ORIGINAL RESEARCH

A community-based participatory survey of public housing conditions and associations between renovations and possible building-related health symptoms

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Abstract: This paper reports on analyses of survey data from two public housing developments in Boston, Massachusetts (USA) that house low-income inner-city residents. The two developments differ in that one has had substantial renovations to walls, roofs, piping, heating and water systems while the other has not. In 2002, we collected 238 surveys from the two developments combined, using a questionnaire that recorded self-reports of housing conditions (pest infestation, water leaks, etc), chronic health conditions and symptoms in the preceding month. Because heating and domestic water system replacement at the renovated development occurred between the 2002 survey and a pilot survey we conducted in 1998, we were also able to assess changes in the responses over time. Crude and adjusted odds ratios (ORs) showed that residents reported worse environmental conditions at the unrenovated development. Only the crude OR for skin rashes was statistically significant and only the adjusted ORs for ear infection, skin rashes and sneezing exceeded 2.0. The longitudinal component of the study also showed changes in environmental factors after renovation, but the evidence was more mixed with both negative and positive trends. Only the crude OR for sneezing was statistically significant and only the adjusted ORs for nosebleeds, sneezing and burning/itching eyes exceeded 2.0. In conclusion, our analysis supports the contention that renovations improve housing conditions and that this may be associated with health improvements, but further research is needed to firmly document any health benefits.

Keywords: housing, environment, health, asthma, renovations, survey

Introduction

Without question, housing conditions have significantly improved since The Council of Hygiene and Public Health of the Citizens' Association of New York reported in 1865 in colourful and now antiquated terminology 'that cholera infantum, convulsions, scrofula and marasmus hover with ghoul-like fiendishness about the dismal and crowded tenant-houses of the great mass of infantile lives in the city' (The Council of Hygiene and Public Health of the Citizens' Association of New York 1973, p 572). Hugely successful sanitation campaigns of the late 19th and early 20th century virtually freed American cities of a myriad of infectious diseases ranging from typhus to tuberculosis.

However, a new landscape of chronic illnesses and health risks has emerged from within current housing conditions. Firstly, asthma morbidity and other chronic respiratory symptoms are well correlated with in-home risk factors such as pest infestation, dampness and mould growth, dust mites, improper heating, inadequate ventilation, environmental tobacco smoke, nitrogen dioxide and volatile organic compounds (Chilmonczyk 1993; Rosenstreich et al 1997; Institute of Medicine 2000; Bornehag et al 2001). Non-respiratory symptoms such as frequent headaches, lumbar backache, tiredness, vomiting and nausea have also been associated with dampness and mould, although the evidence is weaker in comparison with that for respiratory symptoms (Institute of Medicine 2000; Bornehag et al 2001). Lead exposure, and the impaired neurodevelopment with which

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it is linked, is a well established danger (Lanphear 2000; Hynes et al 2001). Finally, substandard housing design and inadequate upkeep increase the risk of both burns and falls (Tinetti et al 1988; Ranson 1991; Anonymous 1996; American Academy of Pediatrics 2001).

As described, somewhat moralistically, in the Wagner-Steagall Act of 1937, public housing was originally intended to 'remedy the unsafe and unsanitary housing conditions and the acute shortage of decent, safe and sanitary dwellings for families of low income, in rural or urban communities, that are injurious to the health, safety and morals of the citizens of the Nation' (Wagner-Steagall Act 1937). In fact, early health intervention studies of poor families relocated from deteriorating private housing units to newly constructed public housing units noted improvements in health outcomes (Wilner et al 1958; Wambem and Piland 1973; Carp 1977). However, in numerous cases, due to poor physical conditions and deferred maintenance over the years, public housing today may have become a contributor to the poor health of its occupants rather than a solution.

Many inner-city neighbourhoods have experienced an escalation of asthma rates in the last twenty years (Kattan et al 1997). Previous community-based survey research in the West Broadway and Franklin Hill public housing developments of the South Boston and Dorchester neighbourhoods of Boston, Massachusetts, USA, respectively, found high prevalence rates of asthma and chronic respiratory symptoms. Poor building conditions were widely present, including pest infestation, moisture damage and mould, inadequate ventilation and lack of temperature control resulting in overheating and underheating, variation of temperature from room to room and use of gas ovens for warmth (Hynes et al 2000; Brugge et al 2001, 2003). Significant correlations between symptoms and exposure were found (Hynes et al 2000; Brugge et al 2001). Identification of associations, however, is only the first step. It is important to follow up data collection with environmental intervention studies to provide clear guidance for public housing building management and policy stakeholders.

The majority of environmental interventions to date have revolved around individual apartment pest control and dust management techniques, including the use of physical and chemical methods for dust mite reduction, high-efficiency particulate air filter vacuum cleaners, allergen-impermeable pillow and mattress covers, and pest extermination (Evans et al 1999; McDonald et al 2002; Francis et al 2003; Gotzsche et al 2003). These short-term interventions have produced mixed results. For instance, the use of air filters, industrial cleaning and mattress covers in individual apartments of the Franklin Hill development led to only short-lived reductions in mouse and cockroach antigen levels (Brugge et al 2003). Given that environmental risk factors are often associated with the fundamental structure of a building, evaluation of the impact of larger housing improvements might be a valuable way to address the underlying origin of the problem. This is the point of the analyses in this paper.

Recent systematic reviews of the effects of housing improvements on health identified two main intervention categories in completed primary intervention studies: rehousing and renovation (Thomson et al 2001, 2003). 'Rehousing' is a word from the British literature that describes the process of moving people from one set of houses, presumably of lower quality, to another set of houses, presumably of higher quality. In the USA this most closely resembles the 'HOPE VI' programme of the federal Department of Housing and Urban Development, which entails complete demolition and rebuilding of physically distressed public housing developments. 'Renovation' involves substantial improvements to occupied housing that exceed those entailed in normal maintenance which is aimed only at preventing deterioration.

