

When home is where the stress is: expanding the dimensions of housing that influence asthma morbidity

M Sandel, R J Wright

Arch Dis Child 2006;**91**:942–948. doi: 10.1136/adc.2006.098376

The influence of physical housing quality on childhood asthma expression, especially the effect of exposure to moulds, allergens, and pollutants, is well documented. However, attempts to explain increasing rates and severity of childhood asthma solely through physical environmental factors have been unsuccessful, and additional exposures may be involved. Increasing evidence has linked psychological stress and negative affective states to asthma expression. At the same time, recent scholarship in the social sciences has focused on understanding how social environments, such as housing, “get under the skin” to influence health, and suggests that psychological factors play a key role. While there is relevant overlapping research in social science, psychology, economics, and health policy in this area, findings from these disciplines have not yet been conceptually integrated into ongoing asthma research. We propose to expand the dimensions of housing considered in future asthma research to include both physical and psychological aspects which may directly and indirectly influence onset and severity of disease expression. This synthesis of overlapping research from a number of disciplines argues for the systematic measure of psychological dimensions of housing and consideration of the interplay between housing stress and physical housing characteristics in relation to childhood asthma.

in poverty. However, variation in asthma morbidity across urban neighbourhoods cannot be explained by economic factors alone. All urban communities do not have elevated asthma morbidity despite the fact that they are comparably low on many economic indicators and have seemingly similar physical environmental exposures as identified high risk neighbourhoods. Among urban low socioeconomic status neighbourhoods, those with predominantly minority, segregated populations appear less burdened than more integrated neighbourhoods.

While traditional asthma epidemiological studies suggest the importance of physical characteristics of the inner-city environment on asthma morbidity (including greater outdoor air pollution (e.g. diesel buses); crowding, which may predispose to viral respiratory illness; poor housing stock of the inner-city, which may increase exposure to indoor allergens; and greater likelihood of tobacco smoke exposure), these factors do not completely explain the observed social disparities in asthma.³ Efforts are beginning to expand our thinking to consider explanations that link asthma morbidity to social and political forces that determine the distribution of physical characteristics of the urban inner-city environment.^{2–4} What remains largely overlooked is that deprivation and disadvantage related to the physical environment also exact an emotional toll on residents that may further impact health. In this light, it is useful to reconsider the role of housing in asthma research.

The link between housing and health has been described for over a century.⁵ Housing improvements, sanitation, and slum clearance in the 19th and 20th centuries played an important role in controlling tuberculosis, typhus, cholera, and other infectious diseases.⁶ Though in many parts of the developing world problems of sanitation and basic habitability persist, better housing has resulted in reduction of morbidity and mortality, improved life expectancy, and improved child health in developed nations.⁷ Even so, contemporary research shows persistent links between the home environment and common childhood diseases, in particular, asthma. Arguably, childhood asthma warrants specific attention in this regard given recently documented trends of increasing prevalence and morbidity.⁸ Since changes in genetic factors alone cannot explain this rise, greater emphasis has been placed on environmental factors to explain these trends. Yet while asthma expression has been associated with a variety of physical environmental exposures, including chronic dampness,⁹ vermin,¹⁰

“Experts agree: The blight of poverty housing reaches beyond rotting roofs and insufficient sanitation systems. It casts low-income families into an unforgiving cycle of physical and emotional duress, compromising their health, academic achievement and sense of security.” (*Habitat World*, June/July 2002)¹

A growing asthma epidemic has been documented worldwide over the past three decades. As the epidemic has grown, the burden of disease has also shifted based on demographic and socioeconomic indicators, where asthma outcomes are socially patterned and clustered by areas of residence.² In the USA, asthma disproportionately affects non-white children living in urban areas and children living

See end of article for authors' affiliations

Correspondence to:
Dr M Sandel, 91 E.
Concord St, Boston, MA
02118, USA; megan.
sandel@bmc.org

Accepted 12 June 2006

dust mites,¹¹ and cockroaches,¹² recent reviews in this area suggest that these known environmental exposures alone cannot explain the asthma trends or observed disparities in disease expression.^{3 13} This has led to the consideration of as yet unidentified factors that may be playing a role.²

At the same time, mechanisms linking psychological stress, negative affect, and emotion to atopic disorders including asthma are being increasingly elucidated.¹⁴ In overlapping research, housing dimensions that may influence health and wellbeing have been increasingly expanded to include the psychological effects of poor housing.^{15 16} Specifically, the proposition that the influence of housing conditions on health may be operating through psychological stress pathways has been explored in sociology, psychology, economics, health policy, stress, and social epidemiological research. To date, the knowledge gained from these disparate literatures has scarcely been considered in asthma research. As we continue to explore both physical and social factors that may contribute to asthma disparities,² it is timely to consider more fully all dimensions of housing risks in future asthma research.

The known links between housing and health,⁶ associations between indoor environmental exposures and asthma morbidity,¹³ and the gaps in our knowledge concerning asthma disparities have been previously reviewed^{2 3} and are not within the scope of the present discussion. The aim of this article is to synthesise the state of knowledge on the psychological dimensions of housing from these traditionally disparate areas of scholarship and then to frame their relevance in the context of future asthma research. We first review the evidence linking stress to asthma. We then review the conceptualisation of psychological housing stress related to a number of housing characteristics (e.g. lack of control over housing, residential instability, high cost of housing, presence of pests and dampness) that have been linked to health. We consider how synthesis of the housing literature may increase our understanding of asthma disparities. Finally, we outline a conceptual model to provide direction for future research considering the possible pathways linking housing stress to asthma.

