

# The Health Impacts of Housing Improvement: A Systematic Review of Intervention Studies From 1887 to 2007

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Investment in improving poor housing conditions has long been proposed as a mechanism for health improvement and the reduction of health inequalities. For example, the World Health Organization (WHO) Knowledge Network on Urban Settings and the WHO Commission on the Social Determinants of Health have highlighted the need to create healthy housing and neighborhoods.<sup>1</sup> The US Centers for Disease Control and Prevention also stresses the improvement of housing and living conditions as a strategy to promote health.<sup>2</sup> Within the field of public health more generally, housing policy is also regularly cited as a determinant of both health and health inequalities<sup>3,4</sup> and as a means by which inequalities may be tackled.<sup>5,6</sup>

Public investment to improve housing conditions can be justified on grounds of social justice and energy efficiency. In addition, the well-established associations between poor housing and poor health also suggest that housing improvement may be justified on health grounds alone. There is a complex interconnectedness between poor housing and poor health and their determinants.<sup>3</sup> For example, vulnerable groups such as the sick, the elderly, and the unemployed are among those most likely to live in poor housing and also tend to spend long periods of time indoors exposed to potentially hazardous environments.<sup>7</sup> Thus, the improvement of housing conditions may be used to tackle the complex dynamic between poverty and poor health.

None of these impacts can be taken for granted, however, and evidence about the actual impacts of housing improvement needs to be rigorously synthesized to ensure that policies meant to improve health through housing have a sound scientific footing. In a previous systematic review examining the health impacts of housing improvements, we found 18 studies from around the world.<sup>8</sup> We concluded that housing improvements may have produced small improvements in health,

**Objectives.** We conducted a systematic review of the health impacts of housing improvement.

**Methods.** Forty-two bibliographic databases were searched for housing intervention studies from 1887 to 2007. Studies were appraised independently by H.T. and S.T. or E.S. for sources of bias. The data were tabulated and synthesized narratively, taking into account study quality.

**Results.** Forty-five relevant studies were identified. Improvements in general, respiratory, and mental health were reported following warmth improvement measures, but these health improvements varied across studies. Varied health impacts were reported following housing-led neighborhood renewal. Studies from the developing world suggest that provision of basic housing amenities may lead to reduced illness. There were few reports of adverse health impacts following housing improvement. Some studies reported that the housing improvement was associated with positive impacts on socioeconomic determinants of health.

**Conclusions.** Housing improvements, especially warmth improvements, can generate health improvements; there is little evidence of detrimental health impacts. The potential for health benefits may depend on baseline housing conditions and careful targeting of the intervention. Investigation of socioeconomic impacts associated with housing improvement is needed to investigate the potential for longer-term health impacts. (*Am J Public Health*. 2009;99: S681–S692. doi:10.2105/AJPH.2008.143909)

particularly mental health. However, the small number, extreme heterogeneity, and poor quality of the studies inevitably limited the ability to draw conclusions in the final synthesis. Our previous review identified 12 ongoing studies of housing improvement that would be complete by 2006, some of which used quasi-experimental designs; it is now timely to prepare an updated synthesis drawing on these recent studies.

We report the findings of a systematic review of the health impacts of housing improvement. The review is distinct from our earlier one; a new and more comprehensive search strategy was developed, a more detailed critical appraisal of the included studies was carried out, and the final synthesis incorporated the use of standardized effect sizes and a narrative synthesis of both quantitative and qualitative data. In addition, the increased quantity and quality of recent studies allowed for synthesis of larger groups of similar studies, increasing the generalizability of the final synthesis.

## METHODS

The protocol for this review has been peer reviewed and published elsewhere by the Campbell Collaboration.<sup>9</sup>

### Inclusion and Exclusion Criteria

Studies of housing improvement that involved enhancement of the physical attributes of housing infrastructure, including interventions to increase warmth, were included. We excluded improvements to mobile homes, psychosocial or educational interventions, and interventions to remove or reduce exposure to lead, radon, or allergens. Modifications for medical reasons, accident prevention, and air quality improvement and to increase disabled occupants' mobility were also excluded. These modifications largely entail provision of equipment, and this literature has been reviewed elsewhere.<sup>10–18</sup> In cases in which housing improvement incorporated equipment-based

interventions in addition to interventions relevant to the review, the study was included. Any health- or illness-related measure was included, as were both qualitative and quantitative studies. Studies in any language, from anywhere in the world, of any design, were included.