In 1950s Baltimore, Maryland, USA, asthma prevalence rates of nearly 20% were already being observed in low-income neighbourhoods. A prospective controlled rehousing study moved families from inferior housing to newly constructed public housing high-rises (Wilner et al 1958). Over the following 18 months, they looked for changes in numerous health problems, including respiratory conditions, but were unable to demonstrate a significant decrease in these problems (Wilner et al 1958). A similar controlled retrospective study assessing moves to new public housing in California in the late 1960s, displayed significant decreases in the number of outpatient visits for poorly defined 'housing-related illness' in the 0–9-year-old age group (Wambem and Piland 1973). Meanwhile, in 1970s San Antonio, Texas, USA, a small number of residents who moved to newly constructed US Department of Housing and Urban Development-sponsored special elderly housing, experienced improvements in mental and physical health (Carp 1977). This included a statistically significant decrease in their mortality rate over the eight years post-intervention in comparison with the control group (Carp 1977). Two other cross-sectional studies analysed the British system of rehousing on medical grounds (Cole and Farries 1986; Smith et al 1997). Only one found improvements in self-reported physical and mental health, although no changes in the use

of health services were reported in that study (Smith et al 1997). Furthermore, neither study controlled for possible confounding variables.

Renovation studies were more diverse in their interventions, focusing on either a single change or a mixture of improvements. Among those employing single-strategy interventions, two quasi-experimental studies from England evaluated the effect that central heating installation had on child respiratory health (Hopton and Hunt 1996; Somerville et al 2000). The first study found significant reductions in respiratory symptoms, including a reduced amount of school missed due to asthma (Hopton and Hunt 1996), while the second longitudinal study suggested that the improved heating system prevented further deterioration in respiratory health rather than initiating an improvement (Somerville et al 2000). A prospective controlled study reported that replacing windows led to a reduction in symptoms related to mucosal surfaces, rheumatic symptoms and headaches in the elderly (Iverson et al 1986).

As for multi-factorial renovation projects, housing and neighbourhood renovations in a pre/post study demonstrated no statistically significant effect on respiratory health problems despite great reductions in dampness; although, without a control group, it is impossible to know whether unrelated factors contributed to the absence of health outcomes (Blackman et al 2001). A retrospective cross-sectional study reported that residents of British public housing units in Sheffield that received major renovations – including new heating systems, better thermal insulation, enclosing balconies with glass and a new ventilation system – experienced a significant decrease in chronic illness and better overall health in comparison with controls (Green et al 2000). Finally, another pre/post intervention study in Central Stepney, England, employed a mixture of rehousing and general renovation interventions. A sevenfold improvement was reported in the rate of illness per person per day post-intervention (Ambrose 2001a, 2001b).

Although the majority of the housing intervention studies demonstrated positive results, they lacked the rigour of blinded randomised controlled trials. Furthermore, it is difficult to generalise their results because the types of interventions – including the types of heating units installed, renovations made and construction models used in the 'improved' rehousing developments – varied greatly within and between studies. Similarly, a lack of a consistent measure of improved health outcomes also impedes the capacity for generalisation of the studies as a collective body (Thomson et al 2003).

The relevance of these studies to the USA or other housing outside England is uncertain given differences in climate and housing styles. While recognising their inherent limitations, these sorts of quasi-experimental studies are needed to document the health value of housing renovation. One of the major challenges for these studies is that it may not be ethical or politically viable to have a control group that is denied housing renovations. Further, it is difficult, if not impossible, to blind participants and researchers to major housing changes. However, the very fact that public money is being spent is a major reason why evaluation is needed to provide the evidence base for future policy decisions. Solutions addressing the methodological limitations may include gathering data from a large number of housing interventions in the hope of discerning emerging patterns in health outcomes and creating standardised tools and outcome measures.

We report here an analysis of survey data arising from the USA-based Healthy Public Housing Initiative, which will eventually also report longitudinal data for apartment-specific interventions. We examined both cross-sectional and longitudinal data to compare physical building conditions and resident health in the unrenovated Franklin Hill and the partially renovated West Broadway public housing developments in Boston, Massachusetts.

Methods

Collaboration

This study was a collaboration among city, university and community partners that incorporated the strengths of each to enhance the project's effectiveness. The university-based co-directors chaired the committees responsible for overseeing the design, conduct and analysis of the survey to ensure the requirements of the funding agencies and Institutional Review Boards (IRBs) and the dictates of sound science were met. Decision making was usually by consensus. Community partners ensured the relevance of the study to the lived experience in the community through adding and modifying both questions in the survey and field methods, and participating in the data analysis and interpretation. City partners contributed housing authority management experience and connections to other health and housing efforts throughout the city.

Housing developments

West Broadway

The West Broadway Housing Development opened in 1949 in the South Boston neighbourhood of Boston. The majority

of residents of West Broadway were of white ethnicity until the 1990s (Vale 2000). It is composed of 26 three-storey brick walk-ups, 6 of which were unoccupied in 2002. The buildings are located in about 8 square city blocks (30 apartments per acre), with 484 apartments available for occupation and 1233 residents living in the development in 2002. Excluding the unoccupied buildings, West Broadway received substantial renovations to roofs, the facade and the interiors in three phases in 1984, 1987 and 1990 (about $77 500 per apartment).[1] All the interior sections of the 20 buildings were gutted, rehabilitated and reconfigured. Rigid board insulation (expanded polystyrene) was installed on some of the exterior wall surfaces and covered with wallboard. The exterior surfaces had some cosmetic and remedial repointing of bricks and sealing of seams. Cosmetic work included the addition of small bump-outs around window areas to provide some depth and visual break-up of the existing brick walls (Helm D, Boston Housing Authority, 2004 Jan 23, pers comm).

About 100 bathroom fans were installed across the development from that period through to the present. In September 2001, the development also changed from a central steam heating system to a distributed forced hot water heating system, with one heating system per building (Carton K, Boston Housing Authority, 2002 Jun 27, pers comm).

Franklin Hill

The Franklin Hill Housing Development is located in the Dorchester neighbourhood of Boston. The development opened in 1952, and residents were of predominantly white ethnicity until a rapid shift to a largely African American population by 1970 (Vale 2000). In the 1990s, increasing numbers of Hispanics moved into the development. Franklin Hill has not undergone major renovations since it was built. Upgrades and repairs in the 1990s to some buildings and apartments included new counters, interior painting, appliances, flooring, bathroom tiles and sinks and repair to walls. In 2000, valves were installed on radiators to allow partial control of heat, but most were broken or unused by 2002. Heating is via a central steam boiler system with steam distribution through underground piping to radiators located in the apartments. The development has 366 apartments in nine three-story brick walk-ups that are located within about 4 square city blocks (40 apartments per acre). There were 930 residents living in the development in 2002 (Carton K, Boston Housing Authority, 2002 Jun 27, pers comm). A detailed comparison of the two developments is given in Table 1.