EVIDENCE LINKING STRESS AND ASTHMA

Psychological stress may have both direct and indirect effects on asthma expression. Increasingly, asthma has been conceptualised as an epidemic of dysregulated immunity.¹⁴ Thus, psychological stress may directly influence asthma expression. Asthma is regulated through immune phenomena, in which many cells (i.e. mast cells, eosinophils, T lymphocytes), and associated cytokines, chemokines, and neuropeptides, play a role. Overlapping mechanisms of inflammation central to the pathophysiology of asthma involve a cascade of events, including the release of immunological mediators. Hormones and neuropeptides released into the circulation when individuals experience stress are thought to be involved in regulating both immune mediated and neurogenic inflammatory processes. Dysregulation of normal homeostatic neural, endocrine, and immunological mechanisms can occur in the face of chronic stress, leading to chronic hyper-arousal and/or hypo-responsiveness that may impact atopic disease expression.

Thus, psychological stress has been conceptualised as a social pollutant that when “breathed into the body” may disrupt these biological systems through inflammatory processes.¹⁴ An increasing number of studies have associated psychological stress with asthma expression, whether experienced directly or indirectly through parents and caretakers. Prospective studies link early life caretaker stress¹⁷ and parenting difficulties¹⁸ with early life wheeze and asthma onset. Stressful life events have recently been shown to have

association with increased asthma attacks in children, up to weeks after the event.¹⁹ Among inner-city children with asthma, parental psychosocial problems and distress are associated with increased asthma morbidity.²⁰ Other evidence has demonstrated the influence of psychological stress on the dysregulation of known underlying neuro-immunological factors related to asthma pathogenesis^{21–23} and response to known asthma triggers.²⁴

Moreover, stress may indirectly impact asthma morbidity by influencing how children and families perceive asthma and manage their disease. For families attending an asthma specialty clinic, higher levels of life stressors (including housing stressors) in caregivers was associated with higher asthma morbidity perhaps because caregivers could not focus adequately on asthma management because of these stressors.²⁵ In one study of an inner-city population of asthmatics, increased caregiver stress was associated with more frequent asthma symptoms in the children, an effect that was in part mediated through lower adherence to asthma medications.²⁶

Another approach to examining the long term implications of housing stress is to document links between housing and behaviours which may translate into later health effects. Behavioural changes occurring as adaptations or coping responses to stressors also influence asthma morbidity. That is, persons exposed to stressors or viewing themselves as under stress tend to engage in poor health practices (e.g. they may smoke, eat poorly, exercise less, sleep less, and be less compliant with prescribed medical treatments). In turn, smoking, lack of sleep, and poor adherence are established factors contributing to poorer asthma outcomes.

Lastly, psychological stress may have independent effects, but also may play a role through the enhancement of neuro-immune responses to other physical environmental factors operating through similar pathways.¹⁴ That is, the effects of environmental toxins (e.g. air pollution, tobacco smoke, allergens) on atopy and asthma may be mediated through common pathways (e.g. neuro-immune dysregulation or oxidative stress). An individual’s response to allergens and air pollutants may thus be potentiated by chronic psychological stressors.

LINKING HOUSING CHARACTERISTICS AND PSYCHOLOGICAL STRESS

Research to date has considered a number of housing characteristics that may cause psychological distress, including physical housing conditions that cause distress (e.g. crowding, presence of pests, dampness in the home or noise), financial strain, perceived housing dissatisfaction, lack of privacy, lack of control over housing conditions (e.g. inability to afford better housing, landlord unavailability), loss of social supports, and other housing hardships. Research linking housing characteristics to psychological stress and co-morbidities are summarised in table 1.

Substandard physical housing conditions have been linked to negative mental health among children and their adult caregivers.²⁷ A number of housing characteristics, including floor level, presence of pests, and dampness have been associated with psychological distress, poor mental health, and lower perceived health status.^{28–30} Noise exposure in and around housing has been associated with increased cortisol levels and higher perceived stress.³¹ McCarthy *et al* found that housing age, type (flats versus single family houses), floor level, and location affected both respiratory (i.e. cough, wheeze, and self-reported asthma) and mental health outcomes.^{27 32} Another study²⁹ linked home dampness and being unable to keep the house warm enough in the winter to increased asthma prevalence among adults. In this study,

Table 1 Housing stress factors, categories, and examples

Housing factors	Categories	Examples	Health outcome examined	References
Physical housing conditions (material)	Substandard conditions	Mould or dampness, infestations	Respiratory effects, mental health scores (GHQ30)	27, 28
		Exposed wiring, cracks floors	Children’s Behavior Inventory (CBI)	59
	Housing quality	Rooms per person	Demoralisation index (Psychiatric Epidemiology Research Institute)	30
		Noise	Perceived Stress Index, cortisol measures	31, 33
		No heat once in past 3 months	Poorer health and respiratory status (SF-36)	29
Housing hardships	Flat versus house	Poorer mental, respiratory health (GHQ30)	32	
Emotional housing conditions (meaningful)	Overcrowding	More child/parent conflicts	Poorer mental health scores	40
	Lack of control	Landlord unavailable	Poor health status (Rand MHI)	16
	Housing tenure	Rent or own	Poor self-rated health status	42
	Housing cost	Fear of eviction	Poor mental health scores, health status (Rand MHI)	16
	Residential instability	Homelessness	Higher distress symptoms	13

inability to keep the house warm was significantly associated with asthma, even after controlling for home dampness. Although these authors touch on the notion that worry about cold or damp housing may have contributed to the observed effects, they were unable to test this directly. In another study, Evans and colleagues³⁰ conducted a prospective longitudinal study linking physical housing quality to mental health. Indeed, although housing characteristics have been linked to mental health outcomes in numerous studies to date, very few studies have systematically explored the underlying mechanism or the mediators of these effects. Of note, the demonstration of increased psychological distress from substandard housing conditions is not unique to the urban environment. For example, Evans and colleagues³³ have described similar findings in poor rural white children.

