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POPULATION DISPARITIES IN ASTHMA

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■ **Abstract** The prevalence of asthma in the United States is higher than in many other countries in the world. Asthma, the most common chronic disease of childhood in the United States, disproportionately burdens many socioeconomically disadvantaged urban communities. In this review we discuss hypotheses for between-country disparities in asthma prevalence, including differences in "hygiene" (e.g., family size, use of day care, early-life respiratory infection exposures, endotoxin and other farm-related exposures, microbial colonization of the infant bowel, exposure to parasites, and exposure to large domestic animal sources of allergen), diet, traffic pollution, and cigarette smoking. We present data on socioeconomic and ethnic disparities in asthma prevalence and morbidity in the United States and discuss environmental factors contributing to asthma disparities (e.g., housing conditions, indoor environmental exposures including allergens, traffic air pollution, disparities in treatment and access to care, and cigarette smoking). We discuss environmental influences on somatic growth (low birth weight, prematurity, and obesity) and their relevance to asthma disparities. The relevance of the hygiene hypothesis to the U.S. urban situation is reviewed. Finally, we discuss community-level factors contributing to asthma disparities.

INTRODUCTION

Asthma, the most common chronic disease of childhood in the United States, disproportionately burdens many socioeconomically disadvantaged urban communities (61, 142, 143). The Centers for Disease Control and Prevention (CDC) has estimated that there are ∼17.3 million people in the United States with the illness (107). Approximately one third of these asthmatics are children (12). The social and economic costs of asthma are considerable. In the United States in 1996, there were 474,000 asthma hospitalizations and 11.9 million medical visits for the disease (48).

DEFINITIONS OF ASTHMA

The estimated prevalence of asthma can vary widely according to the epidemiologic or clinical definition utilized; nevertheless, certain between-country and within-U.S. disparities in asthma prevalence and morbidity have been well documented and are not likely to be a function of definition. In the U.S. National Institutes of Health Guidelines for Management and Diagnosis of Asthma (61, 92), asthma is defined as

> a chronic inflammatory disorder of the airways in which many cells and cellular elements play a role, in particular, mast cells, eosinophils, T lymphocytes, macrophages, neutrophils, and epithelial cells. In susceptible individuals, this inflammation causes recurrent episodes of wheezing, breathlessness, chest tightness, and coughing. . .. These episodes are usually associated with widespread but variable airflow obstruction that is often reversible either spontaneously or with treatment. The inflammation also causes an associated increase in the existing bronchial hyper-responsiveness to a variety of stimuli. (p. 8)

In large-scale epidemiologic studies, the diagnosis of asthma has generally been elicited by a series of questions related to wheeze (doctor-diagnosed or parentally/self-observed) and its persistence or chronicity (5), often with evaluation of secondary phenotypes including allergic sensitization and airway hyperreactivity (138). In the United States, the majority of those with asthma have allergy or elevated IgE, but a minority of asthmatics have symptoms, airway inflammation, and airway hyperreactivity without identifiable allergy (41).

BETWEEN-COUNTRY DISPARITIES IN ASTHMA PREVALENCE

The prevalence of asthma in the United States is higher than in many other countries in the world (Figure 1). Using standardized questionnaires, the International Study of Asthma and Allergy in Childhood (ISAAC) (158) has shown an almost thirty-fold between-country variation in asthma prevalence rates (62). Urbanized, more "Westernized" countries tend to have higher asthma rates than do less developed countries, though exposures related to urbanization and Westernization do not explain all the between-country differences noted in this international effort to understand the patterns of asthma and allergy in children. A number of hypotheses have been proposed as potential partial explanations for between-country and within-country disparities in asthma prevalence, including differences in (*a*) "hygiene," (*b*) diet, (*c*) cigarette smoking, (*d*) traffic pollution, (*e*) antenatal exposures, and (*f*) physical activity/obesity. Despite a growing body of worldwide literature reporting studies testing these hypotheses, the significance of most of these factors in the development of asthma has yet to be fully understood,

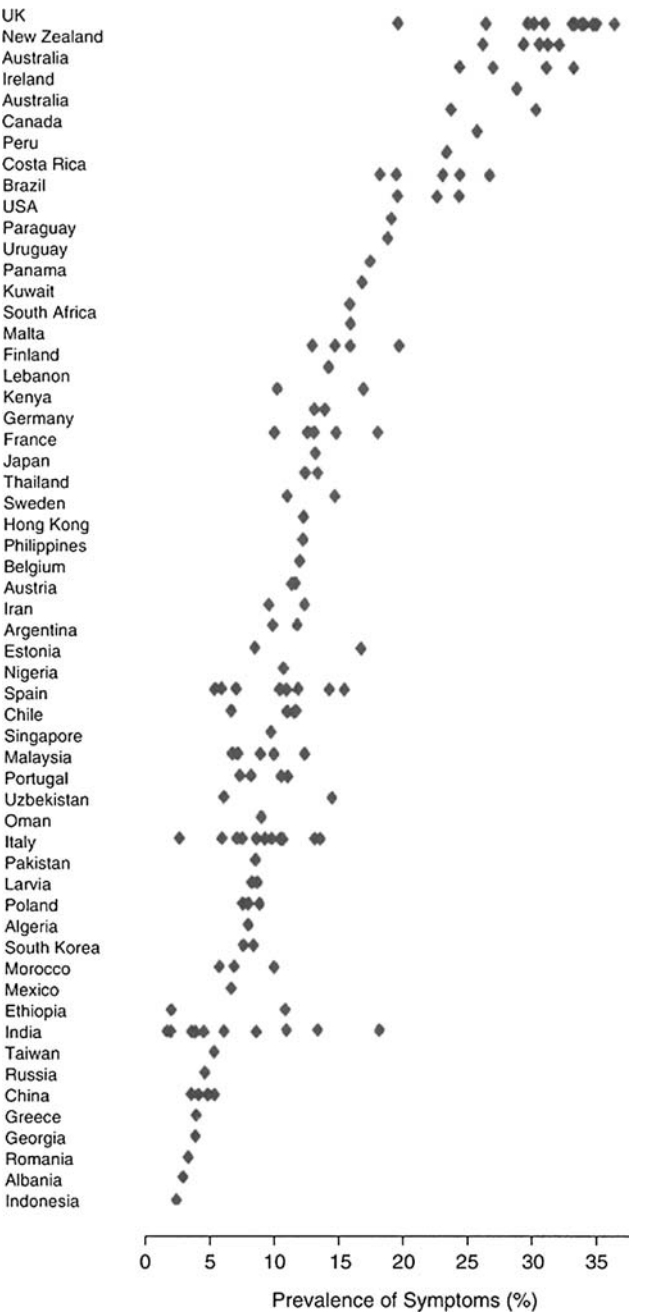

Figure 1 Prevalence of asthma symptoms (percentage) from a questionnaire in the ISAAC database. Source: ISAAC Steer. Comm. (62).

and their significance for explaining between-region or -country disparities in asthma prevalence is uncertain (61). One exception is in utero/early infancy exposure to cigarette smoking, which is consistently found to be an important risk factor for development of wheeze and early asthma. However, its relationship to development of allergy and allergic inflammation is uncertain (61). Environmental factors contributing to increased asthma morbidity are far better understood and are reviewed here only in relation to asthma disparities in the United States (61). But first we present theories potentially explaining worldwide asthma disparities, with a focus on the hygiene and diet hypotheses.

THE HYGIENE HYPOTHESES

The hygiene hypothesis is actually a series of hypotheses that have expanded since the original English and Swiss observations in the late nineteenth and early twentieth centuries that hay fever and wheeze appeared to be diseases of more affluent urban areas, compared with rural farming areas (128, 157). The hypotheses have evolved to include (*a*) small families, earlier birth order, and less use of day care (8, 23, 128); (*b*) less exposure to respiratory infection in early childhood (128); (*c*) a reduction in endotoxin or other farm-related exposures (15); (*d*) a change in microbial colonization of the infant's large bowel through diet or antibiotics (86); (*e*) reduced exposure to parasites (17); or (*f*) reduced exposure to large domestic animal sources of allergens (102) as potential explanations for increases in asthma prevalence in more Westernized urban communities compared with more rural communities.

Family Size, Day Care, and Viral Exposure

In longitudinal U.S. studies, having siblings (8) and early life exposure to day care (8, 23) have been associated with more wheeze in early childhood but with decreased risk of persistent childhood wheeze and with lower IgE levels in later childhood. Later birth order is also associated with reduced allergic disease risk (129). The very early-life increase in wheeze associated with increased exposure to siblings/day care has been attributed to the proinflammatory effects of increased viral infection exposure on small airways and not to allergic responses. The later childhood reduction in wheeze associated with early-life exposure to siblings/day care has been attributed to possible downregulation of chronic allergic immune inflammatory responses by early-life infections. Some investigators hypothesized that early-life respiratory viral or mycobacterial exposure may modify T-regulatory lymphocyte cell behavior and may downregulate T helper 1 (Th1) and Th2 lymphocyte secretion of proinflammatory cytokines (57, 144). The potential of early day care/viral exposure to be protective against later allergic asthmatic responses is likely to vary by familial inheritence. Celedon et al. (26) found that for children of mothers without asthma, day care was protective; for children of mothers with asthma, day care was a risk factor for wheeze. The associations of day care,

siblings, or birth order with later protection against wheeze may well represent effects of exposures other than viral illness. In a review of the literature, the Institute of Medicine (61) report "Clearing the Air" concluded that association with allergy of infant viral exposure to later childhood asthma is uncertain; conflicting results have come from the few prospective studies that directly measure the number and type of viral illnesses encountered in infancy (61).