Table 1 Comparison of characteristics of the partially renovated Franklin Hill and unrenovated West Broadway Housing Developments in 2002

Characteristic	*Franklin Hill apartments*	*West Broadway apartments*
Average m^2 per apartment	53.3	91.0
Average m^2 per resident	21.0	35.7
Apartments per entryway	9–12	8–12
Exterior walls	Uninsulated	Insulated
Piping	Original	Replacement
Heating system	Central steam	Distributed forced hot water
Ventilation	No apartment ventilation	No apartment ventilation
Windows	Aluminium double pane	Aluminium double pane
Utility consumption	Higher	Lower
Stoves	Gas	Gas
Dryer vents	Through windows	Built-in
Yard space	Not designated	Quasi-private

Random samples

The Boston Housing Authority provided us with a database containing apartment numbers and addresses for the Franklin Hill and West Broadway Developments in spring 2001. Random samples were generated for both developments using the RANDBETWEEN function in Microsoft® Excel. After excluding vacant apartments, a sample of 254 apartments was generated for West Broadway. The percentage of apartments selected per building ranged from 39% to 68%. For Franklin Hill, a sample of 193 apartments was generated, and the percentage of apartments selected per building ranged from 31% to 62%. Only one person in each apartment was surveyed.

Survey instruments

The questionnaire used was derived from earlier questionnaires on housing conditions and health symptoms that have been reported elsewhere (Hynes et al 2000; Brugge et al 2001). Adaptation of the questionnaire resulted in changes to more than half of the survey, including altered questions, new questions and questions that were removed. Early versions of the questionnaire were pilot tested with residents who practised administering the survey to each other and to residents who had been part of the pilot studies. The residents provided written or verbal feedback on the survey during pilot testing, and numerous minor modifications were made for clarity. The questionnaire was then translated into Spanish and subsequently back-translated into English to ensure accuracy.

Institutional Review Board approvals

The IRBs at Harvard University School of Public Health, Boston University School of Public Health and Tufts University School of Medicine approved the protocol and consent forms. Recommendations from the three IRBs were reconciled prior to the start of surveying. The Boston Housing Authority agreed to not use any information it learned through the project to enforce violations of its rules by participants in the study.

Resident workers

An important part of this community-based project was the active involvement of public housing residents. Residents of the housing developments received training and were hired as part-time surveyors, called 'Community Health Advocates' or CHAs by the project. There were multiple versions of the training offered, but each consisted of approximately 20 hours of instruction time on the same content. The topics addressed during training were: leadership and community organising; an introduction to asthma and the environmental factors that exacerbate asthma; how to conduct a survey; orientation to the requirements of the Institutional Review Boards; and obtaining informed consent. The study protocol was thoroughly vetted with community residents, and each surveyor practised administering the consent form and questionnaire. The surveyors included persons fluent in English, Spanish or both languages.

Survey protocol

Survey teams consisted of two residents who had completed all aspects of the training and had been hired by the community partners, either the South Boston Community Health Center or the Committee for Boston Public Housing. The community partners hired 'Resident Liaisons' to manage and oversee the surveyors. Survey teams were given address lists from the study sample such that there would be three attempts to contact each address, with one attempt during a weekday day (8am–5pm), one attempt during a weekday evening (5pm–8pm) and one attempt during a weekend day.

Survey teams carried a single page with a message in Spanish, French, Vietnamese and Chinese to show to potential respondents who did not speak English. If the potential respondent indicated interest, up to three more attempts were made to contact that person in the presence of an appropriate interpreter or, if they were Spanish speaking, with Spanish-speaking CHAs. Only 2 surveys were completed that were not in English or Spanish, both with Chinese-speaking residents at the West Broadway development.

The Resident Liaisons maintained a tracking system that included a cover sheet on each questionnaire to ensure that each residence was approached no more than 3 times, each at a different time of the week. Resident survey teams knocked only at the addresses assigned to them, and while they were not prohibited from interviewing persons they knew, they were instructed not to make special arrangements for their friends and acquaintances.

Prior to administering the survey, the consent form was administered and respondents were assured of confidentiality. The surveyors were instructed to administer the survey in a neutral manner and to handle requests for clarification of questions only by repeating the question. If a respondent, after two repeats, felt that they still did not know how to answer, the surveyors were instructed to move on to the next question. After completing the survey, respondents were asked to fill out an envelope with their address so that compensation for their time ($20 per survey for about 1 hour) could be sent to them.

Completed surveys and consent forms were returned to the community partners. The Resident Liaisons at each organisation maintained a file of completed surveys and consent forms either in a locked file drawer or in an office that was locked when unoccupied.

Quality control

For quality control, the Resident Liaison accompanied surveyors on their first few outings. They also debriefed the survey teams on a regular basis. One of the project directors met with the survey teams and Resident Liaisons early in the survey process to clarify questions and to reinforce the survey protocol. Midway through the survey process a graduate research assistant accompanied surveyors on several survey visits and reviewed the files of consent forms, questionnaires and checklists at both community partners.

Based on the field and site visits, it was observed that most surveys were fully filled out and had been administered properly, and that in all instances the requisite consent forms were signed. Tracking and quality control forms were observed to contain more frequent errors, including failure to record the name of the surveyor and, in a smaller number of cases, failure to document the attempts to survey apartments. There were more errors on these forms for the surveys that were completed in Spanish than those completed in English. More tracking and quality control forms were properly filled out at West Broadway than at Franklin Hill.

Data entry

A computer data entry form was developed in Microsoft Access and pilot tested with the Resident Liaisons who were trained in the proper use of the form. Before entry of data, cover pages were separated from the survey and filed separately. Resident Liaisons, staff and/or students double entered the data on designated computers at South Boston Community Health Center or the Committee for Boston Public Housing. Where possible, different persons did the two data entries. Completed database files were then transferred to Harvard School of Public Health (HSPH). Once data entry was complete, the hard copies of the surveys were transferred to HSPH. Discrepancies between the two entries were resolved by reference to the original hard copy of the survey by data management staff at HSPH.

