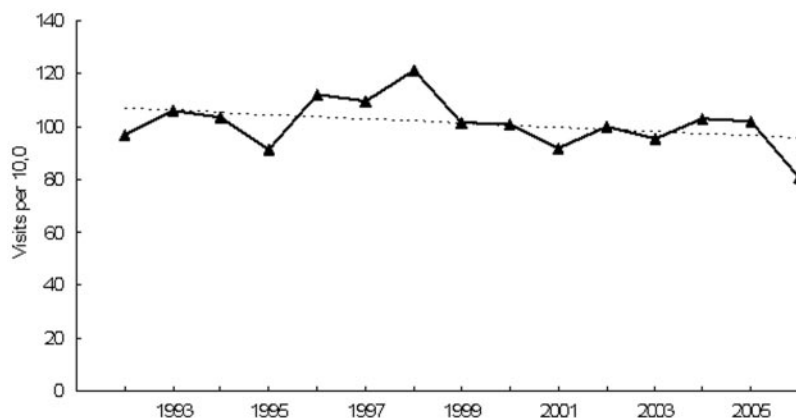


FIGURE 4

Numbers of asthma-related ED visits per 10 000 children 0 to 17 years of age in the United States in 1992–2006. The dashed line represents the optimal trend fitted by Joinpoint for 1992–2006. The optimal model included no joinpoints and yielded an estimated annual rate of change of -0.8% (statistically significant).



with an average increase of 2.1% per year. In 2006, there were 47 visits to physicians' offices per 1000 children (3.4 million visits) and 6 visits to hospital outpatient departments per 1000 children (0.5 million visits). Almost 2% of all ambulatory care visits among children 0 to 17 years of age were attributable to asthma. Although ambulatory care for asthma increased during this time, overall ambulatory care use for children remained steady.²²

Since 1992, when data first became available from the National Hospital Ambulatory Medical Care Survey, the rate of ED visits attributable to asthma among children decreased slightly, by 0.8% per year (Fig 4). In 2006, there were 593 000 visits to EDs attributable to asthma, which represented 2.3% of all ED visits among children 0 to 17 years of age.

After a Significant Increase in the 1980s, Asthma-Related Hospitalization Rates Showed No Distinct Trend

Through the 1980s, asthma-related hospitalization rates increased for children 0 to 17 years of age (Fig 5). Trend analysis identified a 2.9% average increase each year from 1980 through 1991 and no statistically significant trend after 1991. In 2006, there were 21 asthma-related hospitalizations per 10 000 children, for a total of

155 000 hospitalizations; this represented $\sim 5.6\%$ of all hospitalizations among children in 2006.

Asthma-Related Death Rates Among Children Recently Decreased

In 2005, there were 2.3 asthma-related deaths per 1 million children, for a total of 167 deaths. Trend analysis showed that asthma-related death rates increased by an average of 3.2% per year from 1980 through 1996 and then decreased by an average of 3.9% per year from 1996 through 2005 (Fig 6).

The Burden of Childhood Asthma Varied According to Age and Gender

The profile of asthma among children changed with increasing age (Table 1 and Fig 7A). Although asthma prevalence was higher for older children (11–17 years of age), health care use was lower for this age group. The patterns over childhood differed for boys and girls. Boys had higher current asthma prevalence, compared with girls, throughout most of childhood (Fig 7A), with relative risks ranging from 1.3 to 1.5, depending on the age group. At 16 to 17 years of age, however, current asthma prevalence for girls and boys was similar (9.5%), which

FIGURE 5

Numbers of asthma-related hospitalizations per 10 000 children 0 to 17 years of age in the United States in 1980–2006. The dashed line represents the optimal trend fitted by Joinpoint for 1980–2006. The joinpoint year for the trend was 1991. The estimated annual rate of change for 1980–1991 was 2.9% (statistically significant). The estimated annual rate of change for 1991–2006 was -1.2% (not statistically significant).

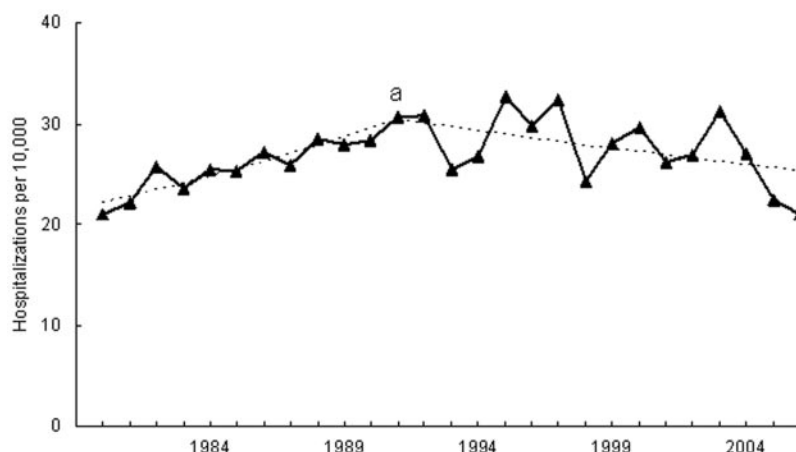


FIGURE 6

Numbers of asthma-related deaths per 1 million children 0 to 17 years of age in the United States in 1980–2005.¹ Beginning with data year 1999, cause-of-death statistics published by the National Center for Health Statistics were classified according to the ICD-10. The comparability ratio for asthma between the ICD-9 and ICD-10 for children 0 to 17 years of age is 1.02. The dashed line represents the optimal trend fitted by Joinpoint for 1980–2005. ^a The joinpoint year for the overall trend from 1980–2005 was 1996. The estimated annual rate of change for 1980–1996 was 3.2% (statistically significant). The estimated annual rate of change for 1995–2004 was –3.9% (statistically significant). A separate trend analysis limited to death rates categorized with ICD-9 codes from 1980 to 1998 yielded an annual rate increase of 2.8% (data not shown). There were insufficient data available after 1998 to analyze separately trends in asthma-related death rates with ICD-10 codes.