Environmental psychologists and social scientists, among others, suggest that housing also has a significant subjective emotional dimension.¹⁶ While the subjective or emotional response to one’s housing can be positive, serving as a reflection of positive personal identity, a site for the exercise of control, and a source of social status,³⁴ it may also be associated with psychological distress.¹⁶ A number of subjective housing characteristics have been linked to adverse psychological outcomes.

Cost of housing

Housing cost has been linked to housing stress in many parts of the world. Financial housing stress has been defined as spending more than 30% of disposable income on housing costs. In Australia, an estimated 1.7 million people have financial housing stress.³⁵ Latest available evidence from the European Union documents that most countries have been able to keep average housing expenditures below 30% of available income housing, though the distribution is wide, with Ireland averaging 12% of available income whereas Denmark averages close to 28% of available income.³⁶ In contrast, in the United States, 3 in 10 families spend more than 30% of their income on housing.³⁷

Overcrowding

High density living or overcrowding has been associated with increased rates of infections³⁸ as well as psychological distress.⁶ Although it has been postulated that the tolerance of crowding is different across cultural groups, high density living conditions have been linked to psychological distress among Asian, Indian, Latino, Anglo-American, and African American cultures, even after controlling for income.^{39 40} Crowding may result in a perceived lack of privacy, which may have a greater impact on physical wellbeing than housing quality itself.⁴¹

Residential satisfaction

Other research argues that the subjective environment, assessed through perceived residential satisfaction, has greater influences on psychological wellbeing than the objective environment. Residential satisfaction taps into an individual’s appraisal of the conditions of their residential environment, in relation to their needs and expectations.⁴² A recent study found that perceived residential satisfaction mediated the effects of objective housing conditions on psychological status among older adults living in Hong Kong.¹⁵

Residential instability

Residential instability can be defined as a lack of stable housing, whether through frequent moving, living “doubled up” with many families sharing one housing space, or homelessness in shelter situations. Having a stable home has been associated with better health ratings and lower psychological distress. Research has consistently shown home ownership to be associated with higher health ratings.⁴² Wong *et al* showed that perceived psychological distress improved after homeless adults were placed in permanent housing.⁴³ The influence of moving on health may in part be mediated through an individual’s perception of the change in their environment. One recent study found that subjects who perceived improvement in environmental quality of housing after moving reported improved self-health ratings.⁴⁴ Social relationships, social supports, and social networks may function as a buffering system which can counteract the negative effects of environmental stressors.⁴⁵ Housing instability and homelessness disrupt social networks, which may have a negative impact on mental health.⁴⁶ However, increased social support alone may not be adequate to buffer the deterioration in mental health caused by high levels of housing stressors.³⁴

Lack of control over housing

When the environment is perceived to be threatening, and individuals lose the ability to cope or take control over life events or their environment, they experience stress.⁴⁷ Therefore, the connection between housing and psychological distress may be mediated through the perceived lack of control over one’s life or circumstances, especially housing.^{48 49} Many families have become aware through asthma education programmes and communication with their healthcare providers that exposure to cockroaches and rodents in the home may adversely impact their own or their child’s asthma. However, many lack the means to move, or to remediate these potentially hazardous exposures.

The potential health effects of these circumstances are not unlike those seen among individuals living near toxic waste sites. Symptoms associated with living proximal to a toxic

waste site include depression, lack of control of the environment, increased family quarrels, increased health worries, and increased intrusive and avoidant thoughts.⁵⁰⁻⁵⁴ Long term stress effects operating through lasting psychological, behavioural, and physiological responses are thought to be maintained through recurrent unwanted or “intrusive” thoughts about past events or circumstances.⁵⁵ Children express increased stress which correlates with parental reports of chronic distress from the uncertainty of toxic exposure.⁵¹

Housing stress can be further mediated through perception of control over housing conditions. Poor psychological health status was found in Japanese women when they perceived that housing was unhealthy for their children.⁵⁶ In another study, control factors, like the presence of a tenants’ self-management structure, was significantly associated with improved mental health, self-rated health status, and satisfaction with health.¹⁶ Such partnerships may promote new social support networks. Neighbours experiencing similar stress can become effective sources of social support for each other.^{51 52} Rich *et al*⁵⁷ recommended a partnership approach to community decision making to minimise the disempowering impact of environmental threats. Community groups can provide information and emotional support, and engender a sense of empowerment.⁵⁸

CONSIDERING PHYSICAL AND EMOTIONAL HOUSING DOMAINS

Findings that suggest independent health effects from both the physical and emotional conditions of housing underscore the need to consider both dimensions in future research on housing and health. In a cross-sectional study of 12 neighbourhoods in Vancouver, Dunn *et al* showed an independent association between poorer perceived health ratings and poorer mental health from both physical (material) and emotional (meaningful) aspects of housing.¹⁶ In another Canadian study, housing quality, including physical problems such as heating problems and cracks in floors, and emotional stressors, such as crowding and fear and insecurity related to housing, were significantly related to parental ratings of children’s socioemotional health, independent of other risk factors such as income and education levels.⁵⁹