Endotoxin

Endotoxin is a biologically active lipopolysaccharide, a primary component of the outer cell membrane of gram-negative bacteria (110). The endotoxin hypothesis has come from reproducible observations in Swiss, German, and Austrian individual and combined studies, demonstrating lower rates of allergy-associated wheeze/asthma and allergic sensitization in children of farming families, compared with children from nonfarming families in the same region (15, 112, 139). In a recent West European multi-country cross-sectional study of school-aged rural children, endotoxin in the bed mattress was associated with lower rates of asthma with allergy and atopic sensitization but not with asthma/wheeze without allergy (15). On the basis of animal and human studies, investigators have hypothesized that at certain doses, with the right timing in the life cycle, endotoxin may downregulate allergic airway inflammation, perhaps by increasing Th1-type lymphocytes through increasing macrophage interleukin-12 secretion, (110) or by alteration of T regulatory cell behavior early in life (144). The effect of endotoxin may depend on the timing of exposure and dose, as well as genotype (7, 42); endotoxin is well known to have an irritant effect causing wheeze symptoms in adults in the occupational setting (110). Endotoxin exposure may reduce the risk of allergy or asthma if encountered in infancy, yet it may increase wheeze risk once individuals have established asthma (89).

Microbial Colonization of the Infant's Large Bowel

The European farm studies have also found that taking children into the barn in infancy and feeding young children raw milk may be protective of wheeze and allergy (112). If farm exposures are protective, then it is possible that bacterial exposures encountered in raw milk, fermented foods (86), and additional farm-associated exposures other than endotoxin may be protective (65, 66). Some researchers have suggested that antibiotic use has increased risk of allergy and asthma by altering bowel flora and intestinal immune mechanisms, but recent prospective articles on antibiotic use in infancy that adjust for infection do not support that hypothesis.

Domestic Allergen Exposure

There is no question that asthmatic individuals who are sensitized to animals such as cats, and who have higher exposure to these animals, have an increase in allergic symptoms compared with sensitized asthmatic individuals with lower

exposure (82). However, multiple studies also suggest an association between early-life exposure to dog or cat in the home and reduced risk of asthma or allergic sensitization (96, 100). The data on cat and protection against asthma are not as consistent as those related to dog. Dogs are associated with endotoxin (97), but domestic dogs kept in the home are also associated with the presence of large quantities of aerosolized dog allergen. Similarly, homes with cats have very high levels of aerosolized cat allergen (104), though there is not a clear-cut correlation between cat allergen levels and measurable dust or air endotoxin in the home. Platts-Mills (102) has hypothesized that for some children, high allergen exposure may result in a "modified Th2 response," leading to increased interleukin 10 antiinflammatory cytokine production, increased IgG4 production, and reduced proinflammatory interleukin 4 production. Yet the data on cat in the home and allergy or asthma are contradictory, perhaps because of both the unmeasured exposures to cat outside the home (depending on the prevalence of cat in the community) and on familial factors. There is likely familial or genetic variation in response to high levels of allergen exposure—not all people will respond in a similar fashion. For example, in a Boston longitudinal study, early exposure to cat in the home appeared protective for children of mothers without asthma, yet it was a risk factor for wheeze for children with asthma (22). In a Wisconson longitudinal study, the relation of dog in the home to atopic dermatitis was modified by the CD14 genotype (42).

DIET

Differences in dietary intake also may contribute to disparities in allergy and asthma. Particularly in the Westernized English-speaking countries such as the United States, the United Kingdom, Australia, and New Zealand, dietary intake of fresh fruits and vegetables containing antioxidants has decreased (135). Asthma was negatively associated with consumption of foods containing Vitamin E in the prospective U.S. Nurses' Health Study of 77,866 female nurses (54). Increases in allergy and asthma may be related also to decreases in dietary intake of n-3 polyunsaturated fatty acids (PUFA), such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) found in oily fish (tuna, salmon, mackerel, and herring) and leafy green vegetables, and to increases in n-6 polyunsaturated fatty acids, such as linoleic acid (LA) and arachidonic acid (AA) found in vegetable oils (13, 54, 106, 125). Investigators have noted a very low prevalence of asthma among Greenland Eskimos, who have a high intake of n-3 fatty acid EPA (59). Peat found an 8% versus 16% prevalence of asthma in regular fish eaters versus nonfish eaters (98). In a more recent Australian dietary intervention trial, children whose mothers were randomized to supplementation with omega-3 fatty acids during pregnancy had less wheeze in the first 18 months of life than did controls (90). Early-life exposure to N-3 PUFA may decrease asthma or allergy risk through decreasing chronic allergic inflammation, including airway inflammation.

Differences in breast-feeding practices also have been suggested as a factor influencing asthma risk but are not reviewed here in depth. Breast-feeding is

complex, as a source of bonding between mother and infant, and a source of small amounts of antigen, antibodies, and protection against potentially diluted formula or bacterial contamination introduced by bottle-feeding using dirty water. The association between breast-feeding and protection (or risk) of allergy and asthma in the child will likely vary depending on other environmental as well as genetic factors (151).

SOCIOECONOMIC AND ETHNIC DISPARITIES IN ASTHMA PREVALENCE, MORBIDITY, AND MORTALITY IN THE UNITED STATES

For almost two decades, socioeconomic and racial/ethnic disparities in asthma prevalence and asthma morbidity in the United States have been well documented (41, 46, 124, 143, 146), though the environmental exposures contributing to these disparities are only partially understood. What is the nature of the disparities in asthma in the United States, and what factors have been considered potential partial explanations for those disparities?

Asthma Disparities: Black/African American versus White/Non-Hispanic Ethnicity in the United States

In the United States, asthma prevalence, hospitalization, and mortality are higher for Black/African American compared to Caucasian (White) children and adults (61). In a Southfield, Michigan, cross-sectional study of childhood asthma in an integrated middle class population (93), the lifetime prevalence of asthma was twice as high for Black compared with White children; this finding suggests that even in middle class communities unmeasured socioeconomic factors (e.g., racial discrimination, differential access to medical care, differential access to housing, differential patterns of medical care use), and perhaps biologic factors [e.g., genetic variation in vulnerability to effects of exposures (81)], may contribute to these disparities.

The disparity in asthma morbidity is greater than the disparity in asthma prevalence, which suggests that once asthma is established, many factors converge to make asthma worse for children and adults who are Black (46, 114, 124, 146). In New York City, asthma hospitalization and death rates among Blacks and Hispanics were 3–5 times those of Whites, in a study of data from all hospital discharges obtained from the New York State Department of Health (19). Asthma hospitalization and mortality were highly correlated with living in the city's poorest neighborhoods, making it impossible to separate ethnicity/race from poverty. Similarly, in a Boston study, asthma hospitalization was positively correlated with the poverty rate of the neighborhood within Boston and also with the proportion of non-White residents (47).

Asthma Disparities in the U.S. Hispanic/Latino Communities

Hispanic or Latino peoples are of many racial, ethnic, cultural, and national origins. A 1999 survey in North Brooklyn, New York, found that the reported asthma prevalence was 5.3% among Dominican Latinos, compared with 13.2% among Puerto Rican Latinos. These differences could not be explained by location, household size, use of home remedies, educational attainment, or country where education was completed (80). Asthma mortality is rare, but in the United States, Puerto Ricans had the highest asthma mortality rates among Hispanics, followed by Cuban Americans and Mexican Americans. Mortality rates for Hispanics were higher in the Northeast than in any other region (58). A 1993–1994 multiethnic study of asthma rates among children in Connecticut found significantly higher asthma rates among Puerto Rican Hispanics, compared with non-Hispanic Whites, and these differences could not be explained by active smoking in the home or various measures of socioeconomic status (SES) (9). In Hartford, Connecticut, Puerto Rican ethnicity was associated with an increased risk of sensitization to indoor and outdoor allergens among children with asthma (25).

ENVIRONMENTAL FACTORS CONTRIBUTING TO ASTHMA DISPARITIES IN THE U.S.