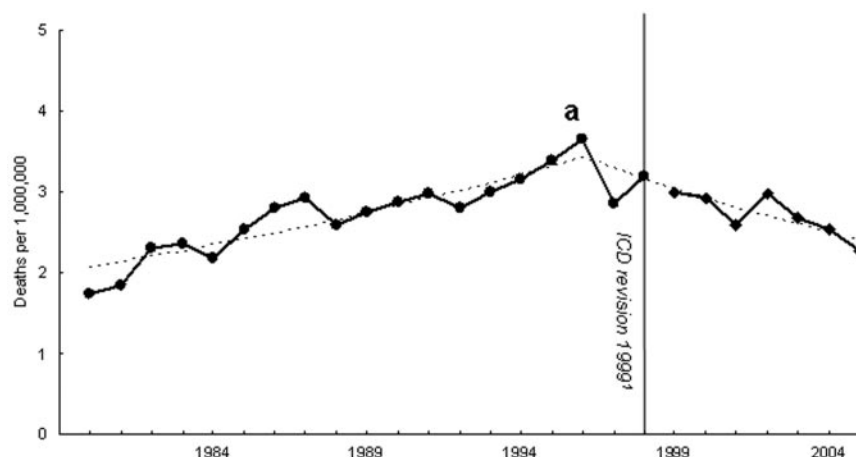


TABLE 1 Asthma Prevalence, Health Care Use, and Mortality Rates in the United States, in 2004–2005, Among Children 0 to 17 Years of Age, According to Age Group and Gender

	Current Prevalence, (SE) %	Ambulatory Care Visits, (SE) No. per 1000 Children ^a	ED Visits, (SE) No. per 10 000 Children	Hospital Discharges, (SE) No. per 10 000 Children	Deaths, (SE) No. per 1 Million Children
0–4 y	6.2 (0.3)	112.8 (18.4)	165.1 (18.9)	45.4 (6.1)	1.9 (0.2)
Male	7.4 (0.5)	173.2 (32.0)	203.4 (27.1)	55.3 (7.6)	2.5 (0.4)
Female	5.0 (0.4)	50.0 (13.6)	125.0 (21.3)	35.1 (5.2)	1.3 (0.3)
5–10 y	9.3 (0.4)	89.2 (20.0)	102.6 (12.3)	26.5 (3.6)	2.3 (0.2)
Male	11.1 (0.6)	96.7 (21.4)	108.6 (16.0)	34.4 (5.2)	2.7 (0.3)
Female	7.4 (0.5)	81.2 (23.4)	96.4 (16.6)	18.2 (2.6)	1.7 (0.3)
11–17 y	10.0 (0.4)	73.4 (11.8)	59.7 (7.7)	9.2 (1.4)	2.8 (0.2)
Male	11.1 (0.5)	78.5 (14.0)	52.1 (10.7)	10.8 (1.9)	3.6 (0.3)
Female	8.8 (0.5)	68.2 (16.2)	67.7 (11.6)	7.5 (1.1)	2.0 (0.3)
Total	8.7 (0.2)	89.4 (13.0)	102.3 (9.3)	24.7 (3.2)	2.4 (0.1)

^a Includes visits to physicians' offices and hospital outpatient departments.

reflects a shift toward the pattern found among adults, with women having a relative risk of current asthma prevalence of 1.3, compared with men. The youngest boys (0–4 years of age) used ambulatory care and hospital services more frequently than did girls, but differences according to gender decreased to insignificance among the 11- to 17-year-old age group. Death rates were higher among boys throughout childhood. The youngest boys (0–4 years of age) had the highest relative risk of death, compared with girls (relative risk: 2.0 [95% confidence interval: 1.2–3.2]) (Fig 7A).

Rates of ambulatory and inpatient health care use and deaths attributable to asthma were analyzed by using an at-risk approach to control for differing current asthma prevalence rates among subgroups (Table 2 and Fig 7B). When rates of ambulatory care use based on the number of children estimated to have current asthma were examined, different patterns were observed according to gender and age. As with population-based rates, at-risk-based rates of health care use decreased with increasing age. In contrast, the at-risk analysis found that the asthma-related mortality rate was lowest in the 5- to 10-year-old group whereas the population-based analysis showed the lowest rate in the youngest group (0–4 years of age). When higher asthma prevalence among boys was accounted for,

the differences between boys and girls diminished. The relative risks for boys compared with girls for ED visits, hospitalizations, and death all had confidence intervals that included 1.0.

Overall, 1 Child in 11 Was Reported to Have Current Asthma, But Racial Disparities Remain

Compared with white children, children of American Indian and Alaska Native descent were 1.3 times more likely and black children were 1.6 times more likely to have current asthma, whereas Asian children had the lowest prevalence (Table 3 and Fig 8A). When Hispanic ethnicity was considered in addition to race, Puerto Rican children had the highest prevalence of all groups and were 2.4 times more likely to have current asthma than were non-Hispanic white children, whereas Mexican children had relatively low current asthma prevalence.