INFORMING SOCIAL DISPARITIES IN ASTHMA

Research linking housing characteristics to psychological stress and asthma morbidities is summarised in table 2. Both housing quality and life stressors, including psychological distress related to housing characteristics, are not uniformly distributed in the population. The negative effects of unequal distribution of housing, overcrowding, and abandoned housing on community health are well known.⁶⁰ Socioeconomic deprivation results in higher percentages of income devoted to rent and more substandard conditions,³⁷ potentially modifying the relationship between housing stress and health. Persons of lower socioeconomic status experience negative life events more frequently, including housing hardship.⁶¹ While most contemporary life event measures do not include items related to housing stress or

hardship,⁶² there are some notable exceptions.^{63 64} The social, political, and economic forces that result in marginalisation of certain populations in disadvantaged neighbourhoods and communities also influence housing quality in these areas.² The legacy of racism, discrimination, and segregation underlies many families’ selection of where to live, both historically and currently.⁶⁵⁻⁶⁷ Families that are residentially unstable have higher levels of cockroach allergen, even after controlling for income and ethnicity.¹² Some investigators concluded from the available information that frequency of moving may be a risk factor in developing asthma,⁶⁸ while others thought moving was a marker for other factors, such as chronic dampness in homes.⁹ Future research should more systematically explore these associations.

Though a thorough discussion of disparities in housing distribution is beyond the scope of this overview, it is clear that housing dimensions cannot be fully separated from the physical and social dimensions of the neighbourhoods and communities in which housing is nested. Community level variables are receiving increased attention for their critical role in determining health inequalities between racial/ethnic and socioeconomic groups, conceivably because they mediate the effects of living in low socioeconomic status neighbourhoods. One potential mediating feature of community life that has attracted considerable attention is the notion of social capital and social cohesion, defined as those features of social organisation (e.g. the extent of interpersonal trust between citizens, norm of reciprocity, and the vibrancy of civic associations) that facilitate cooperation for mutual benefit.^{69 70} Social capital can influence opinions and investment in housing, and plays a large role in how communities deal with issues of crime, poverty, and inadequate housing.⁷¹ Other housing policies, such as ones that promote residential stability, have the potential to influence social organisation and diminish crime.⁷² While it may be challenging to disentangle the effects of housing and neighbourhood, there are studies that suggest independent housing effects. Fullilove *et al* found that housing quality and overall health could be improved if families moved to better, recently renovated housing, even when neighbourhood conditions remained poor.⁷³

Housing quality and health disparities

Housing may also exert effects independent of socioeconomic factors. Housing tenure is related to overall health despite controlling for income and self-esteem.⁷⁴ In comparing low and middle income white children, Evans *et al* found home environmental risk scores correlated with changes in norepinephrine, epinephrine, and cortisol levels in the low income group, even after controlling for income, maternal education, family structure, age, and gender.³³ Race, income, and housing may also be linked, since studies of the possible role of discrimination in racial differences in hypertension found chronic strains, such as housing discrimination, as potentially important.⁷⁵ Relative deprivation of specific factors, including housing, may be important in mediating effects of low income on poor health.⁷⁶

Table 2 Housing stress factors, categories, and examples in asthma

Housing factors	Categories	Examples	References
Physical housing conditions	Substandard conditions	Pest infestation (mice, roaches)	10
Emotional housing conditions	Overcrowding	Lack of privacy	38
	Lack of control	Caretaker stress	20
	Residential instability	Moving	68

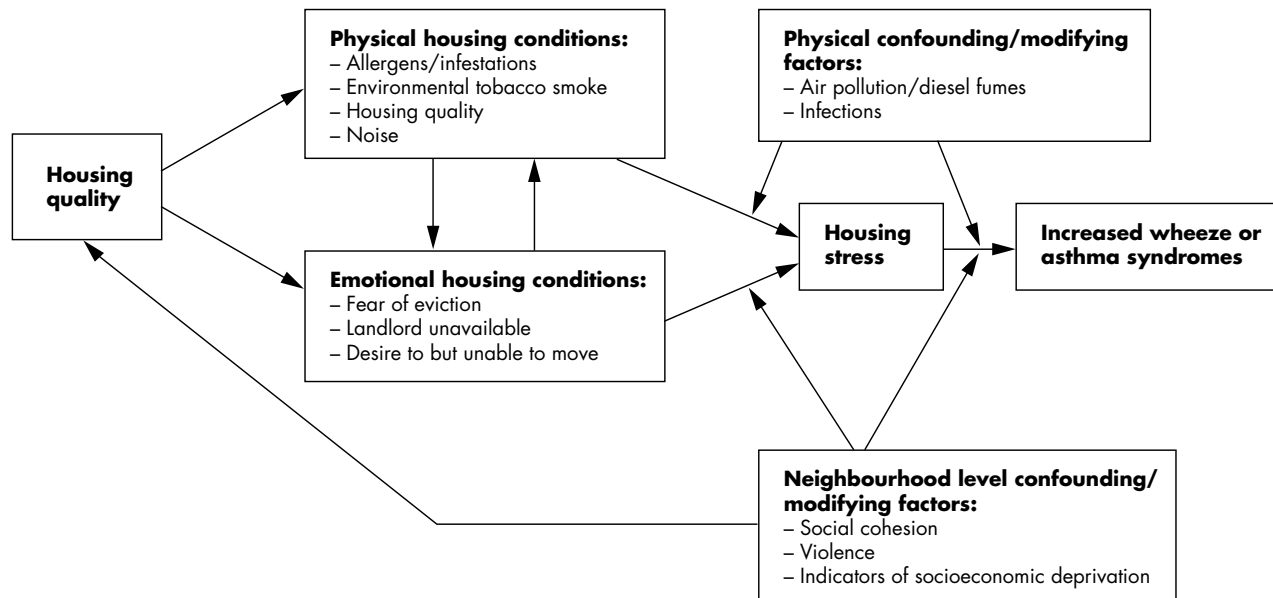


Figure 1 Theoretical model for housing quality, housing stress, and asthma risk.