In trying to define and explain ethnic/racial disparities in asthma prevalence or morbidity in the United States, a number of investigators have analyzed national data from the National Health and Nutrition and Examination Surveys I, II, (124) and III (114); the National Health Interview Surveys (3, 146); and the Six Cities Study of air pollution and respiratory health (46). These data have advantages, in that they survey large populations from many regions of the United States, but they also have disadvantages, in that they often offer relatively sparse or specifically selective environmental exposure data on individuals within specific communities. Most investigators have evaluated whether it is possible to explain ethnic/racial disparities in asthma by urban living or by indices of disadvantage. Using data from four U.S. cities, Black children still had 1.6 times the odds of asthma diagnosis compared with White children, after taking into account exposures including cigarette smoke, body-mass index, air-conditioning use, city of residence, parental respiratory illness, parental education, only-child status, and single-parent household (46). Similarly, in the Second National Health Interview Survey, younger maternal age, residence in the central city, family income, low birth weight, and measures of overweight or obesity partially, but not fully, explain the increased prevalence of asthma among Black compared with White children (124). More recently, investigators analyzing data from the 1988 National Health Interview Survey reported that after controlling for multiple factors, Black children did not have higher rates of asthma, but living in an urban setting, regardless of race or income, increased the risk of asthma (3). Using Maryland hospital discharge

data for the period 1979–1982, investigators found that Black children had higher rates of hospitalization for asthma than did White children, but these racial/ethnic differences could be explained by indices of poverty (149). More detailed small-area analyses suggest that this finding may not be the case. Small-area ecologic analyses of Los Angeles and New York City suggested that Black race/ethnicity and poverty were each associated with increased asthma hospitalization, and that Black race/ethnicity remained a strong predictor of hospitalization after controlling for the available socioeconomic variables (109). Blacks in Los Angeles and New York City had similar rates of hospitalization, but Mexican Hispanics in Los Angeles had far lower rates than did Puerto Rican Hispanics in New York City. Not all poverty and socioeconomic disadvantages are associated with higher rates of asthma, or worse asthma morbidity, as demonstrated in the ISAAC surveys (62). Studies within communities have enabled investigators to dig layers deeper to understand the exposures connected with poverty and disadvantage in U.S. urban life that increase the risk of significant asthma morbidity, particularly in children.

The Hygiene Hypothesis—Is it Relevant?

The hygiene hypotheses has been challenged as being irrelevant to the U.S. setting for explained disparities in asthma prevalence or asthma morbidity. If anything, some investigators have argued, endotoxin and early-life infectious exposures must be higher, yet asthma rates are not lower but higher in U.S. cities. They argue that home endotoxin levels in U.S. urban regions must be higher because of the higher levels of dirt and garbage present in the city, but it is not known whether this is the case. Two important sources of endotoxin—dog and dampness (97)—are often lower in overheated urban apartments where dogs may not be kept for cultural reasons or because the landlord does not allow pets. Similarly, it has been hypothesized that in the United States urban infants have higher exposure to other siblings and to children in day care than do more affluent suburban children, resulting in more exposure to early-life infections, but this hypothesis has not been systematically tested.

Housing Conditions and Indoor Environmental Exposures Including Allergens

Independent of income and ethnicity, the degree of housing disrepair has been associated with increased cockroach allergen levels (108), which has been demonstrated to increase childhood asthma morbidity in sensitized children (117). The associations of indoor environmental exposures with asthma morbidity have been well summarized and are not reviewed here (61). The type of allergens differ by building status and by socioeconomic status, but it is not certain whether, regardless of type of indoor allergen, the total amount of allergen exposure (the allergen burden) differs by socioeconomic status or by ethnicity (28, 75). Certain allergens, such as cockroach, mouse, or rat, may be more potent sources of allergic or nonallergic airway inflammation, or environmental cofactors such as community

stress may increase vulnerability to the effects of these exposures in sensitized individuals.

The multicenter National Cooperative Inner City Asthma Study demonstrated an increase in asthma morbidity in children both sensitized and exposed to cockroach (117). In studies in metropolitan Boston, Massachusetts, and Connecticut, cockroach allergen levels were higher in households of Black and Hispanic families compared with White non-Hispanic families, but dust mite levels were lower (28, 75, 79). In a one-year multicity U.S. environmental intervention trial among urban children with asthma, education and remediation for exposure to both allergens and environmental tobacco smoke resulted in fewer days with asthma symptoms during the intervention, compared with the control group (91). Allergen levels in the home were significantly reduced during the year of intervention. Allergen reduction trials have not been uniformly successful in reducing asthma morbidity in allergic asthmatic adults (150), either because of the more fixed nature of long-established asthma or because these trials have not been as comprehensive as the Inner-City Asthma Study trial.

Traffic Air Pollution

Environmental cofactors may also increase vulnerability to adverse effects of air pollution on asthma morbidity (94). Direct exposure to traffic and industrial pollutants is often high in socioeconomically disadvantaged urban neighborhoods (94), though many secondary pollutants (e.g., ozone) can form some distance from their sources of emission. Increased levels of air pollution from both traffic and industrial sources have been reproducibly demonstrated to be associated with increased asthma morbidity in children, whether measured as increased airway obstruction, increased symptoms, or increased hospitalizations for asthma (123). The relation of air pollution to asthma development is less certain. In the United States and Europe, pollution from industrial sources has often been associated with lower levels of lung function and higher rates of cough and bronchitis but not with higher rates of asthma or allergy (123, 139). In contrast, accumulating evidence suggests a possible association between living near traffic pollution and wheeze or asthma (55, 123); diesel exhaust has been proposed as a potential adjuvant that might increase vulnerability to development of allergy (32). Additional research is needed to ascertain whether these associations represent a relation between traffic pollution and the development of allergic asthma.

Disparities in Treatment for Asthma and Access to Care

Asthma is one of many chronic diseases in the United States in which disparities in treatment and access to care have been documented (29). Even those with apparently equal access to the same health care system may experience disparities in care, and communication with the medical system is far more subtle than expressions of overt racism. In one study, the asthma hospitalization rate was inversely correlated with the ratio of inhaled anti-inflammatory to beta agonist medication

use, which suggests that asthmatics in poor neighborhoods were undertreated for their asthma (47). The National Cooperative Inner-City Asthma Study (NCICAS) found that lack of access to care and adherence to treatment (as well as environmental factors including smoking) were potential contributors to increased asthma morbidity among inner-city children (68), and it demonstrated the efficacy and cost-effectiveness of a comprehensive social worker–based education program and environmental control in the reduction of asthma morbidity (132). Individual-level solutions to disparities in treatment and access to care have severe limitations; community-level approaches to reducing disparities are discussed in subsequent sections of this review.

Maternal Cigarette Smoking

The respiratory health effects of smoking have been well documented. Maternal cigarette smoking is associated with high risk of asthma prevalence in early childhood (130, 131) and with high risk of asthma morbidity, wheeze, and respiratory infection in children (61). Smoke exposure in-utero is associated with increased airway resistance/obstruction in infancy and childhood, but its influence on allergic, as opposed to irritant, airway inflammation is uncertain (53, 61). Cigarette smoking varies by ethnicity and by national origin, and cigarette companies have targeted minorities in an attempt to increase smoking where rates have traditionally been low. In a national survey of U.S. Latino individuals, smoking rates were higher among Puerto Rican women than among other women. Central American men and women had the lowest smoking rates (99). Whereas the overall prevalence of cigarette smoking in the United States declined from 40% in 1965 to 29% in 1987, the decline has been marginal among individuals with low education aspirations (61, 136). More worrisome is the fact that after several years of substantial decline among adolescents in four ethnic minority groups, in the 1990s smoking prevalence increased among African American and Hispanic youth (21). Successful smoking cessation is more difficult among pregnant women and mothers dealing with the circumstances surrounding socioeconomic disadvantage. Moreover environmental tobacco smoke (ETS) exposure of children at greatest risk of adverse asthma outcomes (e.g., children of low-income families) may come from caregivers other than the mother or father (e.g., grandparents, day care), and successful interventions must consider all early childhood sources of ETS (61).

Disparities in Asthma and Somatic Growth (Low Birth Weight, Prematurity, and Obesity)

Smoking and other environmental factors influencing both fetal growth and asthma are more prevalent in many (but not all) socioeconomically disadvantaged populations in the United States (133). Prematurity and low birth weight adjusted for gestational age can be influenced not only by maternal smoking, but also by placental insufficiency, maternal:fetal nutrition, infection, and maternal psychologic as well as physical stress (11, 35). The risk of all these environmental influences

on adverse fetal growth may be higher in many socioeconomically disadvantaged U.S. groups, increasing the risk of prematurity and low birth weight (50, 118, 137). Prematurity and low birth weight are risk factors for early life wheeze (43), but their relationship to allergic airway inflammation in asthma that persists into the school-aged years and adolescence is less certain.