### Search Strategy

The search strategy was prepared by the National Health Service Centre for Dissemination in York, United Kingdom (details available from H.T. on request). Twenty scientific bibliographic databases were searched. Additional gray and nonscientific literature was searched for in 22 specialized health and social science databases (see appendix I, available as a supplement to the online version of this article at <http://www.ajph.org>). In 2007, we searched all years of all the databases, including Psycinfo, which covers citations beginning in 1887. Housing experts were contacted and relevant Web sites were searched.

### Study Quality, Data Extraction, and Intervention Integrity

Studies identified by the literature searches were screened for inclusion and critically appraised by H.T. Included studies also were screened and appraised independently by S.T. or E.S., and any differences were resolved by discussion. An existing critical appraisal tool developed for use in assessing quasi-experimental studies in public health<sup>19</sup> was adapted to reflect relevant methodological issues in housing studies; this allowed for the inclusion of non-randomized studies and the assessment of key confounders such as housing quality at baseline. Studies were assessed for 6 potential sources of bias: sample selection, study design, control for confounding, blinding of participants and assessors, data collection (sources and methods), and withdrawals. A summary grade (A, B, or C) describing the overall study quality was assigned to each study (see the box available as a supplement to the online version of this article at <http://www.ajph.org>). Key methodological aspects of qualitative studies were described, but the overall methodological quality was not categorized.

Data extraction was carried out by one reviewer (H.T., S.T., or E.S.) and checked by a second reviewer (H.T., S.T., or E.S.). Data were entered onto a Microsoft Access database (Microsoft Corp, Redmond, WA), which

facilitated interrogation of the data across studies. In addition to health outcomes, details of the intervention implementation, population, study setting, and changes in housing conditions were extracted. For each study, we assessed within study variation in the extent of intervention delivered and within study variation in how much housing conditions were improved following the intervention, (assessed using objective measure or resident-reported data; see the box available as an online supplement).

### Data Synthesis

The studies were grouped by intervention type as follows: improvements in warmth and energy efficiency (after 1985); rehousing or retrofitting with or without wider neighborhood renewal (after 1995); provision of basic housing needs in developing countries (after 1990); and rehousing from slum conditions (before 1975). When possible, standardized effect sizes were calculated with Comprehensive Meta-Analysis software (Biostat, Englewood, NJ). The extreme heterogeneity of many of the study characteristics (study design, intervention, outcomes assessed, and context) precluded an appropriate statistical synthesis, so the data were synthesized narratively, incorporating both quantitative and qualitative data where available.

Health impact data were grouped according to 4 categories: general health, respiratory health, mental health, and illness or symptoms. The data were then tabulated and prioritized by the quality of the methodology (see table B available as a supplement to the online version of this article at <http://www.ajph.org>) and the direction of the health impact (negative, positive, none, or unclear), the level of statistical significance ( $P < .05$ ), and the study size indicated. Data were further synthesized to produce a single indication of overall impact in each outcome category for each study (Table 2). Where more than one outcome was reported for any one outcome category, the overall impact was indicated. A summary of qualitative data and associated methods was also tabulated (see table D available as a supplement to the online version of this article at <http://www.ajph.org>).

The final synthesis drew on the essential elements of narrative synthesis.<sup>20</sup> This involved an iterative process, examining the data for