CONCEPTUALISATION OF HOUSING STRESS IN FUTURE ASTHMA RESEARCH

Figure 1 demonstrates a conceptual model depicting pathways linking housing stress to asthma expression. Here, the emotional conditions of housing are considered equally with the physical conditions of housing, which have been more extensively recognised and studied. The emotional and physical housing conditions may interact, with physical conditions such as dampness causing emotional distress and emotional conditions, such as lack of control of housing causing families to be less vigilant about housekeeping and have more pest problems as a result. These pathways, through physical and emotional housing conditions, will lead to housing stress. Housing stress may also be conceptualised as a social pollutant that when “breathed” into the body may interact with other physical factors within housing (e.g. allergens, environmental tobacco smoke) and surrounding housing (e.g. air pollution, diesel fumes) to disrupt similar biological pathways to influence asthma expression.¹⁴ Furthermore, neighbourhood level factors may be related to housing quality but also interact with the effects of housing stress as discussed above. For example, housing instability, or frequent moving, may be influenced by housing quality, but also may be related to other factors, such as neighbourhood violence, which has been linked with higher rates of asthma morbidity.²⁶

MOVING TO ACTION

Physical housing issues are universal, whether from Eastern European block housing,⁷⁷ dilapidated public housing in the United States,⁷⁸ or council housing in the UK.⁷⁹ Changing someone’s housing situation has been shown to help mental health after moving from substandard housing stock.⁸⁰ Other relocation studies have shown mental health can be improved by moving from a high poverty to a low poverty neighbourhood, suggesting that neighbourhood factors, in addition to housing, may also play a role.⁸¹ Rental support through the use of housing vouchers has enough evidence to support wider use,⁸² though programmes aimed to promote mixed income or less racial segregation have less evidence to support them.⁸³ To date, housing interventions may not have

adequately accounted for social capital in determining health benefits. Often, they focus only on brief time spans, and single housing units, instead of viewing housing on a broad social and ecological scale.⁸⁴

Though the relationships proposed in this paper are still at the theoretical level, pilot interventions should be designed to improve both physical and emotional aspects of housing.⁸⁴ Future housing studies should measure the impact on quality of life with changes in the physical environment.⁸⁵ Though large housing interventions have been few in number⁸⁶ and therefore the full health impact of housing interventions is difficult to assess,⁸⁷ mental health should be considered among the potential benefits of housing policies and thus examined in future work. It would be important to design future studies, for example, to examine potential independent effects of psychological distress related to residential instability or other housing conditions, controlling for physical factors like cockroach exposure. Such findings would inform an intervention quite different from the mere elimination of cockroach allergen in these homes, and thus may prove more effective in finding potential health benefits.⁸⁸

Disentangling the effects of socioeconomic status, education, and race on housing and health will always be difficult. Through more focus on housing stress, large cohort studies can further illuminate relationships between social deprivation and housing conditions and their potential role in the development and severity of asthma.⁸⁹ This research can inform future intervention points in housing that may reap both physical and psychological benefits. Housing goes beyond shelter and community.⁹⁰ The creation of a home, free from housing stress, may be the best prescription for the physical and mental health of all children, and particularly those with asthma.

Authors’ affiliations

M Sandel, Boston University School of Medicine, Boston MA, Center for Healthy Homes and Neighborhoods, Boston University School of Public Health and Boston Medical Center, Boston, MA, USA

R J Wright, Channing Laboratory, Brigham and Women’s Hospital, Harvard Medical School, and Department of Society, Human Development, and Health, Harvard School of Public Health, Boston, MA, USA

Funding: Dr Sandel is supported by a grant from the Medicine as Profession Open Society Institute, Soros Foundation, and the National Institutes of Health, 1K23 ES013173-02. During preparation of this manuscript Dr Wright was supported by the National Heart, Lung, and Blood Institute, U01 HL072494, and the National Institutes of Environmental Health Sciences, R01 ES10932.

Competing interests: None.