Cross-sectional comparison

The 2002 survey of the Franklin Hill and West Broadway Developments was based on two random samples. Responses were obtained from March to December 2002, with the vast majority of surveys completed between March and July 2002. Questions used in the analyses were those that were relevant to heating system effects and amenable to the pre/post comparison so that the cross-sectional analyses could be easily compared with the longitudinal analysis. A small number of additional questions (eg pests) were also analysed.

Longitudinal comparison

In September 2001, West Broadway was converted from centralised purchased steam heating and domestic hot water to decentralised, gas-fired forced hot water heating and domestic hot water. New low-flow faucet aerators and showerheads and low-volume toilets were also installed. The change did not result in residents having to pay for their heating. To assess the effect of the 2001 renovations, two convenience samples from the development were compared from surveys in the years 1998 and 2002. Methods for the 1998 survey have been reported (Hynes et al 2000). The 2002 survey methods are described above. Because all of the 1998 surveys were administered in March and April, only those 2002 surveys administered in the months of March and April were used, to control for seasonal variation.

Because the survey questionnaire was revised between 1998 and 2002, some questions were not identical. Of the questions in Table 6, 13 were repeated verbatim (A in Table 6), 3 had minor word changes (B), 6 required aggregation of the 2002 survey responses (C) and 2 asked for comparable information in a substantially different manner (D) (see Table 6, footnote b).

Cost of heating and water upgrades

The upgrades at West Broadway cost $7.65 million. This investment reduced the development's heating, domestic hot water and potable water costs by about $697 000 in 2001, or about $1450 per apartment. A significant amount of the savings came from the conversion from expensive purchased steam ($12.91/MMBTU)[2] to less expensive natural gas ($9.00/MMBTU) (Helms D, Boston Housing Authority, 2003, pers comm).

Data analysis

Data were imported into SAS software (SAS Institute, Cary, NC, USA) for analyses. Data analyses included chi-square tests and calculation of odds ratios (ORs). Logistic regression was used to adjust odds ratios for possible confounders. For the analyses, the unrenovated state (the old heating system) has been treated as the exposure of interest.

Results

Collaboration

The majority of the CHAs spoke Spanish, and their language and cultural skills led to a high proportion of Hispanics participating in the survey relative to our pilot studies. It is notable that the CHAs developed job skills through working as surveyors that may help them find future work. CHAs also reported that the knowledge they learned about asthma was helpful in their personal lives in caring for or advising relatives who have asthma. It is notable that both community partners have carried out their own surveys after learning the survey methods from working on this and the pilot studies.

Demographics

The response rate at the Franklin Hill Development was 55% and the response rate at the West Broadway Development was 52%. At Franklin Hill, 29% of all apartments were surveyed. At West Broadway, 27% of all apartments were surveyed. For the 1998 survey at West Broadway the response rate was 77%, but rather than being truly random, this was a convenience sample.

Table 2 shows the demographics reported by the 2000 US Census and the Boston Housing Authority and compares them with the demographics of our survey sample (the HPHI survey). The census data were geographically coincident with

Table 2 Demographics of the Franklin Hill and West Broadway Housing Developments

	US Census 2000 (%)		*BHA 2001 (%)*		*HPHI 2002 (%)*	
Demographics	*Franklin Hill*	*West Broadway*	*Franklin Hill*	*West Broadway*	*Franklin Hill*	*West Broadway*
Age						
18	–	–	–	–	1.9	0.0
18–19	5.9	6.8	–	–	–	–
19–21	–	–	11.4	10.1	7.5	3.0
20–21	5.7	5.7	–	–	–	–
22–26	–	–	15.6	10.6	18.9	6.1
22–29	22.4	15.8	–	–	–	–
27–61	–	–	67.2	62.1	66.0	67.4
30–61	57.8	57.0	–	–	–	–
62–79	7.6	13.6	5.6	15.8	3.8	17.4
80+	0.5	1.1	0.2	1.3	0.0	0.8
Age not stated	–	–	–	–	1.9	5.3
African American	63.6	12.1	45.0	22.2	34.0	9.8
Hispanic	40.0	36.4	57.0	35.6	64.2	40.9
Primary language not English	21.7	22.0	56.0	42.0	38.7	34.1

BHA, Boston Housing Authority; HPHI, Healthy Public Housing Initiative.

the West Broadway Development, but the census data for Franklin Hill extends beyond the Development. Boston Housing Authority data were for the year preceding our survey. The comparison suggests that we modestly undersampled African Americans, modestly oversampled Hispanics and undersampled non-English-speaking residents at both developments, while undersampling white residents at West Broadway. The age distribution of our sample was broadly representative.

Franklin Hill/West Broadway comparison

Table 3 presents prevalence, and crude and adjusted odds ratios, between the Franklin Hill and West Broadway Developments for selected 2002 survey data. Respondents from the Franklin Hill Development were significantly more likely to report adverse environmental factors likely to be associated with the heating system. After adjustment (for sex, age, years in public housing and ethnicity), reports of 'too hot', 'stuffy apartment', 'ever open window in the winter', 'open windows 6–7 days a week', 'wear light cloths in the winter', 'use air conditioner in the winter', 'leaks', 'condensation' and 'smell mould' were statistically higher at the Franklin Hill Development. Additionally, reports of 'enough fresh air' and 'too cold' were statistically lower at the Franklin Hill Development.

Reported health symptoms in the preceding month for both developments are also presented in Table 3. After adjustment, none of the symptoms differed statistically. 'Skin rashes' only differed statistically prior to adjustment. Leaving allergies out of the regression model resulted in both 'sneezing' and 'skin rashes' having statistically significant adjusted ORs (data not shown). Substituting African American for Hispanic in the regression model resulted in 'too cold' remaining statistically significant and 'nausea' becoming statistically significant (data not shown).

Table 4 compares environmental factors less likely to be associated with the different heating systems in West Broadway and Franklin Hill. Franklin Hill respondents reported statistically higher odds of having 'cockroaches', 'mice' and 'bathroom fan that works'. Our tests in one building at Franklin Hill indicated, however, that few if any fans draw air out of the apartments (data not shown). Franklin Hill respondents were also less likely to report that 'common areas were kept clean'.