Racial and Ethnic Disparities Exist in Ambulatory Care Use, ED Visit Rates, and Hospitalization Rates

In contrast to patterns for prevalence, non-Hispanic black children's rate of ambulatory health care use in nonemergency settings was nearly 20% lower than that

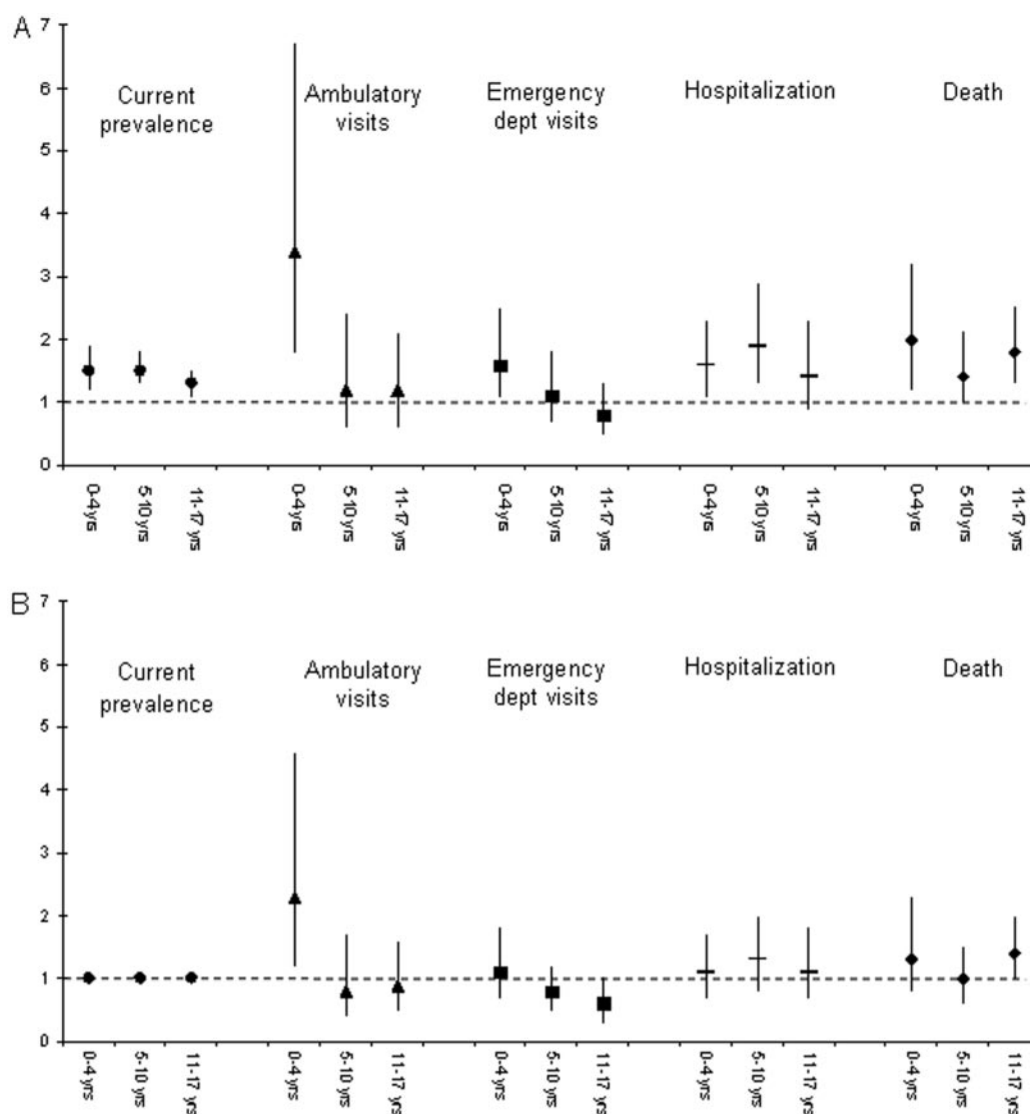


FIGURE 7

A, Relative risks for boys, compared with girls, for asthma prevalence and outcomes, determined by using population-based rates for 2004–2005. B, Results adjusted for asthma prevalence, showing relative risks for boys, compared with girls, for asthma prevalence and outcomes, determined by using at-risk approach-based rates for 2004–2005.

of non-Hispanic white children. Racial disparities in adverse outcomes (ED visits, hospitalizations, and death) were much larger than disparities in prevalence. Non-Hispanic black children had an ED visit rate 4.1 times higher and a death rate 7.6 times higher than the rates for non-Hispanic white children (Fig 8A). For hospitalizations, for which data on Hispanic ethnicity were not available, black children had an asthma-related hospitalization rate 3.0 times higher than that of white children.

When an at-risk approach was used (rates based on the number of children estimated to have current asthma), racial disparities in adverse outcomes were generally reduced (Table 4 and Fig 8B). With accounting for their higher current asthma prevalence, non-Hispanic black children had an ED visit rate 2.6 times higher and a death rate 4.9 times higher than non-Hispanic white children. Hospitalization rates for black children were 2.0 times higher than those for white children (as

noted above, data on Hispanic ethnicity were not available). In contrast, the relative difference between non-Hispanic black and non-Hispanic white children in rates of nonemergency ambulatory care use was accentuated; the at-risk approach-based rate among black children was 50% (vs 20%) lower than that for white children. Examining outcomes for Hispanic children and accounting for differences in asthma prevalence did not change the difference in ED visit rates between Hispanic and non-Hispanic white children (relative risk: 2.0 vs 1.9). Although estimates for Hispanic ethnicity were not reliable for nonemergency ambulatory care data and were not available for hospitalization data, the at-risk analysis for asthma-related death rates among Mexican children versus non-Hispanic white children yielded a higher relative risk than did the population-based analysis (relative risk: 1.5 vs 1.1).