REFERENCES

- World H. The cost of living in...poverty: 5 urgent issues. *Habitat World* June/July 2002. <http://www.habitat.org/hw/june-july02/feature6.html> (accessed 9 August 2006).
- Wright RJ, Fischer EB. Putting asthma into context: community influences on risk, behavior and interventions. In: Kawachi I, Berkman L, eds. *Neighborhoods and health*. New York: Oxford University Press, 2003:222-62.
- Gold DR, Wright R. Population disparities in asthma. *Annu Rev Public Health* 2005;**26**:89-113.
- O'Neill MS JM, Kawachi I, Levy JJ, et al. Health, wealth, and air pollution: advancing theory and methods. *Environ Health Perspect* 2003;**111**:1861-70.
- Takaro TK, Krieger JW, Song L. Effect of environmental interventions to reduce exposure to asthma triggers in homes of low-income children in Seattle. *J Expo Anal Environ Epidemiol* 2004;**14**(suppl 1):S133-43.
- Burridge R, Ormandy D, eds. *Unhealthy housing: research, remedies and reforms*. London: E&FN Spon, 1993.
- Wolff CG, Schroeder DG, Young MW. Effect of improved housing on illness in children under 5 years old in northern Malawi: cross sectional study. *BMJ* 2001;**322**:1209-12.
- Beasley R, Crane J, Lai CK, et al. Prevalence and etiology of asthma. *J Allergy Clin Immunol* 2000;**105**(2 pt 2):S466-72.
- Strachan DP, Sanders CH. Damp housing and childhood asthma; respiratory effects of indoor air temperature and relative humidity. *J Epidemiol Community Health* 1989;**43**:7-14.
- Stevenson LA, Gergen PJ, Hoover DR, et al. Sociodemographic correlates of indoor allergen sensitivity among United States children. *J Allergy Clin Immunol* 2001;**108**:747-52.
- Platts-Mills TA, Carter MC. Asthma and indoor exposure to allergens. *N Engl J Med* 1997;**336**:1382-4.
- Rauh VA, Chew GR, Garfinkel RS. Deteriorated housing contributes to high cockroach allergen levels in inner-city households. *Environ Health Perspect* 2002;**110**(suppl 2):323-7.
- Institute of Medicine. *Clearing the air: asthma and indoor air exposures*. Washington, DC: National Academy Press, 2000.
- Wright RJ, Cohen RT, Cohen S. The impact of stress on the development and expression of atopy. *Curr Opin Allergy Clin Immunol* 2005;**5**:23-9.
- Phillips DR, Siu OL, Yeh AG, et al. The impacts of dwelling conditions on older persons' psychological well-being in Hong Kong: the mediating role of residential satisfaction. *Soc Sci Med* 2005;**60**:2785-97.
- Dunn JR, Hayes MV. Identifying social pathways for health inequalities. The role of housing. *Ann N Y Acad Sci* 1999;**896**:399-402.
- Wright RJ, Cohen S, Carey V, et al. Parental stress as a predictor of wheezing in infancy: a prospective birth-cohort study. *Am J Respir Crit Care Med* 2002;**165**:358-65.
- Klennert MD, Nelson HS, Price MR, et al. Onset and persistence of childhood asthma: predictors from infancy. *Pediatrics* 2001;**108**:e69.
- Sandberg S, Jarvenpaa S, Penttinen A, et al. Asthma exacerbations in children immediately following stressful life events: a Cox's hierarchical regression. *Thorax* 2004;**59**:1046-51.
- Weil CM, Wade SL, Bauman LJ, et al. The relationship between psychosocial factors and asthma morbidity in inner-city children with asthma. *Pediatrics* 1999;**104**:1274-80.
- Chen E, Fisher EB, Bacharier LB, et al. Socioeconomic status, stress, and immune markers in adolescents with asthma. *Psychosom Med* 2003;**65**:984-92.
- Wright RJ, Finn P, Contreras JP, et al. Chronic caregiver stress and IgE expression, allergen-induced proliferation, and cytokine profiles in a birth cohort predisposed to atopy. *J Allergy Clin Immunol* 2004;**113**:1051-7.
- Kang B, Jones J, Johnson J, et al. Analysis of indoor environment and atopic allergy in urban populations with bronchial asthma. *Ann Allergy* 1989;**62**:30-4.
- Rosenkranz MA, Busse WW, Johnstone T, et al. Neural circuitry underlying the interaction between emotion and asthma symptom exacerbation. *Proc Natl Acad Sci U S A* 2005;**102**:13319-24.
- Shalowitz MU, Berry CA, Quinn KA, et al. The relationship of life stressors and maternal depression to pediatric asthma morbidity in a subspecialty practice. *Ambul Pediatr* 2001;**1**:185-93.
- Wright RJ, Mitchell H, Visness CM, et al. Community violence and asthma morbidity: the Inner-City Asthma Study. *Am J Public Health* 2004;**94**:625-32.
- Evans DT, Fullilove MT, Green L, et al. Awareness of environmental risks and protective actions among minority women in Northern Manhattan. *Environ Health Perspect* 2002;**110**(suppl 2):271-5.
- Hopton JL, Hunt SM. Housing conditions and mental health in a disadvantaged area in Scotland. *J Epidemiol Community Health* 1996;**50**:56-61.
- Evans JHS, Stewart-Brown S, Smith D, et al. An epidemiological study of the relative importance of damp housing in relation to adult health. *J Epidemiol Community Health* 2000;**54**:677-86.
- Evans GW, Wells NM, Chan HY, et al. Housing quality and mental health. *J Consult Clin Psychol* 2000;**68**:526-30.
- Evans GW, Lercher P, Meis M, et al. Community noise exposure and stress in children. *J Acoust Soc Am* 2001;**109**:1023-7.
- McCarthy P, Byrne D, Harrison S, et al. Respiratory conditions: effect of housing and other factors. *J Epidemiol Community Health* 1985;**39**:15-19.
- Evans GW, Marcynyszyn LA. Environmental justice, cumulative environmental risk, and health among low- and middle-income children in upstate New York. *Am J Public Health* 2004;**94**:1942-4.
- Smith CA, Smith CJ, Kearns RA, et al. Housing stressors, social support and psychological distress. *Soc Sci Med* 1993;**37**:603-12.
- Gordon J. *Generation facing housing stress*, The Age. 2004. <http://www.theage.com.au/articles/2004/06/28/1088392600115.html?from=storylhs>.
- Nielsen L. *Housing statistics for European Union*. 2003. http://www.ebstat.dk/file/2256/housing_statistics_2003.pdf.
- Joint Center for Housing Studies. *The state of the nation's housing*. Cambridge, MA: Harvard University, 2003.
- Emond AM, Howat P, Evans JA, et al. The effects of housing on the health of preterm infants. *Paediatr Perinat Epidemiol* 1997;**11**:228-39.
- Evans GW, Lepore SJ, Allen KM. Cross-cultural differences in tolerance for crowding: fact or fiction? *J Pers Soc Psychol* 2000;**79**:204-10.
- Evans GW, Lepore SJ, Shejwal BR, et al. Chronic residential crowding and children's well-being: an ecological perspective. *Child Dev* 1998;**69**:1514-23.
- Fuller TD, Edwards JN, Sermisri S, et al. Housing, stress, and physical well-being: evidence from Thailand. *Soc Sci Med* 1993;**36**:1417-28.
- Pollack CE, von dem Knesebeck O, Siegrist J. Housing and health in Germany. *J Epidemiol Community Health* 2004;**58**:216-22.
- Wong YL, Piliavin I. Stressors, resources, and distress among homeless persons: a longitudinal analysis. *Soc Sci Med* 2001;**52**:1029-42.
- Kahlmeier S, Schindler C, Grize L, et al. Perceived environmental housing quality and wellbeing of movers. *J Epidemiol Community Health* 2001;**55**:708-15.
- Cohen S. Social relationships and health. *Am Psychol* 2004;**59**:676-84.
- Meadows-Oliver M. Social support among homeless and housed mothers: an integrative review. *J Psychosoc Nurs Ment Health Serv* 2005;**43**:40-7.
- Cohen S, Williamson GM. Stress and infectious disease in humans. *Psychol Bull* 1991;**109**:5-24.
- Cohen SKG, Salonen JG. The role of psychological characteristics in the relation of socioeconomic status and perceived health. *Journal of Applied Social Psychology* 1999;**29**:445-68.
- Williams D. Socioeconomic differentials in health: a review and redirection. *Cos Psychol Q* 1990;**53**:81-99.
- Davidson LM, Baum A. Chronic stress and posttraumatic stress disorders. *J Consult Clin Psychol* 1986;**54**:303-8.
- Edelstein M. *Contaminated communities: the social and psychological impact of residential toxic exposure*. Boulder, CO: Westview Press, 1988.
- Stone RA, Levine AG. Reactions to collective stress correlates of active citizen participation at Love Canal, New York USA. *Prev Hum Serv* 1985;**4**:153-78.
- Levine AG, Stone RA. Threats to people and what they value: residents' perceptions of the hazards of Love Canal. *Advances in Environmental Psychology* 1986;**6**(109):52-3.
- Horowitz J, Stefanko M. Toxic waste: behavioral effects of an environmental stressor. *Behav Med* 1989;**15**:23-8.
- Baum A. Stress, intrusive imagery, and chronic distress. *Health Psychol* 1990;**9**:653-75.
- Saito K, Iwata N, Hosokawa T, et al. Housing factors and perceived health status among Japanese women living in aggregated dwelling units. *Int J Health Serv* 1993;**23**:541-54.
- Rich RC, Edelstein M, Hallman WK, et al. Citizen participation and empowerment: the case of local environmental hazards. *Am J Community Psychol* 1995;**23**:657-76.
- Edelstein MR, Wandersman A. Community dynamics in coping with toxic contaminants. In: Altman I, Wandersman A, eds. *Neighborhood and community environment*. New York: Plenum, 1987:69-110.
- Gifford R. *Housing quality and children's socioemotional health*. Quebec: Canada Mortgage and Housing Corporation, 2003.
- Leavitt J, Saegert S. *From abandonment to hope: community-households in Harlem*. New York: Columbia University Press, 1990:x,323.
- Cohen CI, Teresi J, Holmes D. Social networks, stress, adaptation, and health. A longitudinal study of an inner-city elderly population. *Res Aging* 1985;**7**:409-31.
- Cohen S, Gottlieb BH, Underwood LG. Social relationships and health: challenges for measurement and intervention. *Adv Mind Body Med* 2001;**17**:129-41.
- Shalowitz MU, Berry CA, Rasinski KA, et al. A new measure of contemporary life stress: development, validation, and reliability of the CRISYS. *Health Serv Res* 1998;**33**(5 pt 1):1381-402.
- Berry C, Shalowitz M, Quinn K, et al. Validation of the Crisis in Family Systems-Revised, a contemporary measure of life stressors. *Psychol Rep* 2001;**88**(3 pt 1):713-24.
- Acevedo-Garcia D, Lochner KA, Osypuk TL, et al. Future directions in residential segregation and health research: a multilevel approach. *Am J Public Health* 2003;**93**:215-21.
- Gold DR, Acevedo-Garcia D. Immigration to the United States and acculturation as risk factors for asthma and allergy. *J Allergy Clin Immunol* 2005;**116**:38-41.
- Subramanian SV, Acevedo-Garcia D, Osypuk TL. Racial residential segregation and geographic heterogeneity in black/white disparity in poor