Also reported in Table 4 are asthma rates for respondents (adult) and their children. Although Franklin Hill respondents reported 50% greater rates of adult asthma than West Broadway, the difference was not significant and was eliminated after adjustment. Childhood asthma rates were statistically higher at Franklin Hill – a difference that held up to statistical adjustment. However, because we did not collect detailed demographic information on the children of respondents, we were unable to adjust for the same factors used in regression of adult respondent data (see Table 4, footnote a).

Longitudinal comparison at West Broadway

Table 5 compares the demographic characteristics of the survey populations before and after the heating system change at the West Broadway Development. Both

Table 3 Odds ratios for heating-related environmental factors and symptom responses between the Franklin Hill (FH) and West Broadway (WB) Housing Developments, 2002

	Franklin Hill (%) (n = 106)	*West Broadway (%) (n = 132)*	*Crude OR (95% CI) FH vs WB*	*Adjusted OR (95% CI) FH vs WB*[a]
Heating-related environmental factors				
Too hot	81	52	**3.84 (2.11–6.96)**	**3.48 (1.79–6.75)**
Too cold	38	51	**0.58 (0.34–0.98)**	0.55 (0.30–1.01)
Enough fresh air	69	86	**0.34 (0.18–0.66)**	**0.30 (0.14–0.64)**
Stuffy apartment	70	51	**2.32 (1.35–3.98)**	**3.07 (1.63–5.78)**
Ever open window in winter	87	77	1.93 (0.97–3.87)	**3.41 (1.52–7.61)**
Open windows 6–7 days a week	50	23	**3.20 (1.84–5.57)**	**6.31 (3.07–12.96)**
Heat started about right time in fall	60	69	0.67 (0.38–1.15)	0.60 (0.32–1.14)
Wear light clothes in winter	60	36	**2.67 (1.56–4.55)**	**3.02 (1.61–5.67)**
Know how to operate radiators	74	84	0.49 (0.22–1.11)	0.65 (0.25–1.68)
Oven used for heating	19	21	0.86 (0.46–1.64)	0.99 (0.47–2.10)
Use air conditioner in winter	42	31	1.58 (0.92–2.69)	**2.10 (1.12–3.93)**
Leaks	51	37	**1.77 (1.05–2.98)**	**2.11 (1.14–3.88)**
Condensation	50	24	**3.23 (1.85–5.63)**	**2.69 (1.45–5.00)**
Smell mould	35	17	**2.51 (1.37–4.59)**	**2.08 (1.05–4.10)**
Symptom responses				
Dizziness	29	20	1.69 (0.93–3.07)	1.75 (0.86–3.59)
Headaches	54	47	1.31 (0.79–2.19)	1.21 (0.66–2.24)
Nausea	24	14	1.84 (0.95–3.56)	1.39 (0.65–2.99)
Coughing	32	39	0.75 (0.44–1.28)	0.75 (0.39–1.46)
Wheezing	20	14	1.47 (0.74–2.90)	1.50 (0.64–3.54)
Breathing problems	25	24	1.07 (0.59–1.93)	0.85 (0.40–1.78)
Nosebleeds	13	7	2.08 (0.86–5.01)	1.29 (0.47–3.56)
Tired	37	32	1.25 (0.73–2.14)	1.47 (0.76–2.84)
Blurry vision	15	14	1.06 (0.51–2.17)	1.16 (0.52–2.60)
Ear infection[b]	12	5	2.50 (0.96–6.50)	2.44 (0.84–7.11)
Skin rashes	17	8	**2.50 (1.10–5.67)**	2.49 (0.96–6.46)
Sneezing	24	20	1.26 (0.68–2.34)	2.11 (0.93–4.82)
Burning/itching eyes	19	20	0.95 (0.50–1.81)	0.89 (0.41–1.91)
Sore/dry throat	28	33	0.82 (0.47–1.43)	0.72 (0.37–1.42)

[a] All ORs are adjusted for sex, age, years in public housing and Hispanic status. In addition, symptoms were adjusted for smoking and allergies.
[b] Validity of model questionable due to quasi-complete separation (sex; no males reported ear infections).
Values in bold are statistically significant. OR, odds ratio; CI, confidence interval.

Table 4 Odds ratios for non-heating-related environmental factors and for chronic health conditions between the Franklin Hill (FH) and West Broadway (WB) Housing Developments, 2002

	Franklin Hill (%)	*West Broadway (%)*	*Crude OR (95% CI) FH vs WB*	*Adjusted OR (95% CI) FH vs WB*[a]
	n = 106	*n = 132*		
Non-heating-related environmental factors				
Common areas kept clean	58	86	**0.22 (0.12–0.43)**	**0.30 (0.15–0.61)**
Cockroaches	66	36	**3.52 (2.06–6.02)**	**4.05 (2.14–7.68)**
Mice	43	13	**5.19 (2.74–9.81)**	**7.51 (3.45–16.33)**
Bathroom fan works	16	6	**3.00 (1.24–7.27)**	**4.07 (1.47–11.24)**
Chronic health conditions				
Adults with asthma	30	20	1.68 (0.93–3.04)	0.88 (0.42–1.85)
Total number of children	*n = 169*	*n = 180*		
Children with asthma	30	14	**2.68 (1.57–4.58)**	**2.46 (1.34–4.52)**

[a] All ORs are adjusted for sex, age, years in public housing and Hispanic status. In addition, respondent asthma was adjusted for smoking and allergies. Children with asthma were adjusted for multiple children in the same household, smokers in apartment and caregiver's asthma.
Values in bold are statistically significant. OR, odds ratio; CI, confidence interval.

Table 5 Demographics of West Broadway Housing Development residents in 1998 and 2002

Attribute	*1998 (%) (n = 50)*	*2002 (%) (n = 48)*	*p-value*
Age 35+	66.0	83.0	0.06
< 5 years in public housing	12.0	18.8	0.35
Sex: female	87.5	85.1	0.73
Ethnicity: Hispanic	12.0	47.7	0.0001
Smoking status: smoker	49.0	31.3	0.08
Has allergies[a]	39.6	37.5	0.83

[a] There were minor word changes between the survey questions applied in 1998 and 2002.

comparison groups are convenience samples. The 1998 survey population was younger, had lived in public housing for fewer years, was less likely to be Hispanic and more likely to smoke. Rates of being female and having allergies differed only slightly.