TABLE 2 At-Risk Analysis of Asthma-Related Health Care Use and Mortality Rates in the United States, in 2004–2005, Among Children 0 to 17 Years of Age With Current Asthma, According to Age Group and Gender

	Ambulatory Care Visits, (SE) No. per 1000 Children With Current Asthma ^a	ED Visits, (SE) No. per 10 000 Children With Current Asthma	Hospital Discharges, (SE) No. per 10 000 Children With Current Asthma	Deaths, (SE) No. per 1 Million Children With Current Asthma
0–4 y	1827 (314)	2676 (340)	736 (106)	31 (4)
Male	2353 (464)	2764 (415)	751 (116)	34 (5)
Female	1004 (290)	2538 (489)	712 (123)	26 (6)
5–10 y	963 (221)	1109 (143)	286 (42)	25 (3)
Male	879 (201)	988 (157)	313 (51)	24 (3)
Female	1092 (324)	1296 (243)	244 (39)	26 (4)
11–17 y	739 (122)	604 (81)	93 (15)	29 (2)
Male	703 (130)	471 (100)	98 (15)	33 (4)
Female	786 (197)	783 (141)	87 (14)	23 (3)
Total	1029 (152)	1183 (112)	285 (38)	28 (2)

^a Includes visits to physicians' offices and hospital outpatient departments.

TABLE 3 Asthma Prevalence, Health Care Use, and Mortality Rates in the United States, in 2004–2005, Among Children 0 to 17 Years of Age, According to Race and Ethnicity

	Current Prevalence, (SE) %	Ambulatory Care Visits, (SE) No. per 1000 Children ^a	ED Visits, (SE) No. per 10 000 Children	Hospital Discharges, (SE) No. per 10 000 Children	Deaths, (SE) No. per 1 Million Children
Total	8.7 (0.2)	89.4 (13.0)	102.3 (9.3)	24.7 (3.2)	2.4 (0.1)
Race					
Black	12.8 (0.7)	85.7 (21.5)	274.1 (34.2)	46.8 (8.3)	9.0 (0.6)
White	7.9 (0.3)	92.5 (14.4)	75.6 (8.3)	14.9 (2.6)	1.3 (0.1)
American Indian/Alaska Native	9.9 (2.5)	—	—	—	—
Asian	4.9 (0.8)	—	—	—	—
Race/ethnicity					
Hispanic	7.8 (0.4)	—	120.1 (23.5)	NA	1.5 (0.2)
Puerto Rican	19.2 (2.1)	NA	NA	NA	—
Mexican	6.4 (0.4)	NA	NA	NA	1.3 (0.3)
Non-Hispanic black	12.7 (0.7)	70.3 (16.4)	263.7 (33.4)	NA	8.8 (0.6)
Non-Hispanic white	8.0 (0.3)	86.3 (14.4)	64.7 (8.0)	NA	1.2 (0.1)

NA indicates not available; —, estimate was unreliable.

^a Includes visits to physicians' offices and hospital outpatient departments.

Figure 9 presents recent trends in asthma-related hospitalization and death rates per 1 million children for black and white children, on a logarithmic scale, to illustrate relative trends. Asthma-related hospitalization rates remained level for both black and white children from 1999 through 2005, as did the black/white hospitalization rate ratio. Although overall asthma-related death rates decreased after 1999, this pattern was not observed for black children; their death rates remained relatively level (Fig 9A). An analysis of recent trends in asthma-related hospitalization and death rates using an at-risk approach (Fig 9B) showed fluctuating racial disparities in hospitalization rates, with a decrease in 2005. At-risk approach-based death rates among black and white children peaked in 2002; thereafter, death rates decreased more among white children than among black children. The time period from 2001 through 2005 is too brief for discernment of definitive trends, but the results from the at-risk analysis suggest large persistent dispar-

ities in outcomes even after accounting for differences in asthma prevalence.

PUBLIC HEALTH CRISIS: CONTEXT AND RESPONSE

Asthma Is a Significant Public Health Burden About Which Many Questions Remain

Asthma presents a significant burden for the estimated 6.7 million affected children, their families and caretakers, school systems, parents' employers, and the health care system. The factors driving the increase in prevalence to current levels are poorly understood. The hygiene hypothesis is a prominent theory formulated to explain the increasing prevalence of allergies and asthma that has been documented in many developed countries. This theory postulates that reduced exposure to infectious disease and environmental microbial contamination shifts the balance in children's developing immune systems away from fighting infection and toward atopic