- self-rated health in the US: a multilevel statistical analysis. *Soc Sci Med* 2005;**60**:1667–79.
- 68 **Hughes CH**, Baumer JH. Moving house: a risk factor for the development of childhood asthma? *BMJ* 1995;**311**:1069–70.
- 69 **Field J**. *Social capital. Key ideas*. London, New York: Routledge, 2003:vi, 165.
- 70 **Kawachi I**, Kennedy BP. Health and social cohesion: why care about income inequality? *BMJ* 1997;**314**:1037–40.
- 71 **Saegert S**, Thompson JP, Warren MR. *Social capital and poor communities. Ford Foundation series on asset building*. New York: Russell Sage Foundation, 2001:xviii, 333.
- 72 **Sampson RJ**, Raudenbush SW, Earls F. Neighborhoods and violent crime: a multilevel study of collective efficacy. *Science* 1997;**277**:918–24.
- 73 **Fullilove MT**, Green L, Fullilove RE 3rd. Uplifting momentum: an ethnographic study of inner-city redevelopment. *Am J Public Health* 1999;**89**:840–4.
- 74 **Macintyre S**, Ellaway A, Der G, et al. Do housing tenure and car access predict health because they are simply markers of income or self esteem? A Scottish study. *J Epidemiol Community Health* 1998;**52**:657–64.
- 75 **Rooks R**, Williams D. #81 Unfair treatment and hypertension prevalence in the Ypsilanti Everyday Stress (Yes) Health study. *Ann Epidemiol* 2002;**12**:519.
- 76 **Sironks K**, van de Mheen HD, Mackenbach JP. A higher prevalence of health problems in low income groups: does it reflect relative deprivation? *J Epidemiol Community Health* 1998;**52**:548–57.
- 77 **Macarthur I**. Ensuring shelter in Eastern Europe. *J Epidemiol Community Health* 2001;**55**:2–3.
- 78 **Hynes HP**, Brugge D, Osgood ND, et al. "Where does the damp come from?". Investigations into the indoor environment and respiratory health in Boston public housing. *J Public Health Policy* 2003;**24**:401–26.
- 79 **Blackman T**, Evason E, Melaugh M, et al. Housing and health: a case study of two areas in West Belfast. *J Soc Policy* 1989;**18**:1–26.
- 80 **Blackman T**, Anderson J, Pye P. Change in adult health following medical priority rehousing: a longitudinal study. *J Public Health Med* 2003;**25**:22–8.
- 81 **Leventhal T**, Brooks-Gunn J. Moving to opportunity: an experimental study of neighborhood effects on mental health. *Am J Public Health* 2003;**93**:1576–82.
- 82 **Anderson LM**, Shinn C, St CJ, et al. Community interventions to promote healthy social environments: early childhood development and family housing. A report on recommendations of the Task Force on Community Preventive Services. *MMWR Recomm Rep* 2002;**51**(RR-1):1–8.
- 83 **Anderson LM**, Charles JS, Fullilove MT, et al. Providing affordable family housing and reducing residential segregation by income. A systematic review. *Am J Prev Med* 2003;**24**(3 suppl):47–67.
- 84 **Saegert SC**, Klitzman S, Freudenberg N, et al. Healthy housing: a structured review of published evaluations of US interventions to improve health by modifying housing in the United States, 1990–2001. *Am J Public Health* 2003;**93**:1471–7.
- 85 **Levy JI**, Welker-Hood LK, Clougherty JE, et al. Lung function, asthma symptoms, and quality of life for children in public housing in Boston: a case-series analysis. *Environ Health* 2004;**3**:13.
- 86 **Thomson H**, Petticrew M, Morrison D. Health effects of housing improvement: systematic review of intervention studies. *BMJ* 2001;**323**:187–90.
- 87 **Thomson H**, Petticrew M, Douglas M. Health impact assessment of housing improvements: incorporating research evidence. *J Epidemiol Community Health* 2003;**57**:11–16.
- 88 **Sandel M**, Phelan K, Wright RJ, et al. The effects of housing interventions on child health. *Pediatr Ann* 2004;**33**:474–81.
- 89 **Dedman DJ**, Gunnell D, Davey Smith G, et al. Childhood housing conditions and later mortality in the Boyd Orr cohort. *J Epidemiol Community Health* 2001;**55**:10–15.
- 90 **Fullilove MT**, Fullilove RE 3rd. What's housing got to do with it? *Am J Public Health* 2000;**90**:183–4.