Underweight and obesity may both be risk factors for wheeze or asthma (24, 45), and paradoxically, they may even have similar origins in fetal life or early childhood. Overweight has increased markedly in the United States over the past decade, for all Americans (77). The relation of obesity to respiratory disease has been reviewed recently (145). Accumulating evidence suggests that obesity may be not only a result of asthma symptoms, but also a factor contributing to asthma development and the persistence of wheeze (20, 45). The circumstances of urban living and socioeconomic disadvantage, as well as cultural factors, may contribute to obesity (40, 84). Obesity may be a primary contributor to asthma risk; additionally the circumstances leading to obesity may influence risk. The need to keep children indoors because of community violence (decreasing activity, increasing indoor allergen exposures) and the lack of access to playgrounds or healthy foods during school and after-school periods are all factors leading to obesity and may explain some of the association of obesity with asthma (77).

COMMUNITY-LEVEL FACTORS CONTRIBUTING TO ASTHMA DISPARITIES

The etiology of health problems is increasingly recognized as a result of the complex interplay of influences operating at several levels, including the individual, the family, and the community levels (140). Evidence points to the potential influence on health of diverse community (or group-level) characteristics in addition to the economic and individual-level characteristics and exposures (71). The observed wide geographic and sociodemographic variation in asthma expression has led to reconsideration of the interplay among biological and social determinants in understanding such disparities in the asthma burden (153, 155). The balance of this chapter emphasizes how this variation in asthma burden may be explained by community-level factors, including both physical environmental determinants of asthma and the potential influence of social, cultural, and institutional structures.

Neighborhood Contextual Factors

Community-level social variables are receiving increased attention for their potential role in determining inequalities across several health outcomes (33, 51, 72, 78, 113, 115, 147). Few studies have directly examined the influence of such contextual factors on asthma. Two recent studies have shown significant associations between greater neighborhood income inequality and higher childhood asthma hospitalization rates (60, 141). In New Zealand, Salmond and colleagues

(119) used small-area analysis to find a linear increase in a 12-month period prevalence of asthma with increasing area deprivation. In addition, they demonstrated a persistent independent effect for ethnicity.

Given the range of variables that may be considered, identifying pathways that may link community influences, which are supported in existing research, to asthma morbidity may be most informative. Plausible pathways include (*a*) differential environmental exposures, (*b*) stress, and (*c*) impact on health behaviors.

Differential Environmental Exposures

To date, much of the literature has focused on the potential importance of physical environmental characteristics on asthma morbidity: outdoor air pollution (101); crowding, as it may predispose to viral respiratory illness (122); and changing housing stock, which may increase exposure to indoor allergens (31, 103). Future research may need to pay increased attention to social, political, and economic forces that result in marginalization of certain populations in disadvantaged neighborhoods, which may increase exposure to these known environmental risk factors (49, 95). We also need to understand better how the physical and psychological demands of living in a relatively deprived environment may potentiate an individual's susceptibility to such exposures.

Stress

There is a renewed interest in the influence of psychological stress on asthma (18, 37, 155). This is a useful way to conceptualize community-level (or group-level) influences on health, whether one operationalizes the environment as a social or a physical construct. Both physical and social factors can be a source of environmental demands that contribute to stress experienced by populations living in a particular area (37). Differential exposure to and perception of stress may, in part. explain the associations between SES and health (2). Various sociodemographic characteristics (e.g., lower social class, ethnic minority status, gender) may predispose individuals to particular pervasive forms of chronic life stress (34, 88, 105), which may, in turn, be significantly influenced by the characteristics of the communities in which they live (134). Growing evidence in prospective population-based and laboratory studies support the role of differential life stress experiences and asthma expression. In a prospective birth-cohort study, our laboratory demonstrated that greater levels of caregiver-perceived stress was independently associated with subsequent risk of recurrent wheeze (2 or more) episodes in early childhood (152), controlling for variables that may have been related to stress (i.e., birth weight**,** parental asthma, race/ethnicity, and socioeconomic status). Moreover, high levels of caregiver stress predicted an increased risk of wheeze in the index children even after adjusting for potential mediators (i.e., maternal smoking, lower respiratory illness, allergen levels, and breast feeding), which suggests that the relation between stress and early childhood repeated wheeze may not be primarily mediated through these caregiver behaviors or through susceptibility to lower respiratory

infections. A plausible alternative hypothesis may be that there is a more direct effect on airway inflammation through influences on the immune system, which may promote airway obstruction and wheeze. In this same Boston-based cohort study, we have examined the influence of chronic caregiver stress in early childhood on the expression of intermediate phenotypes potentially related to the development of atopy (156a). Increased stress in the home predicted higher levels of IgE expression, enhanced allergen-specific lymphocyte proliferation, and differential cytokine expression in the index children. Sandberg and colleagues (121) found an increased risk of asthma exacerbations among children aged 6–13 years to be associated with acute severe life events. This effect was enhanced in the context of chronic ongoing stress. Two prospective studies of preschool-aged children attending day care in California found that children with high autonomic and immune reactivity to stress had higher subsequent rates of respiratory infections during high environmental stress experienced during follow-up (14). Lower respiratory infections, particularly during childhood, play a role in asthma exacerbations (44).

Recent evidence links stress and differential immunological responses among asthmatic adolescents. Chen and colleagues (27) recently reported differential neuroendocrine and immune reactivity in a group of adolescent asthmatics relative to SES. Adolescents in the low-SES group had significantly higher levels of a mitogen-stimulated cytokine associated with a Th-2 immune response (IL-5), higher levels of a stimulated cytokine associated with a Th-1 immune response (IFN-γ), and marginally lower morning cortisol values compared with the high-SES group. Low SES adolescents also had greater stress experiences and lower beliefs about control over their health, which partially explained the relationship between SES and IL-5/IFN-γ.

One type of chronic stress that has been investigated in relation to the well-being of U.S. urban populations is neighborhood disadvantage (ND), characterized by the presence of a number of community-level stressors including poverty, unemployment, substandard housing, and high crime/violence rates (6). Some data suggest that the health implications of low income are significantly different for individuals living in areas with high ND (52). In the United States, trends in social environmental factors over the past few decades have resulted in many urban communities characterized by high ND (148). Changes have occurred in the residential distribution of the U.S. population and have resulted in the disproportionate concentration of minority groups in areas of concentrated poverty (74). Similar to ND are the constructs of social organization, social capital, or community assets (83). Closely related to these are physical features of the environment such as crowding and noise. Research has linked these to stress, but few studies have evaluated their relationship to asthma outcomes (37).

The broad constructs of ND or low levels of community assets subsume key exposures such as living in the presence of pervasive violence and crime. Violent crime undermines social cohesion (70, 73, 120) and is associated with the erosion of social capital and community resilience. Crime is most prevalent in societies with large disparities in the material standards of living (70). Thus, in addition to

direct impacts on community residents, crime and violence (or the lack thereof) can be used as indicators of collective well-being, social relations, or social cohesion within a community and society. Furthermore, the conditions known to be associated with violence exposure are related to experienced stress (16), and chronic violence exposure has been conceptualized as a pervasive environmental stressor imposed on already vulnerable populations (63).

Violence exposure has been associated with asthma in both the clinical (156) and research settings. We examined the association between exposure to community violence and caretaker-reported asthma symptoms and behaviors in the Inner-City Asthma Study (ICAS) (154). We hypothesized that those families and children living with high levels of violence would have increased asthma morbidity. Greater community violence exposure was independently associated with asthma morbidity after simultaneous adjustment for income, employment status, caretaker education, a number of housing problems, and other adverse life events, which suggests that violence was not merely a marker for these other factors. Psychological stress and caretaker behaviors (keeping children indoors, smoking, and skipping medications) partially explained the association between higher violence and increased asthma morbidity.

Minority group status may predispose individuals to pervasive chronic stressors (e.g., discrimination, racism) and societal factors that link minorities and ND. For example, the broader political and economic forces that result in marginalization of minority populations in disadvantaged inner-city neighborhoods may lead to increased stress experienced by these populations and thus greater disease morbidity (70). Future studies need to examine the links among ND, minority group status, low levels of social capital, violence exposure, and other social influences (and the heightened stress that they may elicit) as risk factors for childhood asthma analogous to physical environmental exposures (e.g., allergens, tobacco smoke, air pollution). Such studies are likely to further our understanding of the increased asthma burden on populations of children living in poverty in urban areas or other disadvantaged communities.

Health Behaviors and Other Psychological Factors

Smoking can be viewed as a strategy to cope with negative affect or stress (1, 4, 10). This relationship among stress and smoking may be considered from a neighborhood perspective as well. Studies have demonstrated effects of neighborhood social factors on smoking behavior (67, 76, 111). Neighborhood SES may be related to increased social tolerance and norms supporting behavioral risk factors such as smoking (30).

In adult African American populations, prevalence of smoking is higher relative to Whites. Evidence from the 1987 General Social Survey suggests that stress may be one factor promoting increased prevalence of smoking in African American communities (38). Romano and colleagues (116) surveyed adults from 1137 African American households and found that the strongest predictor of smoking

was household report of high-level stress, represented by an abbreviated hassles index. The hassles index was a ten-item scale based on items chosen to represent a dimension that community residents perceived to be especially relevant. Among the items were neighborhood-level factors including concern about living in an unsafe area. Community violence exposure has been linked to smoking rates in Harlem (39).