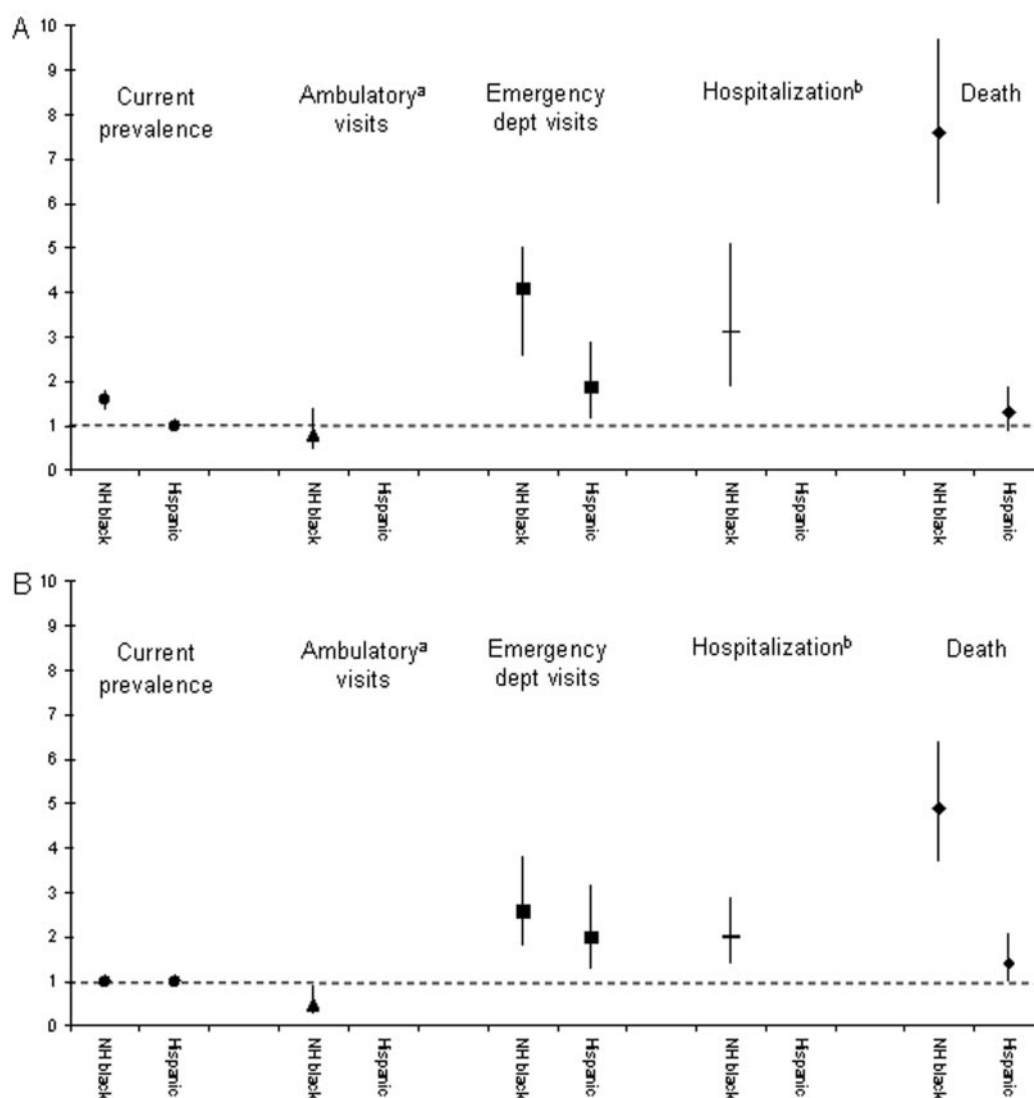


FIGURE 8

A, Relative risks for asthma prevalence and adverse outcomes for non-Hispanic black and Hispanic children, compared with non-Hispanic white children (using population-based rates for 2004–2005). B, Results adjusted for asthma prevalence, showing relative risks for asthma prevalence and adverse outcomes for non-Hispanic black and Hispanic children, compared with non-Hispanic white children (using at-risk approach-based rates for 2003–2004). NH indicates non-Hispanic. ^a Estimate for Hispanic ethnicity was unreliable; ^b data on Hispanic ethnicity were not available. Comparisons were made between black and white children (reference) without regard to Hispanic ethnicity.

responses.^{32–34} Numerous epidemiological associations with asthma and lung development have been documented, including increased body mass,^{35,36} exposures to environmental risks (eg, close proximity to major roadways^{37,38}), and use of medications such as antibiotics and antiinflammatory agents.^{39,40} There are inconsistencies across studies, and the relative contributions of these and other factors to the increase in asthma prevalence and/or the recent stabilization remain unknown. The contributions of other etiologic factors common to both asthma and implicated risk factors (eg, obesity), including diet, physical activity levels, comorbid conditions, and time spent indoors, also are unknown.

It is not clear how much of the measured changes in prevalence over time reflect true changes. In addition to actual changes in prevalence, asthma surveillance could

be measuring improved recognition of asthma by patients and health care professionals.⁴¹ If greater public familiarity and diagnostic transfer from other conditions (eg, bronchitis) contribute to the increase in measured prevalence, then these are positive developments. Accurate labeling of the disease allows effective treatment and management, as well as better accounting of the public health impact and adequate mobilization of resources to address it. Despite progress in better recognition of asthma, however, concern remains that asthma is underdiagnosed and that children with undiagnosed disease remain at high risk of decreased quality of life and adverse outcomes.^{42–44} Populations of concern include adolescents,⁴⁵ inner-city children,^{42,43} and girls, who may present with more-subtle patterns of symptoms than boys.⁴⁶ However, 1 study in an urban area found rela-

TABLE 4 At-Risk Analysis of Asthma-Related Health Care Use and Mortality Rates in the United States, in 2003–2004, Among Children 0 to 17 Years of Age With Current Asthma, According to Race and Ethnicity

	Ambulatory Care Visits, Mean (SE), No. per 1000 Children With Current Asthma ^a	ED Visits, Mean (SE), No. per 10 000 Children With Current Asthma	Hospital Discharges, Mean (SE), No. per 10 000 Children With Current Asthma	Deaths, Mean (SE), No. per 1 Million Children With Current Asthma
Total	1029 (152)	1183 (112)	285 (38)	28 (2)
Race				
Black	678 (174)	2179 (301)	372 (69)	68 (6)
White	1162 (184)	951 (108)	187 (34)	16 (1)
Race/ethnicity ^b				
Hispanic	—	1606 (325)	NA	20 (3)
Mexican	NA	NA	NA	21 (4)
Non-Hispanic black	552 (133)	2084 (293)	NA	70 (7)
Non-Hispanic white	1062 (181)	798 (103)	NA	14 (2)

NA indicates not available; —, estimate was unreliable.