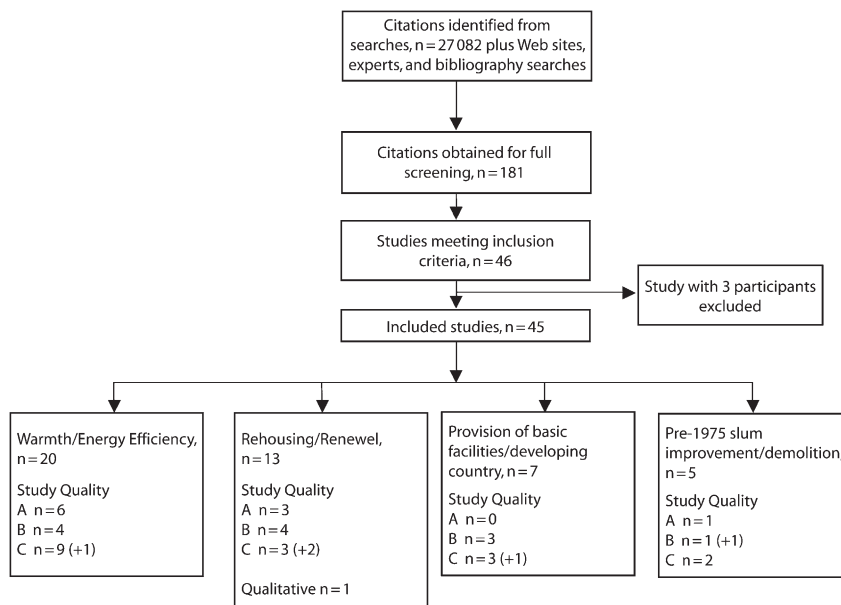
evidence of factors that may have influenced the reported health impact and for patterns within groups of studies. The main factors examined were study quality, study design, study setting, intervention integrity, and extent of housing improvement actually reported. The final assessment of overall impacts for an intervention category reflects the weight of evidence available, taking account of study quality.

## RESULTS

Following extensive searching, 45 studies (Health Action Calderdale Kirklees and Wakefield, unpublished data, 2005; B. Heyman et al., unpublished data, 2007)<sup>21–63</sup> met the inclusion criteria (Figure 1); 8 of these studies reported quantitative and qualitative data, and 1 study<sup>63</sup> reported only qualitative data. Five studies reported only impacts on health service use<sup>32,48,50,57,59</sup> and were not included in the synthesis because it is unclear how to interpret changes in health service use in terms of actual health impacts. (Excluded studies are detailed in Appendix II, available as a supplement to the online version of this article at <http://www.ajph.org>).

Study quality varied. Nine studies were considered to be grade A in terms of overall methodological quality. Five studies used a randomized controlled design, each assessing a warmth and energy efficiency intervention (B. Heyman et al., unpublished data, 2007)<sup>21,22,23,34</sup>. In 2 of these studies, the randomization did not appear to have been rigorously enforced (B. Heyman et al., unpublished data, 2007).<sup>34</sup> Sixteen studies used a prospective controlled design (7 for warmth and energy efficiency, 7 for rehousing or retrofitting, and 2 for rehousing from slums). Fewer than half of the studies (grades A [ $n=4$ ] and B [ $n=16$ ]) incorporated adequate control—through either study design or statistical analysis—of important confounders such as housing quality and health status at baseline. Most of the studies used accepted methods of data collection and validated measures of health status (data collection grade A,  $n=33$ ). None of the studies reported blinding the participants or the assessors to the intervention status.

We present a synthesis of the 40 studies that reported direct health impacts. The studies and their syntheses that are most relevant to current housing investment in the developed world are



Note. Numbers in parentheses indicate additional studies that reported only impacts on health service use or prescribed medications. Some studies presented both quantitative and qualitative data. One study reported only qualitative data.

**FIGURE 1—Flowchart of studies systematically reviewed for the health impact of housing improvements.**

reported in more detail than pre-1975 studies and interventions providing basic facilities. Table 1 presents the standardized effect sizes that could be calculated. Table 2 presents a summary of the overall direction of effect for each study and for each of 4 broad outcome categories (a visual interpretation of the synthesis is available as a supplement to the online version of this article at <http://www.ajph.org>). (Data for individual impacts are reported in table A, available online as a supplement to the online version of this article at <http://www.ajph.org>. Other online tables present a summary of individual impacts reported for each study and list details of the interventions and study populations for each study [table C].)

### Improvements in Warmth and Energy Efficiency After 1985

Nineteen studies assessed health impacts following improvements in warmth or energy efficiency, or both (B. Heyman et al., unpublished data, 2007).<sup>21–31,33–38</sup>

*Intervention content, intervention integrity, study context, and study population.* The type of intervention included at least 1 of the following: insulation (roof or cavity wall or both), installation or upgrade of central heating system,

or replacement of an unflued with an improved flued heat source. Some programs included additional measures (e.g., light bulbs, domestic repairs, advice on receipt of appropriate state welfare benefits).