In addition to community-level stress influences on health behaviors such as smoking, evidence has linked community-level variables to key individual characteristics such as perceived control. A large body of research indicates the importance of constructs such as perceived control (global feeling of the ability to deal with an event) over health as, for example, they mediate the relationship between illness experience, understanding, and compliance (126). Perceived control has been found to correlate with many aspects of disease burden (56, 127).

Evidence indicates that exposure to indicators of neighborhood disadvantage including violence reduces perceived control. DuRant and colleagues (36) examined the relationships between exposure to community violence and depression, hopelessness, and purpose in life among Black urban youth. These authors found that higher current depression and hopelessness and lower purpose in life were significantly associated with the reported higher frequency of exposure to, or victimization by, violence in a youth's lifetime. Thus, tying together several of the findings discussed here, exposure to violence or living in a community with high ND may lead to reduced perceived control, which may, in turn, be associated with poorer asthma management and outcomes. An important methodological issue should be raised here. If increased exposure to tobacco smoke or reduced perceived control is a result of increased stress caused by the physical or social environment, then they should be considered as mediators rather than confounders of the relationships between community-level variables and asthma outcomes. Inappropriate adjustment for such factors may result in the attenuation of a true effect (37, 69).

Populations in communities that experience environmental inequities may also be characterized by high levels of poverty, low social capital, lack of opportunity and employment, high violence or crime rates, lack of perceived control, and hopelessness. The health problems of these disadvantaged populations are not likely to be solved without understanding the potential role of such social determinants of health.

CONCLUSION

Community-level and individual-level factors both contribute to disparities in asthma morbidity and the incidence/prevalence of asthma. We understand more about factors that influence asthma morbidity (the worsening of asthma in allergic asthmatic individuals) than we do about factors that influence the development of allergy and asthma. Our understanding of asthma morbidity comes from both observational studies and intervention trials. Recent evidence suggests

that in the United States, among socioeconomically disadvantaged children with asthma and allergy, asthma morbidity can be improved with targeted interventions (91).

The effects of individual environmental factors on asthma morbidity and asthma development are likely to be modified by other environmental factors and by genes. With the exception of cigarette smoking cessation, policy makers should be cautious when recommending global solutions for protection against development of early-life asthma, given the lack of certainty regarding factors influencing asthma development and the likelihood that individual responses to environmental interventions will be significantly modified by genetic and other environmental factors. It is not trite to say that "more research is needed" to improve our understanding of factors responsible for disparities in asthma prevalence. However, where community-level or individual-level interventions have been demonstrated to decrease asthma morbidity with reasonable certainty (85, 91), policy makers should develop the means to apply the lessons learned through changes in governmental and social policy as well as through recommendations to individuals (64). Subsequently, the outcome of changes in policy should be systematically evaluated. In the United States, effective reduction in disparities in asthma morbidity will be dependent only in part on specific measures like establishment of smoking cessation programs, home allergen reduction in sensitized asthmatic children, physician feedback, and/or health education. The long-term success of any of these specific measures is likely to depend, in great part, on more general improvements in living conditions and life opportunities (64, 87).

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LITERATURE CITED

1. Acierno R, Kilpatrick DG, Rsesnick HS, Saund CL. 1996. Violent assault, posttraumatic stress disorder, and depression: risk factors for cigarette use among adult women. *Behav. Modif.* 20:363–84
2. Adler NE, Boyce T, Chesney MA, Cohen S, Folkman S, et al. 1994. Socioeconomic status and health: the challenge of the gradient. *Am. Psychol.* 49:15–24
3. Aligne CA, Auinger P, Byrd RS, Weitzman M. 2000. Risk factors for pediatric asthma. Contributions of poverty, race, and urban residence. *Am. J. Respir. Crit. Care Med.* 162:873–77
4. Anda RF, Williamson DF, Escobedo LG,

Mast EE, Giovino GA, Remington PL. 1990. Depression and the dynamics of smoking: a national perspective. *JAMA* 264:1541–45

5. Asher MI, Keil U, Anderson HR. 1995. International study of asthma and allergies in childhood (ISAAC): rational and methods. *Eur. Respir. J.* 8:483–91
6. Attar BK, Guerra NG, Tolan PH. 1994. Neighborhood disadvantage, stressful life events and adjustment in urban elementary-school children. *J. Clin. Child Psychol.* 23:391–40
7. Baldini M, Lohman IC, Halonen M, Erickson RP, Holt PG, Martinez FD. 1999. A polymorphism in the 5′ flanking region of the CD14 gene is associated with circulating soluble CD14 levels and with total serum immunoglobulin E. *Am. J. Respir. Cell Mol. Biol.* 20:976–83
8. Ball TM, Castro-Rodriguez JA, Griffith KA, Holberg CJ, Martinez F, Wright AL. 2000. Siblings, day-care attendance, and the risk of asthma and wheezing during childhood. *N. Engl. J. Med.* 343:538–43
9. Beckett WS, Belanger K, Gent JF, Holford TR, Leaderer BP. 1996. Asthma among Puerto Rican Hispanics: a multiethnic comparison study of risk factors. *Am. J. Respir. Crit. Care Med.* 154:894–99
10. Beckham J, Roodman A, Shipley R, Hetzberg M, Cunha G, et al. 1995. Smoking in Vietnam combat veterans with posttraumatic stress disorder. *J. Trauma Stress* 8:461–72
11. Benson CB, Doubilet PM. 1998. Fetal measurements: normal and abnormal fetal growth. In *Diagnostic Ultrasound*, ed. CM Rumack, SR Wilson, JW Charboneau, pp. 1013–31. St. Louis: Mosby-Year Book
12. Benson V, Marano M. 1998. Current estimates from the National Health Interview Survey, 1995. Vital Health Stat. 10 (199). Hyattsville, MD: Natl. Cent. Health Stat.
13. Black PN, Sharpe S. 1997. Dietary fat and asthma: Is there a connection? *Eur. Respir. J.* 10:6–12
14. Boyce TW, Chesney M, Alkon A, Tschann JM, Adams S, et al. 1995. Psychobiologic reactivity to stress and childhood respiratory illnesses: results of two prospective studies. *Psychosom. Med.* 57:411–22
15. Braun-Fahrlander C, Riedler J, Herz U, Eder W, Waser M, et al. 2002. Environmental exposure to endotoxin and its relation to asthma in school-age children. *N. Engl. J. Med.* 347:869–77
16. Breslau N, Davis G, Andreski P, Petersen E. 1991. Traumatic events and posttraumatic stress disorder in an urban population of young adults. *Arch. Gen. Psychiatry* 48:216–22
17. Britton J. 2003. Parasites, allergy, and asthma. *Am. J. Respir. Crit. Care Med.* 168:266–67
18. Busse W, Kiecolt-Glaser J, Coe C, Martin R, Weiss S, Parker S. 1994. Stress and asthma: NHLBI Workshop Summary. *Am. J. Respir. Crit. Care Med.* 151: 249–52
19. Carr W, Zeitel L, Weiss K. 1992. Variations in asthma hospitalizations and deaths in New York City. *Am. J. Public Health* 82:59–65
20. Castro-Rodriguez JA, Holberg CJ, Morgan WJ, Wright AL, Martinez FD. 2001. Increased incidence of asthmalike symptoms in girls who become overweight or obese during the school years. *Am. J. Respir. Crit. Care Med.* 163:1344–49
21. CDC. 1998. *Tobacco Use Among U.S. Racial/Ethnic Minority Groups-African American, America Indians and Alaska Natives, Asian American and Pacific Islanders, and Hispanics: A Report of the Surgeon General*. Atlanta, GA: US Dep. Health Hum. Serv., Natl. Cent. Chronic Dis. Prev. Health Promot. Off. Smok. Health
22. Celedon JC, Litonjua AA, Ryan L, Platts-Mills T, Weiss ST, Gold DR. 2002. Exposure to cat allergen, maternal