^a Includes visits to physicians' offices and hospital outpatient departments.

^b Data for Puerto Rican children were either unavailable or unreliable.

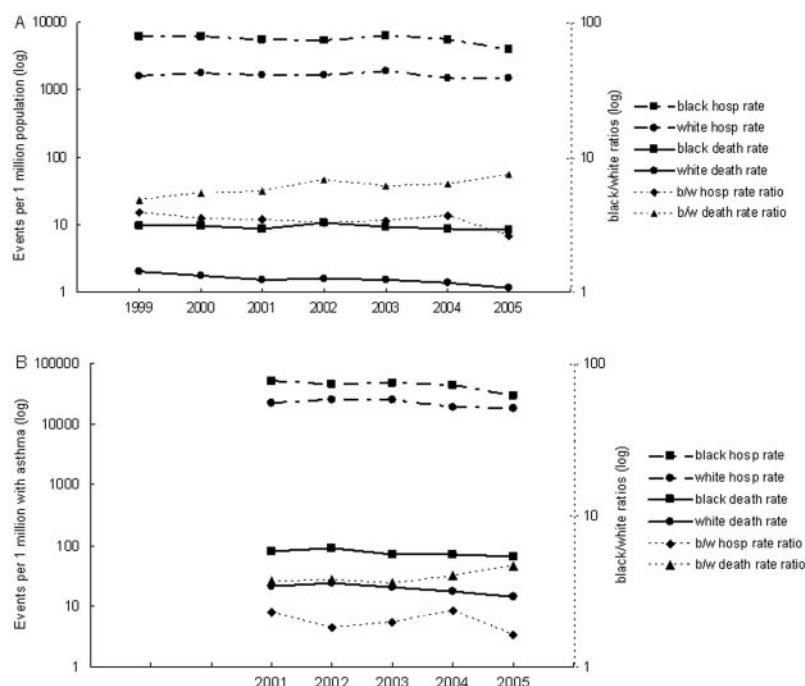
tively low prevalence of undiagnosed wheezing among children; the authors credited public awareness campaigns and asthma education for this finding.⁴⁷ Efforts must continue to ensure the prompt recognition and adequate treatment of asthma to improve quality of life for affected children.

Direct measures of quality of life, such as the ability to sleep through the night or to participate fully in school activities, are not consistently available on a national level. However, the more-extreme measures of adverse outcomes in this report (ED visits, hospitalizations, and death) show that certain populations of children are more vulnerable, including children of minority race/ethnicity, boys, and very young children and adolescents. The higher rates of adverse outcomes among mi-

nority children at levels disproportionate to prevalence and increasing racial disparities over the past 2 decades have been well documented.^{7,11,48–50} Through the first decade of life, boys have higher rates of emergency health care use and death. Very young children of both genders have increased vulnerability to adverse outcomes because of small airways, changing patterns of airway flow related to rapid postnatal growth,³⁴ and possibly increased airway reactivity, in comparison with older children.³⁴ Respiratory distress in young children, especially in the setting of infection, can rapidly become life-threatening and warrants prompt attention. For this reason, the relatively high utilization of ED and hospital services among the very young may be appropriate. Adolescence also can complicate asthma management

FIGURE 9

A, Numbers of asthma-related hospitalizations and deaths per 1 million children 0 to 17 years of age, according to race. B, Numbers of asthma-related hospitalizations and deaths per 1 million children with current asthma, according to race. Because NHIS estimates for the numbers of children with current asthma are not available for the years before 2001, B includes only 2001–2005. B/W indicates black/white; hosp, hospital.



because adolescents need to learn to recognize and to treat their own symptoms; issues with emerging autonomy may exacerbate problems with asthma control and may contribute to the higher rates of death observed in our analysis.

Overall, the trends in adverse outcomes for children with asthma show that the increases of past decades have abated. Although the improvement may be partially attributable to the plateau in prevalence, the rates of ED visits and hospitalizations are at least partially sensitive to the availability, quality, and continuity of ambulatory health care,^{51,52} as well as disease severity, hospital admission practices, and inappropriate use of emergency services.^{52,53} Diagnostic transfer from other conditions, such as pneumonia and bronchitis, also contributed over time to the increase in hospitalizations attributed to asthma.⁷ Previous work showed variations in hospital admission rates for asthma within and across regions.^{46,47,54} One of those studies⁴⁷ showed that differences in prevalence only partially explained the variations in hospitalization rates among zip codes throughout an urban center; asthma prevalence differed by threefold, but hospitalization rates differed by >30-fold. There is also evidence of an increased threshold of severity for asthma-related hospital admission. The authors of a study in the Rochester, New York, area concluded that a decrease in admissions of milder cases explained an observed plateau in overall asthma admissions,⁵⁵ and our analysis showed that asthma-related hospitalization rates remained level over a time period when hospitalization rates overall among children decreased,⁵⁶ which suggests that asthma-related hospitalizations in recent years may represent a higher threshold of severity for hospital admissions on a national level as well. Although a plateau in asthma-related hospitalization rates is better than an increasing trend, the outcome measured by this indicator might have changed over time, and more information may be necessary to interpret the trend. The promising trend of decreasing overall asthma-related death rates also has many possible contributing factors. The promulgation and dissemination of national asthma management guidelines in 1997⁵ and of updates in 2002³⁷ and 2007,⁵⁸ which highlight the central role of inflammation and preventive treatment, might have affected asthma-related death rates. In addition to more-effective clinical management, concerted efforts to prevent asthma complications continue on many fronts, ranging from community education programs to intensive school interventions. The trends to date allow optimism that adverse outcomes can be prevented and the burden reduced. The large remaining burden and the persistence of racial differences in adverse asthma outcomes indicate areas for future efforts to build on this progress.