Improvements in housing conditions were reported in all but 3 studies.<sup>22,26,34</sup> Within most studies, there was considerable variation in the intervention delivered (as assessed by intervention integrity; see the box available as an online supplement), and interventions were often tailored according to need. For example, energy efficiency interventions ranged from minor heating repairs to the installation of central heating and insulation measures.

Most of the interventions were set in deprived areas. Four studies included only children,<sup>21,28,29,34</sup> and 2 studies included both adults and children.<sup>22,36</sup> Six studies targeted households where at least 1 member had a diagnosed cardiac or respiratory condition (Health Action Calderdale Kirklees and Wakefield, unpublished data, 2005),<sup>21,23,31,33,34</sup> and in 3 studies the majority of the population were elderly.<sup>25,31,35</sup>

*General health impacts.* Nine studies assessed general health impacts. In 4 well-conducted studies,<sup>21,23–25</sup> after the housing improvement,

measures of general health were better in the intervention group than in the control group; these differences were statistically significant. In 2 New Zealand randomized controlled trials,<sup>21,23</sup> general health was better after the intervention (poor or fair self-reported health odds ratio (OR), respectively, [OR]=0.480; 95% confidence interval [CI]=0.310, 0.740<sup>21</sup>; and OR=0.589; 95% CI=0.467, 0.743<sup>23</sup>). In one UK study,<sup>25</sup> Short Form-36 scores (100-point scale) for general health and physical functioning in the intervention group were better by 2.570 points (95% CI=0.870, 7.592) and 2.510 points (95% CI=0.620, 10.161), respectively, compared with the control group, but this result probably lacks clinical significance. Impacts in the less rigorous studies were unclear.<sup>30,33,35,36</sup>

*Respiratory health impacts.* Eleven studies reported respiratory impacts. The standardized effect sizes (ORs) for the respiratory outcomes derived from 5 controlled studies that reported relevant data<sup>21–23,25,27</sup> are presented in Figure 2. Heterogeneity among the outcomes and other aspects of the 5 studies prevent appropriate pooling of these data, and the data were therefore synthesized narratively.

Compared with the control group, there was improved respiratory health in the intervention group in the 2 New Zealand studies.<sup>21,23</sup> Improvement was reported for all the respiratory measures, mainly asthma symptoms, assessed for both adults and children. These differences were statistically significant for most measures, for example “sleep disturbed by wheeze” in children (OR=0.550; 95% CI=0.350, 0.850<sup>21</sup>; OR=0.57; 95% CI=0.400, 0.812<sup>23</sup>). Among the remaining European studies, a mix of positive, unclear, or conflicting respiratory impacts were reported regardless of study quality.<sup>22,24,25,27,28,30,34,36,38</sup>

*Mental health impacts.* Seven studies reported mental health impacts. All but one<sup>29</sup> of these studies<sup>23,24,27,30,31,33</sup> reported a positive impact; one of these studies was a well-conducted randomized controlled trial (for Short Form-36 score for low happiness, OR=0.560; 95% CI=0.409, 0.767).<sup>23</sup>

*Other illness or symptom impacts.* Ten studies reported illness or symptom impacts. The range of outcomes reported within this category was diverse, and there was no consistent effect reported for similar outcomes between studies. Within studies, the overall impact was

**TABLE 1—Measures of Standardized Effect (Intervention Group Compared With Control Group) Following Housing Improvement Interventions**