history of asthma, and wheezing in first 5 years of life. *Lancet* 360:781–82

23. Celedon JC, Litonjua AA, Ryan L, Weiss ST, Gold DR. 2002. Day care attendance, respiratory tract illnesses, wheezing, asthma, and total serum IgE level in early childhood. *Arch. Pediatr. Adolesc. Med.* 156:241–45
24. Celedon JC, Palmer LJ, Litonjua AA, Weiss ST, Wang B, et al. 2001. Body mass index and asthma in adults in families of subjects with asthma in Anqing, China. *Am. J. Respir. Crit. Care Med.* 164:1835–40
25. Celedon JC, Sredl D, Weiss ST, Pisarski M, Wakefield D, Cloutier M. 2004. Ethnicity and skin test reactivity to aeroallergens among asthmatic children in Connecticut. *Chest* 125:85–92
26. Celedon JC, Wright RJ, Litonjua AA, Sredl D, Ryan L, et al. 2003. Day care attendance in early life, maternal history of asthma, and asthma at the age of 6 years. *Am. J. Respir. Crit. Care Med.* 167:1239–43
27. Chen E, Fisher EB, Bacharier LB, Strunk RC. 2003. Socioeconomic status, stress, and immune markers in adolescents with asthma. *Psychosom. Med.* 65:984–92
28. Chew GL, Burge HA, Dockery DW, Muilenberg ML, Weiss ST, Gold DR. 1998. Limitations of a home characteristics questionnaire as a predictor of indoor allergen levels. *Am. J. Respir. Crit. Care Med.* 157:1536–41
29. Comm. Underst. Elimin. Racial Ethn. Disparities Health Care, Board Health Sci. Policy, Inst. Med. 2002. *Unequal Treatment Confronting Racial and Ethnic Disparities in Health Care*. Washington, DC: Natl. Acad. Press
30. Curry SJ, Wagner EH, Cheadle A, Diehr P, Koepsell T, et al. 1993. Assessment of community-level influences on individual's attitudes about cigarette smoking, alcohol use, and consumption of dietary fat. *Am. J. Prev. Med.* 9:78–84
31. Dekker C, Dales R, Bartlett S, Brunekree B, Zwanenburg H. 1991. Childhood asthma and the indoor environment. *Chest* 100:922–26
32. Diaz-Sanchez D, Dotson AR, Takenaka H, Saxon A. 1994. Diesel exhaust particles induce local IgE production in vivo and alter the pattern of IgE messenger RNA isoforms. *J. Clin. Invest.* 94:1417–25
33. Diez-Roux AV, Nieto FJ, Muntaner C, Tyroler HA, Comstock GW, et al. 1997. Neighborhood environments and coronary heart disease: a multilevel analyses. *Am. J. Epidemiol.* 146:48–63
34. Dohrenwend BP, Dohrenwend BS. 1969. *Social Status and Psychological Disorder.* New York: Wiley
35. Doubilet PM, Benson CB, Callen PW. 2000. Ultrasound evaluation of fetal growth. In *Ultrasonography in Obstetrics and Gynecology*, ed. PW Callen, pp. 206–20. Philadelphia: Saunders
36. DuRant R, Getts A, Cadenhead C, Emans S, Woods E. 1995. Exposure to violence and victimization and depression, hopelessness, and purpose in life among adolescents living in and around public housing. *Dev. Behav. Pediatr.* 16:233–37
37. Evans G. 2001. Environmental stress and health. In *Handbook of Health Psychology*, ed. A Baum, T Revenson, J Singer, pp. 365–85. Mahwah, NJ: Erlbaum
38. Feigelman W, Gorman B. 1989. Toward explaining the higher incidence of cigarette smoking among Black Americans. *J. Psychoactive Drugs* 21:299–305
39. Ganz ML. 2000. The relationship between external threats and smoking in central Harlem. *Am. J. Public Health* 90: 367–71
40. Gennuso J, Epstein LH, Paluch RA, Cerny F. 1998. The relationship between asthma and obesity in urban minority children and adolescents. *Arch. Pediatr. Adolesc. Med.* 152:1197–200
41. Gergen PJ, Mullally DI, Evans R. 1988. National survey of prevalence of asthma

among children in the United States. *Pediatrics* 81:1–7
42. Gern JE, Reardon CL, Hoffjan S, Nicolae D, Li Z, et al. 2004. Effects of dog ownership and genotype on immune development and atopy in infancy. *J. Allergy Clin. Immunol.* 113:307–14
43. Gold DR, Burge HA, Carey V, Milton DK, Platts-Mills T, Weiss ST. 1999. Predictors of repeated wheeze in the first year of life: the relative roles of cockroach, birth weight, acute lower respiratory illness, and maternal smoking. *Am. J. Resp. Crit. Care Med.* 160:227–36
44. Deleted in proof
45. Gold DR, Damokosh AI, Dockery DW, Berkey CS. 2003. Body-mass index as a predictor of incident asthma in a prospective cohort of children. *Pediatr. Pulmonol.* 36:514–21
46. Gold DR, Rotnitzky A, Damokosh AI, Ware JH, Speizer FE, et al. 1993. Race and gender differences in respiratory illness prevalence and their relationship to environmental exposures in children 7 to 14 years of age. *Am. Rev. Resp. Dis.* 148:10–18
47. Gottlieb DJ, Beiser AS, O'Connor GT. 1995. Poverty, race, and medication use are correlates of asthma hospitalization rates. A small area analysis in Boston. *Chest* 108:28–35
48. Graves E, Kozak L. 1998. *Detailed diagnoses and procedures. National Hospital Discharge Survey, 1996*. Natl. Cent. Health Stat. Vital Health Stat. Ser. 13: Data from the National Health Survey (138):i–iii
49. Green RS, Smorodinsky S, Kim JJ, McLaughlin R, Ostro B. 2003. Proximity of California public schools to busy roads. *Environ. Health Perspect.* 112: 61–66
50. Grischkan J, Storfer-Isser A, Rosen CL, Larkin EK, Kirchner HL, et al. 2004. Variation in childhood asthma among former preterm infants. *J. Pediatr.* 144:321–26
51. Haan M, Kaplan G, Camacho T. 1987. Poverty and health: prospective evidence from the Alameda County Study. *Am. J. Epidemiol.* 125:989–98
52. Haan M, Kaplan N, Syme S. 1989. Socioeconomic status and health: old observations and new thoughts. In *Pathways in Health*, ed. J Bunder, D Gomby, B Kehrer, pp. 76–135. Menlo Park, CA: Henry J. Kaiser Family Found.
53. Hanrahan JP, Tager IB, Segal MR, Tosteson TD, Castile RG, et al. 1992. The effect of maternal smoking during pregnancy on early infant lung function. *Am. Rev. Respir. Dis.* 145:1129–35
54. Hodge L, Salome CM, Peat JK, Haby MM, Xuan W, Woolcock AJ. 1996. Consumption of oily fish and childhood asthma risk. *Med. J. Aust.* 164:137–40
55. Hoek G, Brunekreef B, Goldbohm S, Fischer P, van den Brandt PA. 2002. Association between mortality and indicators of traffic-related air pollution in the Netherlands: a cohort study. *Lancet* 360:1203–9
56. Holden G. 1991. The relationship of self-efficacy appraisals to subsequent health related outcomes: a meta-analysis. *Soc. Work Health Care* 16:53–93
57. Holt PG, O'Keeffe P, Holt BJ, Upham JW, Baron-Hay MJ, et al. 1995. T-cell "priming" against environmental allergens in human neonates: sequential deletion of food antigen reactivity during infancy with concomitant expansion of responses to ubiquitous inhalant allergens. *Pediatr. Allergy Immunol.* 6:85–90
58. Homa DM, Mannino DM, Lara M. 2000. Asthma mortality in U.S. Hispanics of Mexican, Puerto Rican, and Cuban heritage, 1990–1995. *Am. J. Respir. Crit. Care Med.* 161:504–9
59. Horrobin DF. 1987. Low prevalences of coronary heart disease (CHD), psoriasis, asthma and rheumatoid arthritis in Eskimos: Are they caused by high dietary intake of eicosapentaenoic acid (EPA), a genetic variation of essential fatty acid