Table 6 presents descriptive statistics and ORs comparing 1998 and 2002 survey responses at the West Broadway Development. After installation of the new heating system, there were statistically significant adjusted ORs for reports of 'too cold' and 'enough fresh air'. The variable, 'leaks', was significant only prior to adjustment. The trend in other responses was toward less overheating, fewer water leaks and more condensation.

Also in Table 6 are ORs for reported symptoms in the preceding month. None were statistically significant after adjustment and only 'sneezing' was statistically significant prior to adjustment. Nevertheless, 'nosebleeds', 'sneezing' and 'burning/itching eyes' had adjusted ORs above 2.0, and 'wheezing' had a crude OR above 2.0; all these warrant further study. Leaving allergies out of the model resulted in similar ORs.

Table 6 Odds ratios for heating-related environmental factors and symptom responses before (1998) and after (2002) heating system renovations at the West Broadway Housing Development

	1998 (%) (n = 50)	*2002 (%) (n = 48)*	*Crude OR (95% CI) 1998 vs 2002*	*Adjusted OR (95% CI) 1998 vs 2002*[a]	*Comment*[b]
Heating-related environmental factors					
Too hot	66	52	1.79 (0.79–4.03)	1.54 (0.57–4.11)	C
Too cold	24	67	**0.16 (0.07–0.38)**	**0.16 (0.05–0.47)**	C
Enough fresh air	54	83.3	**0.24 (0.09–0.60)**	**0.19 (0.05–0.67)**	C
Stuffy apartment	58	56	1.07 (0.48–2.39)	0.66 (0.25–1.80)	C
Ever open window in winter	82	72.9	1.65 (0.63–4.33)	0.74 (0.21–2.58)	C
Oven used for heating	32	29	1.14 (0.48–2.70)	1.58 (0.53–4.72)	C
Use air conditioner in winter	33	25	1.50 (0.55–4.08)	2.30 (0.68–7.72)	D
Leaks	59	38	**2.34 (1.03–5.30)**	1.78 (0.67–4.70)	B
Condensation	17	34	0.41 (0.15–1.08)	0.55 (0.17–1.82)	D
Smell mould	20	21	0.95 (0.36–2.54)	0.81 (0.23–2.83)	A
Symptom responses					
Dizziness	16	31	0.42 (0.16–1.11)	0.71 (0.20–2.47)	A
Headaches	54	52	1.08 (0.49–2.39)	1.20 (0.41–3.54)	A
Nausea	16	19	0.83 (0.29–2.35)	0.96 (0.28–3.35)	A
Coughing	46	44	1.10 (0.49–2.43)	0.51 (0.17–1.54)	A
Wheezing[c]	36	19	2.44 (0.97–6.16)	1.69 (0.46–6.24)	A
Breathing problems	32	31	1.04 (0.44–2.43)	0.52 (0.16–1.63)	B
Nosebleeds	20	13	1.75 (0.58–5.26)	4.01 (0.90–17.83)	A
Tired	40	40	1.02 (0.45–2.29)	0.78 (0.26–2.33)	B
Blurry vision	16	13	1.33 (0.43–4.18)	1.00 (0.26–3.82)	A
Ear infection	14	8	1.79 (0.49–6.56)	1.47 (0.30–7.11)	A
Skin rashes	24	15	1.85 (0.66–5.19)	1.70 (0.48–6.01)	A
Sneezing[c]	44	22	**2.64 (1.10–6.34)**	2.43 (0.75–7.90)	A
Burning/itching eyes	28	17	1.94 (0.73–5.17)	3.77 (0.86–16.62)	A
Sore/dry throat	50	40	1.53 (0.69–3.40)	1.17 (0.41–3.37)	A

[a] All ORs are adjusted for sex, age, years in public housing and Hispanic status. In addition, symptoms were adjusted for smoking and allergies.

[b] Comparison of questionnaire questions from the 1998 and 2002 surveys: A, question repeated verbatim; B, minor word change (eg 'respiratory problems' changed to 'breathing problems' at request of IRB); C, aggregation of 2002 survey responses (for most of the questions marked C (eg 'enough fresh air'), the 1998 survey had a yes/no response and the 2002 survey had yes/no/sometimes); D, substantial word change (eg 'Have you ever noticed that water condenses on the walls, ceiling or floor of your apartment (not including the bathroom after a shower)?' changed to 'Other than from leaks, has water/moisture formed droplets on apartment walls, ceiling and windows not including those in the bathroom in the last 12 months?').

[c] Only 2 respondents who lived in public housing less than 5 years reported wheezing or sneezing. Years in public housing was removed from the model.

Values in bold are statistically significant. OR, odds ratio; CI, confidence interval.

Satisfaction questions

We asked residents of West Broadway in 2002 (including the subset analysed in Tables 2 and 3, n = 132) about their satisfaction with the new heating and water systems. Between 76% and 89% of respondents reported that the new toilets, showerhead and faucets worked all the time. About 59% reported that the radiators worked all the time. Between 66% and 83% of respondents reported that the new water faucets and toilets were consistently better than the old system, while 43% reported that the heating was better 'all the time' in 2002.

Discussion

Benefits of collaboration

We believe that the use of a community collaborative research model, and especially the hiring and training of residents to conduct the surveys, had benefits both for the research project and for the community. In particular, the CHAs were likely to be able to gain access and enrol other residents because they were from the community. This is important because the residents have a tendency to distrust outsiders and to fear retaliation by the housing authority. Similarly, the CHAs had a rapport with other residents that we think most likely ensured more honesty in responses. For the community, knocking on doors afforded an opportunity to introduce the tenant task force and build greater support for its community building agenda.

Limitations of certain survey questions

After completion of the survey, several of the questions we asked appeared to us to have potential limitations. Both 'stuffy' and 'fresh air' are decidedly more subjective than most of the other environmental questions. Reports of more fresh air may be due to cooler air being perceived as fresher air, while reports of stuffy may be due to having a hot temperature in the apartment. In addition, reports of breathing problems, other than wheezing, appeared rather general, and we suspect that respondents' answers pooled a wide range of respiratory conditions from bronchitis to chronic obstructive pulmonary disease.