Outcome Category	Study (Year)	Study Grade	Specific Outcome	Intervention Group OR (95% CI)
<b>Warmth and energy efficiency improvements (after 1985)</b>				
General health	Howden-Chapman et al. <sup>21a</sup> (2008)	A	Poor or fair self-reported health	0.480*** (0.310, 0.740)
	Howden-Chapman et al. <sup>23</sup> (2007)	A	Poor or fair self-reported health	0.589† (0.467, 0.743)
Respiratory health	Howden-Chapman et al. <sup>21a</sup> (2008)	A	Sleep disturbed by wheeze	0.550*** (0.350, 0.850)
			Speech disturbed by wheezing	0.690 (0.400, 1.180)
			Dry cough at night	0.520** (0.320, 0.830)
			Wheeze during exercise	0.670 (0.420, 1.060)
	Howden-Chapman et al. <sup>23</sup> (2007)	A	Morning phlegm	0.640† (0.523, 0.784)
			Wheezing in past 3 mo	0.570† (0.467, 0.696)
			Cold or flu	0.545† (0.430, 0.691)
			Sleep disturbed by wheeze	0.570† (0.400, 0.812)
	Barton et al. <sup>22</sup> (2007)	A	Speech disturbed by wheezing	0.514** (0.310, 0.852)
			Asthma	0.946 (0.598, 1.496) <sup>d</sup>
			Bronchitis	1.007 (0.477, 2.127) <sup>d</sup>
	Platt et al. <sup>25</sup> (2007)	A	Other respiratory symptoms	1.010 (0.560, 1.820) <sup>d</sup>
			First diagnosis nasal allergy	1.520** (1.050, 2.200)
	Shortt et al. <sup>27</sup> (2007)	B <sup>b</sup>	Asthma <sup>c</sup>	0.568 (0.099, 3.254) <sup>d</sup>
Chest infection/bronchitis <sup>c</sup>			1.875 (0.495, 7.102) <sup>d</sup>	
Mental health	Braubach et al. <sup>24</sup> (2008)	A	Pneumonia or hypothermia <sup>c</sup>	3.593 (0.143, 90.361) <sup>d</sup>
			Depression	1.404 (0.329, 5.987)
Illness or symptom	Howden-Chapman et al. <sup>23</sup> (2007)	A	Low happiness (SF-36)	0.560† (0.409, 0.767)
			Low vitality (SF-36)	0.510† (0.408, 0.637)
			Stress or mental illness	0.261 (0.053, 1.299) <sup>d</sup>
Illness or symptom	Howden-Chapman et al. <sup>21a</sup> (2008)	A	Diarrhea	0.720 (0.450, 1.160)
			Ear infection	1.160 (0.680, 1.990)
	Barton et al. <sup>22</sup> (2007)	A	Vomiting	0.880 (0.550, 1.400)
			Arthritis	1.058 (0.533, 2.100) <sup>d</sup>
	Platt et al. <sup>25</sup> (2007)	A	Rheumatism	1.908 (0.829, 4.395) <sup>d</sup>
			First diagnosis of hypertension	0.770** (0.610, 0.972)
	Shortt et al. <sup>27</sup> (2007)	B <sup>b</sup>	First diagnosis of heart disease	0.690** (0.520, 0.916)
			“Other” illnesses <sup>c</sup>	0.568 (0.099, 3.254) <sup>d</sup>
			Arthritis <sup>c</sup>	1.619 (0.343, 7.641) <sup>d</sup>
				Angina <sup>c</sup>
<b>Rehousing or retrofitting with or without neighborhood renewal (after 1995)</b>				
General health	Kearns and Petticrew <sup>39</sup> (2008)	A <sup>b</sup>	Self-reported poor health	0.769 (0.500, 1.176)
			Long-standing illness	0.680 (0.440, 1.050)
			Health not improved since 1 y ago	0.787 (0.541, 1.163)
	Thomson et al. <sup>40</sup> (2007)	A	Fair or poor health	1.757 (0.777, 3.973)
			Lower SF-36 Physical Component Score	0.960 (0.437, 2.110)
	Barnes <sup>43</sup> (2003)	B <sup>b</sup>	Fair or poor health	0.273** (0.110, 0.682) <sup>d</sup>
Health somewhat or much worse than 1 y ago			0.356 (0.135, 0.942) <sup>d</sup>	
Health interferes with daily activities			0.516 (0.617, 3.730) <sup>d</sup>	
Mental health	Thomson et al. <sup>40</sup> (2007)	A	Physical or emotional problems with daily life (in past 4 wk)	0.338 (0.138, 0.829) <sup>d</sup>
			Lower SF-36 Mental Component Score	0.733 (0.333, 1.613)
	Barnes <sup>43</sup> (2003)	B <sup>b</sup>	Anxiety or depression self-reported	0.361** (0.152, 0.856) <sup>d</sup>