To Reduce the Prevalence of Asthma, the Primary Causes of the Disease Must Be Better Understood

Asthma incidence, that is, the development of new cases over time, is 1 factor leading to increased prevalence. Increases in the duration of the disease or decreases in mortality rates also can increase prevalence, although,

given the low asthma-related death rate among children, the impact of the latter is negligible. Among these factors, asthma incidence may be the most poorly understood, although increased understanding holds great promise in reducing the disease's prevalence. There is growing agreement that asthma represents a spectrum of syndromes with multiple complex causes.^{12,33,34} Research efforts continue to develop a better understanding of interactions between environmental factors and genotypes/phenotypes and differing susceptibility to risk factors.

Although disease surveillance (ie, data collection, analysis, and dissemination) has made important contributions to a better understanding of asthma, gathering data on asthma incidence has been an elusive goal because of conflicting lay terms and understandings, differing diagnostic criteria, and the episodic nature of disease expression. The limited measures available from the NHIS indicate increasing incidence from 1980 through 1996,⁵⁹ but the 1997 NHIS survey redesign does not allow for population-based incidence estimation after that year. Efforts to gather incidence data continue, however. In 2005, the CDC added a question to the Behavioral Risk Factor Surveillance System (BRFSS) call-back survey that was designed to estimate asthma incidence; data for the first collection year will be released in 2001.

Greater geographic detail in asthma prevalence surveillance can help to define more completely the risk factors for the development of asthma. Before 1998, no uniform data on asthma were available at the state or city level. To address this gap, the CDC National Center for Environmental Health expanded analysis of existing data and increased geographic specificity in its data collection, including development of the NAS by the National Asthma Control Program. In 2003, the NAS produced data for Alabama, California, Illinois, and Texas at the state and city levels.²¹ The National Asthma Control Program also has used existing data collection mechanisms to enhance local asthma surveillance, including the BRFSS. An optional asthma module was added to the BRFSS in 2001, and a child asthma module was added in 2005. Tables of asthma prevalence rates among children for an increasing number of states are available on the CDC Web site.⁶⁰ Also in 2005, the NAS questionnaire was reformatted as a call-back survey following the BRFSS; this reformatted version was used in 25 states in 2006, 35 states in 2007, and will be used in 39 states in 2009.

More-detailed data also can help pinpoint risk factors. Improved race and ethnicity reporting in the NHIS and other surveys helped reveal the heterogeneous nature of asthma among Hispanic individuals. Merging the survey results and similar data sets with other sources of information, such as air quality data, provides additional avenues for assessing risk factors for asthma development. The combination of epidemiological, clinical, and primary science research should help health care professionals better customize prevention efforts for specific at-risk populations and expand existing prevention efforts, such as promoting breastfeeding, eliminating sec-

ondhand smoke, and controlling residential exposures such as mold and cockroaches.

Although Asthma Cannot Be Prevented, Its Symptoms and Adverse Effects on Children Can Be Controlled

In contrast to the situation for asthma incidence prevention, the tools to relieve the symptoms of asthma are readily available. The National Asthma Education and Prevention Program clinical guidelines for the treatment of asthma^{5,57,58} outline clear and achievable disease management tools that have revolutionized control of the underlying factors leading to airway reactivity and inflammation. However, the first-line preventive therapy for chronic asthma symptoms, that is, antiinflammatory medication, is often underprescribed and underused.^{9,61–63} Studies have shown that patients do not develop a full understanding of the tools necessary to improve their quality of life.^{64,65} The good news is that clinical studies and pilot programs demonstrated that increased provider adherence to the National Asthma Education and Prevention Program guidelines can be achieved and is effective in decreasing asthma ED visits and hospitalizations.^{8,9} In addition, the National Cooperative Inner-City Asthma Study demonstrated a significant increase in symptom-free days at the end of a 12-month, social worker-based, asthma education program.¹⁰ These and similar successful programs must be replicated on a large scale, and additional effort must be made to disseminate adapted guidelines to important allies in controlling asthma symptoms, such as school staff members and community health workers.