(EFA) metabolism or a combination of both? *Med. Hypotheses* 22:421–28
60. Howard DE, Cross SI, Li X, Huang W. 1999. Parent-youth concordance regarding violence exposure: relationship to youth psychosocial functioning. *J. Adolesc. Health* 25:396–406
61. Inst. Med. Comm. Assess. Asthma Indoor Air. 2000. *Clearing the Air: Asthma and Indoor Air Exposures.* Washington, DC: IOM
62. Int. Study Asthma Allerg. Childhood (ISAAC) Steer. Comm. 1998. Worldwide variation in prevalence of symptoms of asthma, allergic rhinoconjunctivitis, and atopic eczema: ISAAC. *Lancet* 351:1225–32
63. Isaacs M. 1992. *Violence: The Impact of Community Violence on African American Children and Families.* Arlington, VA: Natl. Cent. Educ. Matern. Child Health
64. Isaacs SL, Schroeder SA. 2004. Class—the ignored determinant of the nation's health. *N. Engl. J. Med.* 351:1137–42
65. Kalliomaki M, Kirjavainen P, Eerola E, Kero P, Salminen S, Isolauri E. 2001. Distinct patterns of neonatal gut microflora in infants in whom atopy was and was not developing. *J. Allergy Clin. Immunol.* 107:129–34
66. Kalliomaki M, Salminen S, Arvilommi H, Kero P, Koskinen P, Isolauri E. 2001. Probiotics in primary prevention of atopic disease: a randomized placebo-controlled trial. *Lancet* 357:1076–79
67. Karvaonen S, Rimpela A. 1996. Socioregional context as a determinant of adolescents' health in Finland. *Soc. Sci. Med.* 43:1467–74
68. Kattan M, Mitchell H, Eggleston P, Gergen P, Crain E, et al. 1997. Characteristics of inner-city children with asthma: the National Cooperative Inner-City Asthma Study. *Pediatr. Pulmonol.* 24:253–62
69. Kaufman J, Kaufman S. 2001. Assessment of structured socioeconomic effects on health. *Epidemiology* 12:157–67
70. Kawachi I. 1999. Social capital and community effects on population and individual health. *Ann. NY Acad. Sci.* 896: 120–30
71. Kawachi I, Berkman LF, eds. 2003. *Neighborhoods and Health.* New York: Oxford Univ. Press
72. Kennedy B, Kawachi I, Prothrow-Smith D. 1996. Income distribution and mortality: test of the Robin Hoos Index in the United States. *Br. Med. J.* 312:1004–7
73. Kennedy B, Kawachi I, Prothrow-Smith D, Lochner K, Gupta V. 1998. Social capital, income inequality, and firearm violent crime. *Soc. Sci. Med.* 47:7–17
74. Kilpatrick KL, Williams LM. 1998. Potential mediators of post-traumatic stress disorder in child witnesses to domestic violence. *Child Abuse Negl.* 22:319–30
75. Kitch BT, Chew G, Burge HA, Muilenberg ML, Weiss ST, et al. 2000. Socioeconomic predictors of high allergen levels in homes in the greater Boston area. *Environ. Health Perspect.* 108:301–7
76. Kleinschmidt I, Hills M, Elliott P. 1997. Smoking behavior can be predicated by neighborhood deprivation measures. *J. Epidemiol. Community Health* 87:1113–18
77. Krebs NF, Jacobson MS. 2003. Prevention of pediatric overweight and obesity. *Pediatrics* 112:424–30
78. La Veist T. 1993. Segregation, poverty, and empowerment: health consequence for African Americans. *Milbank Q.* 71: 41–64
79. Leaderer BP, Belanger K, Triche E, Holford T, Gold DR, et al. 2002. Dust mite, cockroach, cat, and dog allergen concentrations in homes of asthmatic children in the northeastern United States: impact of socioeconomic factors and population density. *Environ. Health Perspect.* 110:419–25
80. Ledogar RJ, Penchaszadeh A, Garden CC, Iglesias G. 2000. Asthma and Latino

cultures: different prevalence reported among groups sharing the same environment. *Am. J. Public Health* 90:929–35

81. Lester LA, Rich SS, Blumenthal MN, Togias A, Murphy S, et al. 2001. Ethnic differences in asthma and associated phenotypes: collaborative study on the genetics of asthma. *J. Allergy Clin. Immunol.* 108:357–62
82. Lewis SA, Weiss ST, Platts-Mills TA, Burge H, Gold DR. 2002. The role of indoor allergen sensitization and exposure in causing morbidity in women with asthma. *Am. J. Respir. Crit. Care Med.* 165:961–66
83. Lochner K, Kawachi I, Kennedy B. 1999. Social capital: a guide to its measurement. *Health Place* 5:259–70
84. Luder E, Melnick TA, DiMaio M. 1998. Association of being overweight with greater asthma symptoms in inner city black and Hispanic children. *J. Pediatrics* 132:699–703
85. Martinez FD, Wright AL, Taussig LM, Holberg CJ, Halonen M, Morgan WJ. 1995. Asthma and wheezing in the first six years of life. The Group Health Medical Associates. *N. Engl. J. Med.* 332: 133–38
86. Matricardi PM, Rosmini F, Rapicetta M, Gasbarrini G, Stroffolini T. 1999. Atopy, hygiene, and anthroposophic lifestyle. San Marino Study Group. *Lancet* 354:430
87. McKinlay J. 1975. The help-seeking behavior of the poor. In *Poverty and Health: A Sociological Analysis*, ed. J Kosa, A Antonovsky, I Zoal, pp. 224–73. Cambridge, MA: Harvard Univ. Press
88. McLean D, Hatfield-Timajchy K, Wingo P, Floyd R. 1993. Psychosocial measurement: implications for the study of preterm delivery in black women. *Am. J. Prev. Med.* 9(Suppl. 6):39–81
89. Michel O, Kips J, Duchateau J, Vertongen F, Robert L, et al. 1996. Severity of asthma is related to endotoxin in house dust. *Am. J. Respir. Crit. Care Med.* 154: 1641–46
90. Mihrshahi S, Peat JK, Marks GB, Mellis CM, Tovey ER, et al. 2003. Eighteen-month outcomes of house dust mite avoidance and dietary fatty acid modification in the Childhood Asthma Prevention Study (CAPS). *J. Allergy Clin. Immunol.* 111:162–68
91. Morgan WJ, Crain EF, Gruchalla RS, O'Connor GT, Kattan M, et al. 2004. Results of a home-based environmental intervention among urban children with asthma. *N. Engl. J. Med.* 351:1068–80
92. Murphy S. 1997. *Expert Panel Report 2: Guidelines for the Diagnosis and Management of Asthma. Rep. 97–4051*. Bethesda, MD: Natl. Inst. Health, Natl. Heart, Lung, Blood Inst.
93. Nelson DA, Johnson CC, Divine GW, Strauchman C, Joseph CL, Ownby DR. 1997. Ethnic differences in the prevalence of asthma in middle class children. *Ann. Allergy Asthma Immunol.* 78:21–26
94. O'Neill MS, Jerrett M, Kawachi I, Levy JI, Cohen AJ, et al. 2003. Health, wealth, and air pollution: advancing theory and methods. *Environ. Health Perspect.* 111:1861–70
95. Deleted in proof
96. Ownby DR, Johnson CC, Peterson EL. 2002. Exposure to dogs and cats in the first year of life and risk of allergic sensitization at 6 to 7 years of age. *JAMA* 288:963–72
97. Park JH, Spiegelman DL, Gold DR, Burge HA, Milton DK. 2001. Predictors of airborne endotoxin in the home. *Environ. Health Perspect.* 109:859–64
98. Peat JK, Salome CM, Woolcock AJ. 1992. Factors associated with bronchial hyperresponsiveness in Australian adults and children. *Eur. Respir. J.* 5:921–29
99. Perez-Stable EJ, Ramirez A, Villareal R, Talavera GA, Trapido E, et al. 2001. Cigarette smoking behavior among US Latino men and women from different

countries of origin. *Am. J. Public Health* 91:1424–30

100. Perzanowski MS, Ronmark E, Platts-Mills TA, Lundback B. 2002. Effect of cat and dog ownership on sensitization and development of asthma among preteenage children. *Am. J. Respir. Crit. Care Med.* 166:696–702
101. Pierson WE, Koenig JQ. 1992. Respiratory effects of air pollution on allergic disease. *J. Allergy Clin. Immunol.* 90: 557–66
102. Platts-Mills T, Vaughan J, Squillace S, Woodfolk J, Sporik R. 2001. Sensitisation, asthma, and a modified Th2 response in children exposed to cat allergen: a population-based cross-sectional study. *Lancet* 357:752–56
103. Platts-Mills TA, Ward GW Jr, Sporik R, Gelber LE, Chapman MD, Heymann PW. 1991. Epidemiology of the relationship between exposure to indoor allergens and asthma. *Int. Arch. Allergy Appl. Immunol.* 94:339–45
104. Platts-Mills TAE, Erwin EA, Allison AB, Blumenthal K, Barr M, et al. 2003. The relevance of maternal immune responses to inhalant allergens to maternal symptoms, passive transfer to the infant, and development of antibodies in the first 2 years of life. *J. Allergy Clin. Immunol.* 111:123–30
105. Rabkin J, Struening E. 1976. Life events, stress and illness. *Science* 194:1013–20
106. Raper NR, Cronin FJ, Exler J. 1992. Omega-3 fatty acid content of the US food supply. *J. Am. Coll. Nutr.* 11:304–8
107. Rappaport S, Boodram B. 1998. Forecasted state-specific estimates of self-reported asthma prevalence–United States, 1998. *MMWR* 47:1022–25
108. Rauh VA, Chew GR, Garfinkel RS. 2002. Deteriorated housing contributes to high cockroach allergen levels in inner-city households. *Environ. Health Perspect.* 110(Suppl. 2):323–27
109. Ray NF, Thamer M, Fadillioglu B, Gergen PJ. 1998. Race, income, urbanicity, and asthma hospitalization in California: a small area analysis. *Chest* 113:1277–84
110. Reed CE, Milton DK. 2001. Endotoxin-stimulated innate immunity: a contributing factor for asthma. *J. Allergy Clin. Immunol.* 108:157–66
111. Reijneveld S. 1998. The impact of individual and area characteristics on urban socioeconomic differences in health and smoking. *Int. J. Epidemiol.* 27:33–40
112. Riedler J, Braun-Fahrlander C, Eder W, Schreuer M, Waser M, et al. 2001. Exposure to farming in early life and development of asthma and allergy: a cross-sectional survey. *Lancet* 358:1129–33
113. Roberts EM. 1997. Neighborhood social environments and the distribution of low birth weight in Chicago. *Am. J. Public Health* 87:597–603
114. Roberts EM. 2002. Racial and ethnic disparities in childhood asthma diagnosis: the role of clinical findings. *J. Natl. Med. Assoc.* 94:215–23
115. Roberts S. 1998. Community-level socioeconomic status effects on adult health. *J. Health Soc. Behav.* 39:18–37
116. Romano P, Bloom J, Syme S. 1991. Smoking, social support, and hassles in an urban African-American Community. *Am. J. Public Health* 81:1415–22
117. Rosenstreich DL, Eggleston P, Kattan M, Baker D, Slavin RG, et al. 1997. The role of cockroach allergy and exposure to cockroach allergen in causing morbidity among inner-city children with asthma. *N. Engl. J. Med.* 336:1356–63
118. Rowley DL. 2001. Closing the gap, opening the process: why study social contributors to preterm delivery among black women. *Matern. Child Health J.* 5: 71–74
119. Salmond C, Crampton P, Hales S, Lewis S, Pearce N. 1999. Asthma prevalence and deprivation: a small area analysis. *J. Epidemiol. Community Health* 53:476–80
120. Sampson R, Raudenbush S, Earls F. 1997. Neighborhoods and violent crime:

a multilevel study of collective efficacy. *Science* 277:918–24

121. Sandberg S, Paton JY, McCann DC, McGuiness D, Hillary CR, Oja H. 2000. The role of acute and chronic stress in asthma attacks in children. *Lancet* 356: 982–87
122. Schenker M, Samet J, Speizer F. 1983. Risk factors for childhood respiratory disease. *Am. Rev. Respir. Dis.* 128:1038–43
123. Schwartz J. 2004. Air pollution and children's health. *Pediatrics* 113:1037–43
124. Schwartz J, Gold DR, Dockery DW, Weiss ST, Speizer FE. 1990. Predictors of asthma and persistent wheeze in a national sample of children in the United States. Association with social class, perinatal events and race. *Am. Rev. Respir. Dis.* 142:555–62
125. Seaton A, Godden DJ, Brown K. 1994. Increase in asthma: a more toxic environment or a more susceptible population? *Thorax* 49:171–74
126. Shagena M, Sandler H, Perrin E. 1988. Concepts of illness and perception of control in healthy children and in children with chronic illnesses. *J. Dev. Behav. Pediatr.* 9:252–56
127. Stein M, Wallston K, Nicassio P, Castner N. 1988. Correlates of a clinical classification schema for the Arthritis Helplessness Index. *Arthritis Rheum.* 31:876–81
128. Strachan DP. 1989. Hay fever, hygiene, and household size. *Br. Med. J.* 299: 1259–60
129. Strachan DP. 2000. Family size, infection and atopy: the first decade of the "hygiene hypothesis." *Thorax* 55(Suppl. 1):S2–10
130. Strachan DP, Cook DG. 1997. Health effects of passive smoking. 1. Parental smoking and lower respiratory illness in infancy and early childhood. *Thorax* 52:905–14
131. Strachan DP, Cook DG. 1998. Health effects of passive smoking. 6. Parental smoking and childhood asthma: longitudinal and case-control studies. *Thorax* 53:204–12
132. Sullivan SD, Weiss KB, Lynn H, Mitchell H, Kattan M, et al. 2002. The cost-effectiveness of an inner-city asthma intervention for children. *J. Allergy Clin. Immunol.* 110:576–81
133. Tager IB. 1998. Smoking and childhood asthma—Where do we stand? *Am. J. Respir. Crit. Care Med.* 158:349–51
134. Taylor SE, Repetti RL, Seeman T. 1997. Health psychology: What is an unhealthy environment and how does it get under the skin? *Annu. Rev. Psychol.* 48:411–47
135. Troisi RJ, Willett WC, Weiss ST, Trichopoulos D, Rosner B, Speizer FE. 1995. A prospective study of diet and adult-onset asthma. *Am. J. Respir. Crit. Care Med.* 151:1401–8
136. U.S. Dep. Health Hum. Serv. 1991. *Healthy People 2000: National Health Promotion and Disease Prevention Objectives. DHHS Publ. No. (PHS) 91–50212*. Washington, DC: Off. Assist. Secretary Health
137. Vintzileos AM, Ananth CV, Smulian JC, Scorza WE, Knuppel RA. 2002. The impact of prenatal care in the United States on preterm births in the presence and absence of antenatal high-risk conditions. *Am. J. Obstet. Gynecol.* 187:1254–57
138. von Mutius E, Illi S, Hirsch T, Leupold W, Keil U, Weiland SK. 1999. Frequency of infections and risk of asthma, atopy and airway hyperresponsiveness in children. *Eur. Respir. J.* 14:4–11
139. von Mutius E, Martinez FD, Fritzsch C, Nicolai T, Roell G, Thiemann HH. 1994. Prevalence of asthma and atopy in two areas of West and East Germany. *Am. J. Respir. Crit. Care Med.* 149:358–64
140. Wagener D, Williams D, Wilson P. 1993. Equity and environmental health: data collection and interpretation issues. *Toxicol. Ind. Health* 9:775–95
141. Watson J, Cowen P, Lewis R. 1996. The relationship between asthma admission rates, routes of admission, and

socioeconomic deprivation. *Eur. Respir. J.* 9:2087–83

142. Weiss KB, Gergen PJ, Hodgson TA. 1992. An economic evaluation of asthma in the United States. *N. Engl. J. Med.* 326:862–66
143. Weiss KB, Gergen PJ, Wagener DK. 1993. Breathing better or wheezing worse? The changing epidemiology of asthma morbidity and mortality. *Annu. Rev. Public Health* 14:491–513
144. Weiss ST. 2002. Eat dirt—the hygiene hypothesis and allergic diseases. *N. Engl. J. Med.* 347:930–31
145. Weiss ST, Shore S. 2004. Obesity and Asthma: Directions for Research NHLBI Workshop, Bethesda, MD, July 15, 2002. *Am. J. Respir. Crit. Care Med.* 169:963–68
146. Weitzman M, Gortmaker S, Sobol A. 1990. Racial, social, and environmental risks for childhood asthma. *Am. J. Dis. Child.* 144:1189–94
147. Wilkinson R. 1996. *Unhealthy Societies. The Afflictions of Inequality.* London: Routledge
148. Wilson WJ. 1987. *The Truly Disadvantaged: The Inner-City, the Underclass, and Public Policy*. Chicago: Univ. Chicago Press
149. Wissow LS, Gittelsohn AM, Szklo M, Starfield B, Mussman M. 1988. Poverty, race, and hospitalization for childhood asthma. *Am. J. Public Health* 78:777–82
150. Woodcock A, Forster L, Matthews E, Martin J, Letley L, et al. 2003. Control of exposure to mite allergen and allergen-impermeable bed covers for adults with asthma. *N. Engl. J. Med.* 349:225–36
151. Wright AL, Sherrill D, Holberg CJ, Halonen M, Martinez FD. 1999. Breastfeeding, maternal IgE, and total serum IgE in childhood. *J. Allergy Clin. Immunol.* 104:589–94
152. Wright RJ, Cohen S, Carey V, Weiss ST, Gold DR. 2002. Parental stress as a predictor of wheezing in infancy: a prospective birth-cohort study. *Am. J. Respir. Crit. Care Med.* 165:358–65
153. Wright RJ, Fisher EB. 2003. Putting asthma into context: influences on risk, behavior, and intervention. In *Neighborhoods and Health*, ed. I Kawachi, LF Berkman, pp. 233–62. New York: Oxford Univ. Press
154. Wright RJ, Mitchell H, Visness CM, Cohen S, Stout J, et al. 2004. Community violence and asthma morbidity in the Inner-City Asthma Study. *Am. J. Public Health* 94:625–32
155. Wright RJ, Rodriguez M, Cohen S. 1998. Review of psychosocial stress and asthma: an integrated biopsychosocial approach. *Thorax* 53:1066–74
156. Wright RJ, Steinbach SF. 2001. Violence: an unrecognized environmental exposure that may contribute to greater asthma morbidity in high risk inner-city populations. *Environ. Health Perspect.* 109:1085–89

156a. Wright RJ, Wright RO, Finn P, Staudenmayer J, Contreras JP, et al. 2004. Chronic caregiver stress and IgE expression, allergen-induced proliferation, and cytokine profiles in a birth cohort predisposed to atopy. *J. Allergy Clin. Immunol.* 113:1051–57

157. Wuthrich B. 1989. Epidemiology of the allergic diseases: Are they really on the increase? *Int. Arch. Allergy Appl. Immunol.* 90(Suppl. 1):3–10
158. Yamada E, Vanna AT, Naspitz CK, Sole D. 2002. International Study of Asthma and Allergies in Childhood (ISAAC): validation of the written questionnaire (eczema component) and prevalence of atopic eczema among Brazilian children. *J. Investig. Allergol. Clin. Immunol.* 12: 34–41

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