ARCHIVIST

Non-invasive testing for severe fetal anaemia

The fetus with severe rhesus haemolytic disease may be at risk of dying from severe anaemia and in need of intrauterine blood transfusion. Standard testing includes repeated amniocentesis with spectrophotometric measurement of amniotic fluid bilirubin levels using change in optical density at wavelength 450 nm (ΔOD_{450}). The risks of repeated amniocentesis make non-invasive monitoring attractive, and many centres have turned to measurement of blood flow in the middle cerebral artery using Doppler ultrasound (high flow indicating severe anaemia). Now, researchers in North America and Europe (D Oepkes and colleagues, *N Engl J Med* 2006;**355**:156–64; also see Editorial, *ibid*: 192–4) have compared the two methods. The study included 164 women with rhesus alloimmunisation and an indirect Coombs' test titre of at least 1/64. Of the 165 fetuses (one pair of twins), 74 had severe anaemia on intrauterine or postnatal testing of umbilical cord blood. Doppler ultrasound assessment of the middle cerebral artery blood flow was carried out before the first amniocentesis using ΔOD_{450} . The sensitivities, specificities and accuracies for the detection of severe fetal anaemia were 88%, 82% and 85% (Doppler ultrasound) and 76%, 77% and 76% (amniocentesis), respectively. The non-invasive method was considerably more sensitive and accurate than the invasive method.

Women with severe rhesus alloimmunisation should be cared for in specialised centres where expertise is available in the management of this condition and the use of Doppler ultrasound. Non-invasive detection of fetal anaemia may replace amniocentesis and measurement of ΔOD_{450} .