Franklin Hill/West Broadway comparison

The main strengths of the cross-sectional comparison of the West Broadway and Franklin Hill Developments were the relatively large sample size, the large percentage of total residents surveyed, the substantial participation of Hispanic residents and the well documented differences in renovations between the developments. The primary limitation was that there are undoubtedly differences between the developments besides the renovations and those demographic characteristics that we were able to capture. The lack of a longitudinal follow-up also limits the type of conclusions that can be drawn.

The cross-sectional comparison found robust indications that reported environmental problems were more severe in the unrenovated Franklin Hill Development compared with the twice-renovated West Broadway Development. This finding is consistent with our expectations and suggests that renovations are a significant factor in environmental quality in this public housing setting. On the other hand, some of the differences were unlikely to be related directly to the state of renovation, such as keeping common areas clean. Nevertheless, overall, our findings suggest that renovation of low-income housing improves living conditions.

Given the substantial difference in reported environmental conditions between the two developments, it is somewhat surprising that we did not find a greater difference in reported health symptoms in the preceding month among adult respondents. While there were modest trends toward higher rates of symptoms at Franklin Hill, none of the ORs remained statistically significant after adjustment.

This study found lower asthma rates than our earlier surveys in the same housing, possibly because the smaller pilot studies were more susceptible to selection bias (Hynes et al 2000; Brugge et al 2001). The finding that adult asthma rates did not differ between the developments while child asthma rates were significantly different is consistent with the aetiology of asthma. Adults may have developed asthma when they were children living in a different setting. Alternately, they may have developed asthma from smoking, which would not be related to building conditions. Further, asthma rates do not tell us about severity of asthma. Children are more likely to have developed asthma while living in the development. Thus, children in the more environmentally contaminated development may be at greater risk. The apartment-specific intervention component of the Healthy Public Housing Initiative has enrolled 66 children in a longitudinal study that should shed more light on the role of housing environment and asthma.

Pre/post analysis

The main strengths of the pre/post comparison at West Broadway were the longitudinal assessment and our ability

to control for seasonality. The main limitations were demographic differences, our inability to control for temporal trends in symptoms and our modest-sized convenience sample. Temporal trends in symptoms are a particular concern because during the time period of the study there were national-level changes in the USA that increased economic stress on the public housing population, including changes to welfare, food stamps and an economic recession.

While less dramatic than the cross-sectional comparison, perhaps because there was a single intervention and the survey sample size was smaller, the longitudinal study also found improvements in environmental conditions following renovation of the heating and water systems. However, the environmental changes were not uniformly positive. A prime example was the perceived apartment temperature. The new heating system was anticipated to dramatically reduce overheating. Continued reports of excessive heating suggest inadequacy in the new system and may reflect the fact that residents still don't have individual control of their heat other than with an on/off shut-off valve on each radiator. Because our survey was administered the year after installation, it is also possible that complaints were higher during what might, arguably, be considered an adjustment period for the system.

Furthermore, reports of excessive cold increased dramatically. While we cannot distinguish whether changes in reporting 'too cold' resulted from people having adapted themselves to years of overheating, it is possible that the changed response is also due to deficiencies in the new system. A prime concern with lowering apartment temperatures is that it could lead to cold surfaces and increased condensation. Indeed, rates of reported condensation were higher in 2002. Cold, damp homes have been associated with negative health symptoms (Platt et al 1989; Spengler et al 1994). However, reports of mould in our survey did not change.

The adjusted health data from the longitudinal investigation are interesting given the mixed environmental changes. The analyses suggest improvements (crude or adjusted OR > 2.0) in several symptoms associated with allergies and asthma: wheezing, nosebleeds, sneezing and burning/itching eyes (Institute of Medicine 2000). However, only the crude OR for sneezing was statistically significant. Coughing and sore/dry throat, which might also be expected to be associated with allergies, did not have elevated ORs. The small sample size may have limited our ability to discern associations.

Conclusions

The pattern that emerged in this study was that the renovations of public housing were associated with substantial, and in some cases dramatic, improvements in reported environmental conditions. Reported health symptoms were, however, only modestly tilted toward improvements for adult residents in the renovated housing. There are several possible explanations for the apparent discrepancy. One is that the residents may have developed underlying conditions due to environmental exposure that do not completely abate even if conditions improve. Another is that the residents are buffeted by numerous factors besides home environment (eg nutrition, exercise, stress, compromised health care, violence) that may exacerbate some of the same symptoms that we were measuring (Pettit et al 2003). Further, this paper addresses only a subset of those environmental factors included in the survey.

It is worth noting that controlled intervention studies for asthma and allergies have frequently seen reductions in contaminants, but less often seen strong reductions in symptoms (Woodstock et al 2003). It is possible that some of the environmental factors, despite being associated with morbidity, may not relieve symptoms when they are reduced. A possible reason for this could be that the threshold for adverse effects is below the level reached after renovations were complete. It is worth noting that in this study, despite improvements, appreciable problems with pests, condensation and apartment overheating and underheating continued to plague renovated apartments.

We conclude that our findings provide evidence that heating system, water system and structural renovations provide a solid framework for better apartment environmental conditions that may be beneficial to the health of residents. Our findings are consistent with other quasi-experimental studies of housing reviewed in the introduction, but the combined literature is not conclusive. Because true placebo-controlled clinical trials of major housing renovation are difficult politically and, indeed, questionable ethically, there is a need for more studies like this to bolster confidence in our conclusions. Future studies can improve on ours by following the same population longitudinally (instead of comparing two cross-sectional samples), increasing sample sizes (especially with respect to our longitudinal data) and gathering environmental samples and objective measures of health outcome, such as doctors visits, medication use and work and school days lost. The intervention component of

the Healthy Public Housing Initiative, the sponsor of this survey study, is gathering environmental sampling and objective health outcome data from children in the same developments reported here.

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Notes

[1] All dollar values in this paper refer to US currency.

[2] MMBTU is one million British Thermal Units.

References

Ambrose P. 2001a. Living conditions and health promotion strategies. *J R Soc Promot Health*, 121:9–15.