Minority Children Have a Critical Need for Improved Interventions

Multiple factors contribute to the pattern of higher adverse outcomes for minority children, including lower rates of ambulatory care visits. In addition, there is evidence that minority children do not receive the same quality of ambulatory care.^{66,67} Even within the same tier of managed Medicaid populations or privately insured populations, minority children are less likely to be given prescriptions for and to use preventive asthma medications.^{48,67–69} The relatively high levels of use of ED services for asthma among minority children have been hypothesized to result in part from inappropriate use of ED services for mild symptoms or routine care; however, a study of ED use for asthma in 18 states found, by using a validated indicator of respiratory distress, that children from different racial/ethnic groups presented to the ED with equally severe symptoms.⁷⁰ The same study documented inappropriately low prescription rates for preventive medications for minority children in emergency care settings. Additional factors contributing to racial differences in adverse outcomes may include more-severe disease, variations in disease phenotypes and responsiveness to medication, environmental exposures, lag in uptake of medical advances to control asthma symptoms among health care providers who treat minority children, lack of cultural competence policies among health care providers, and lack of asthma educa-

tion or difficulties in adopting certain asthma control methods for minority race/ethnic families.^{44,71}

Improving Outcomes for All Children With Asthma Is an Achievable Goal

Removing the adverse impact of asthma in the life of a child is an achievable but demanding goal. Recognizing early symptoms, avoiding asthma triggers, arranging appropriate health care, and managing the schedule of medication administration can be complex for children and their families. Additional resources may be necessary in settings with environmental threats, such as residences close to air pollution sources or housing with high mold and pest burdens. Providing high-quality health care and continuous access is critical to supporting families with asthma. Groups that have been successful in achieving sustained reductions in asthma-related hospitalizations and ED visits for children have found that prescribing antiinflammatory medication is necessary but not sufficient; other elements of treatment, including written treatment plans and standardized therapy within a medical home, are also important.⁸ Other obstacles to full use of comprehensive care, such as transportation barriers, cultural and language barriers, and issues of trust, must also be overcome.⁴⁴ Improvements in asthma care quality among medical practices using cultural competence policies have already been demonstrated.⁷¹ Although bringing such promising interventions to effective and widespread use poses a great challenge, doing so should be part of the public health response to asthma.

The CDC has worked to build partnerships to bolster the public health role in coordinated prevention and intervention efforts. The asthma control program operates on 2 cooperative levels, first, a basic national health infrastructure built and enhanced through funding of state health departments and, second, support of asthma control programs on various local levels. State health departments play a pivotal role in a comprehensive approach to addressing the complexity of asthma diagnosis, management, and surveillance. Thirty-three states, Washington, DC, and Puerto Rico use CDC funding to develop and to implement components of comprehensive asthma programs, including assessing and using sources of asthma-related data in surveillance and program planning, developing public health approaches to reduce the burden of asthma, establishing linkages of state health department to many agencies and organizations addressing asthma in the population, and implementing interventions to achieve positive health effects. CDC support for multiple local efforts, such as those of urban school districts and nongovernmental organizations, and coalition programs such as the Controlling Asthma in American Cities Program enables these organizations to target urban children and schools and to assess various potentially effective, asthma control interventions. The Controlling Asthma in American Cities Program operates in New York, New York, Chicago, Illinois, St Louis, Missouri, Minneapolis, Minnesota, Oakland, California, Philadelphia, Pennsylvania, and Richmond, Virginia, and uses current tools and strategies

in a comprehensive, community-based, collaborative approach to reducing asthma burden. It also explores and evaluates innovative asthma control interventions. After project completion in June 2008, the Controlling Asthma in American Cities Program will disseminate lessons learned, including effective interventions and prioritization of asthma interventions based on feasibility, effectiveness, and cost. On a larger scale, the BRFSS asthma data for several states, available in 2009 should allow researchers to assess symptom control levels among children and adults with asthma. The BRFSS included questions that enable classification of respondents with asthma with the National Asthma Education and Prevention Program and Global Initiative for Asthma symptom severity and control scales. In addition, questions about environmental exposures should enable researchers to estimate the association of those exposures with symptom control.

School-based programs also address adverse asthma outcomes among children. One example is the Coordinated School Health Program, which strives to reduce asthma episodes, school absences, and lost classroom time among children and youths. The CDC oversees this program and also supports state and local education agencies with funding, educational materials and training, policy guidance (eg, medication self-carry criteria and screening versus case detection in schools), school-based surveillance reports, and planning and evaluation tools (eg, a logic model for school-based interventions developed by an expert panel and the School Health Index Module for Asthma).

Nonprofit and professional organizations, including the American Lung Association, the Allergy and Asthma Foundation of America, the American Academy of Allergy, Asthma, and Immunology, the Allergy and Asthma Network/Mothers of Asthmatics, and the American Thoracic Society, are also central in prevention efforts. CDC funded 12 grantees (including hospital systems, city health departments, school systems, and asthma organizations) to implement either the Allergy and Asthma Foundation Asthma Care Training for Kids or the American Lung Association Open Airways for Schools program. Both programs have been validated as safe and effective. Asthma Care Training for Kids increases asthma control compliance behaviors and decreases numbers of ED visits and days spent in the hospital.⁷² Open Airways for Schools has been shown to increase school performance and self-management behaviors and to decrease the number of asthma episodes.⁷³

CONCLUSIONS

Analysis of the current burden of childhood asthma yields a mixture of positive and negative findings. Prevalence trends have plateaued and asthma-related death rates have decreased. Major steps have been made to increase the quality, quantity, and geographic availability of asthma surveillance data. However, although innovative approaches and broad public health programs have focused on minimizing the impact of asthma, the disease burden remains high. Even after controlling for

their higher asthma prevalence, minority children have much greater rates of adverse outcomes. Given that the primary causes of developing asthma are only partially understood, research, prevention, and intervention efforts aimed at reducing the burden of childhood asthma remain as important as ever.

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