Continued

TABLE 1—Continued

Respiratory	Kearns and Petticrew <sup>39</sup> (2008)	A <sup>b</sup>	Wheezing in past y	1.040 (0.690, 1.560)		
			Kearns and Petticrew <sup>39a</sup> (2008)	A <sup>b</sup>	Asthma	1.039 (0.650, 1.661)
					Breathlessness	1.185 (0.459, 3.063)
					Persistent cough	1.093 (0.663, 1.800)
					Bronchitis	0.311 (0.032, 3.010)
Illness or symptom	Kearns and Petticrew <sup>39</sup> (2008)	A <sup>b</sup>	Sinus or catarrh	0.890 (0.480, 1.650)		
			Smoker	1.470 (0.849, 2.546)		
			Heavy drinker	0.610 (0.300, 1.240)		
			Less than 5 portions fruit and vegetables per d	0.794 (0.519, 1.215)		
			Kearns and Petticrew <sup>39a</sup>	A <sup>b</sup>	Chronic illness	1.039 (0.549, 1.966)
			Headaches	0.991 (0.604, 1.626)		
			Indigestion	0.941 (0.058, 15.145)		
			Sleeping problems	1.128 (0.618, 2.059)		
			Eczema	1.148 (0.683, 1.931)		
			Hay fever	0.990 (0.513, 1.913)		
	Barnes <sup>43</sup> (2003)	B <sup>b</sup>	Pain and discomfort	0.400 (0.170, 0.940) <sup>d</sup>		
			Limitations to mobility	0.533 (0.215, 1.322) <sup>d</sup>		
<b>Provision of basic housing needs in developing countries (after 1990)</b>						
Respiratory	Wolff et al. <sup>56a</sup> (2001)	C <sup>b</sup>	Respiratory infection	0.560 (0.310, 1.012)		
Illness or symptom	Aga Khan Health <sup>53</sup> (2001)	B	Illness in past winter	0.433 (0.257, 0.730)**		
	Wolff et al. <sup>56a</sup> (2001)	C <sup>b</sup>	Any illness	0.560 (0.347, 0.903)*		
			Malaria	0.730 (0.360, 1.480)		
			Gastrointestinal disorder	0.580 (0.260, 1.294)		
	Choudhary et al. <sup>52</sup> (2002)	B <sup>b</sup>	Malnutrition (first 6 mo of life)	0.739 (0.466, 1.170)		
<b>Rehousing from slums (before 1975)</b>						
Mental health	Wilner et al. <sup>58</sup> (1960)	A	Nervousness	1.157 (0.890, 1.504) <sup>d</sup>		
			Negative mood	0.912 (0.704, 1.182) <sup>d</sup>		
			Dissatisfaction with status quo	0.863 (0.663, 1.122) <sup>d</sup>		
			Potency (“nothing can be done to improve situation”)	0.814 (0.628, 1.055) <sup>d</sup>		
			Pessimism	0.815 (0.628, 1.056) <sup>d</sup>		
			Emotionality (not able to control temper)	0.796 (0.613, 1.034) <sup>d</sup>		
Illness/symptom	Wilner et al. <sup>58</sup> (1960)	A	At least 1 d of disability	1.145 (0.977, 1.342) <sup>d</sup>		

Note. OR=odds ratio; CI=confidence interval; SF-36=Short Form-36 questionnaire.

<sup>a</sup>Children only.

<sup>b</sup>Grade C for inadequate control for confounding or because a key confounder not previously accounted for emerged in analysis.

<sup>c</sup>Proportion of households as opposed to individuals.

<sup>d</sup>Estimated, as there was no indication of missing data for specific outcomes.

\*\* $P < .05$ ; \*\*\* $P < .005$ ; † $P < .001$ .

unclear because of conflicting findings across different outcomes.

**Socioeconomic impacts.** Seven studies reported socioeconomic impacts. The types of impacts reported included having reduced fuel bills and less time off from school or work and inviting people into the home.<sup>23,26,28,34,36</sup> Data from the qualitative research suggest that improving warmth and energy efficiency leads to increased use of the home for studying and leisure, increased privacy, and improved relationships between household members (see the

table available as a supplement to the online article)<sup>36,64–66</sup>

### Rehousing or Retrofitting With or Without Neighborhood Renewal After 1995

Of 11 identified studies of rehousing or retrofitting,<sup>39–47,49,63</sup> only one<sup>63</sup> reported qualitative data.