Ambrose P. 2001b. Some way short of holism: United Kingdom urban regeneration and non-housing outcomes. Housing Policy and Research Report. Occasional Paper nr 8. Queensland: Department of Housing, Queensland Government.

American Academy of Pediatrics. 2001. Falls from heights: windows, roofs, and balconies. *Pediatrics*, 107:1188–91.

Anonymous. 1996. Home radiator burns among inner-city children – Chicago, September 1991–April 1994. *MMWR Morb Mortal Wkly Rep*, 45:814–15.

Blackman T, Harvey J, Lawrence M et al. 2001. Neighborhood renewal and health: evidence from a local case study. *Health Place*, 7: 93–103.

Bornehag CG, Blomquist G, Gyntelberg F et al. 2001. Dampness in buildings and health. Nordic interdisciplinary review of the scientific evidence on associations between exposure to 'dampness' in buildings and health effects (NORDDAMP). *Indoor Air*, 11:72–86.

Brugge D, Rice P, Terry P et al. 2001. Housing conditions and respiratory health in a Boston public housing community. *New Solutions J Environ Occup Health Policy*, 11:149–64.

Brugge D, Vallarino J, Ascolillo L et al. 2003. Comparison of multiple environmental factors for asthmatic children in public housing. *Indoor Air*, 13:18–27.

Carp F. 1977. Impact of improved living environment on health and life expectancy. *Gerontologist*, 17:242–9.

Chilmonczyk B. 1993. Association between exposure to environmental tobacco smoke and exacerbations of asthma in children. *N Engl J Med*, 328:1665–9.

Cole O, Farries JS. 1986. Rehousing on medical grounds – assessment of its effectiveness. *Public Health*, 100:229–35.

Evans R, Gergen PJ, Mitchell H et al. 1999. A randomized clinical trial to reduce asthma morbidity among inner-city children: results of the National Cooperative Inner-City Asthma Study. *J Pediatr*, 135: 332–8.

Francis H, Fletcher G, Anthony C et al. 2003. Clinical effects of air filters in homes of asthmatic adults sensitized and exposed to pet allergens. *Clin Exp Allergy*, 33:101–5.

Gotzsche PC, Johansen HK, Burr ML et al. 2003. House dust mite control measures for asthma. Cochrane Database of Systematic Reviews. Volume 1.

Green G, Ormandy D, Brazier J et al. 2000. Tolerant building: the impact of energy efficiency measures on living conditions and health status. In Rudge J, Nicol F, eds. Cutting the cost of cold: affordable warmth for healthier homes. London: E & FN Spon.

Hopton J, Hunt S. 1996. The health effects of improvements to housing: a longitudinal study. *Housing Stud*, 11:271–86.

Hynes HP, Maxfield R, Carroll P et al. 2001. Dorchester Lead-Safe Yard project: a pilot program to demonstrate low-cost, on-site techniques to reduce exposure to lead-contaminated soil. *J Urban Health*, 78: 199–211.

Hynes P, Brugge D, Watts J et al. 2000. Public health and physical environment in Boston public housing. *Plann Pract Res*, 15:31–49.

Institute of Medicine. 2000. Clearing the air: asthma and indoor air exposures. Washington, DC: National Academy Pr.

Iverson M, Bach E, Lundqvist G. 1986. Health and comfort changes among tenants after retrofitting of their housing. *Environ Int*, 12:161–6.

Kattan M, Mitchell H, Eggleston P et al. 1997. Characteristics of inner-city children with asthma: the National Cooperative Inner-City Asthma Study. *Pediatr Pulmonol*, 24:253–62.

Lanphear BP. 2000. Cognitive deficits associated with blood lead concentrations <10 μg/dL in US children and adolescents. *Public Health Rep*, 115:521–9.

McDonald E, Cook D, Newman T et al. 2002. Effect of air filtration systems on asthma: a systematic review of randomized trials. *Chest*, 122:1535–42.

Pettit KLS, Kingsley T, Coulton CJ. 2003. Neighborhoods and health: building evidence for local policy. Washington, DC: The Urban Institute.

Platt SD, Martin CJ, Hunt SM et al. 1989. Damp housing, mould growth, and symptomatic health state. *BMJ*, 298:1673–8.

Ranson R. 1991. Healthy housing: a practical guide. London: Spon Pr, and World Health Organization Regional Office for Europe.

Rosenstreich DL, Eggleston P, Kattan M. 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.

Smith S, Alexander A, Easterlow D. 1997. Rehousing as a health intervention: miracle or mirage? *Health Place*, 3:203–16.

Somerville M, Mackenzie I, Owen P et al. 2000. Housing and health: does installing heating in their homes improve the health of children with asthma? *Public Health*, 114:434–9.

Spengler J, Neas L, Satoshi N et al. 1994. Respiratory symptoms and housing characteristics. *Indoor Air*, 4:72–82.

The Council of Hygiene and Public Health of the Citizens' Association of New York. 1973. Report of the Council of Hygiene and Public Health of the Citizens' Association of New York Upon the Sanitary Condition of the City. *Bull NY Acad Med*, 49:571–2.

Thomson H, Petticrew M, Douglas M. 2003. Health impact assessment of housing improvements: incorporating research evidence. *J Epidemiol Community Health*, 57:11–16.

Thomson H, Petticrew M, Morrison D. 2001. Health effects of housing improvement: systematic review of intervention studies. *BMJ*, 323:187–90.

Tinetti ME, Speechley M, Ginter SF. 1988. Risk factors for falls among elderly persons living in the community. *N Engl J Med*, 319: 1701–7.

Vale LJ. 2000. From the puritans to the projects: public housing and public neighbours. Cambridge, MA: Harvard Univ Pr.

Wagner-Steagall Act. 1937. Wagner-Steagall Act [online]. Accessed 26 Feb 2004. URL: http://tucnak.fsv.cuni.cz/~calda/Documents/1930s/Wagner_1937.html

Wambem D, Piland N. 1973. Effects of improved housing on health in South Dos Palos, California. *Health Serv Rep*, 88:47–58.

Wilner DM, Price-Walkley R, Glasser MN et al. 1958. The effects of housing quality on morbidity: preliminary findings of the Johns Hopkins longitudinal study. *Am J Public Health*, 48:1607–15.

Woodcock A, Forster L, Matthews E 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.