**Intervention content, intervention integrity, study context, and study population.** One study from the United States evaluated a program that provided improved housing conditions and also alleviated

overcrowding. This intervention also involved an affordable home ownership arrangement to assist those on the margins of home ownership (Habitat for Humanity).<sup>47</sup>

The remaining 10 studies evaluated programs of housing-led neighborhood renewal in the United Kingdom (“housing-led” refers to programs of residential neighborhood investment in which the major structural change is demolition and new build housing or housing retrofitting, but in which other neighborhood changes are also implemented); relocation to

TABLE 2—Summary of Studies Included in This Review and Their Reported Health Impacts

Study (Year)	Study Design	Study Grade	Change in Housing Condition	Intervention Integrity, Grade	Final Sample, Intervention/Control	Time Since Intervention	General Health Impact; No. of Outcomes	Respiratory Health Impact; No. of Outcomes	Mental Health Impact; No. of Outcomes	Illness or Symptoms Impact; No. of Outcomes
<b>Warmth and energy efficiency improvements (after 1980)</b>										
Heyman et al. (unpublished, 2007) <sup>a</sup>	Randomized controlled trial	A	Improvement*	C	~96/82	2 y	Unclear/mixed effects <sup>b</sup> , 2 outcomes			
Howden-Chapman et al. <sup>21</sup> (2008) <sup>b</sup>	Randomized controlled trial	A	Improvement**	C	175/174	4-5 mo	Improvement**	Improvement**; 11 outcomes		Unclear/mixed effects*; 4 outcomes
Barton et al. <sup>22</sup> (2007) <sup>c</sup>	Randomized controlled trial	A	Unclear/mixed effects**	C	14/13	<2 y	Improvement* <sup>d</sup> , 7 outcomes			Unclear/mixed effects* <sup>d</sup> , 2 outcomes
Howden-Chapman et al. <sup>23</sup> (2007) <sup>c</sup>	Randomized controlled trial	A	Improvement**	C	1689/1623	<1 y	Improvement**; 3 outcomes	Improvement**; 5 outcomes	Improvement**; 3 outcomes	
Braubach et al. <sup>24</sup> (2008)	Prospective controlled study	A	Improvement <sup>h</sup>	C	~210/165	5-8 mo	Improvement <sup>h</sup>	Improvement <sup>h</sup>	Improvement*; 4 outcomes	
Platt et al. <sup>25</sup> (2007)	Prospective controlled study	A	Improvement**	B	1281/1084	1-2 y	Improvement**; 2 outcomes	Unclear/mixed effects*; 2 outcomes		Improvement**; 2 outcomes
Lloyd et al. <sup>26</sup> (2008)	Prospective controlled study	B		C	9/27	1-2.5 y		2 outcomes		Improvement** <sup>d</sup>
Shortt and Rigkasa <sup>27</sup> (2007)	Prospective controlled study	B	Improvement**	C	46/54	1-3.5 y	Improvement**	Unclear/mixed effects* <sup>e</sup> , 3 outcomes	Improvement* <sup>b</sup>	Improvement** <sup>e</sup> , 3 outcomes
Somerville et al. <sup>28</sup> (2000) <sup>b</sup>	Prospective uncontrolled study	B	Improvement**	B	72	3 mo	Improvement**	Improvement**; 7 outcomes		
Hopton and Hunt <sup>29</sup> (1996) <sup>b</sup>	Prospective controlled study	B	Improvement**	C	55/77	5-11 mo	Improvement**		Unclear/mixed effects* <sup>e</sup> , 2 outcomes	Unclear/mixed effects* <sup>e</sup> , 11 outcomes
Warm Front Study Group <sup>30</sup> (2006)	Retrospective controlled study	C	Improvement <sup>h</sup>	C	1561/619	~3-5 mo	Improvement <sup>h</sup>	Unclear/mixed effects* effects*	Improvement** <sup>f</sup>	Unclear/mixed effects*
Allen (2005) <sup>33</sup>	Prospective uncontrolled study	C	Improvement <sup>h</sup>	C	16	<1 y	Improvement <sup>h</sup>		Improvement**	
Allen (2005) <sup>31</sup>	Prospective uncontrolled study	C	Improvement <sup>h</sup>	C	24	<3 y	Improvement <sup>h</sup>	Deterioration*	Improvement**; 3 outcomes	
Health Action Calderdale Kirklees and Wakefield (unpublished, 2005)	Retrospective uncontrolled study	C	Improvement <sup>h</sup>	B	102	2-8 mo	Improvement <sup>h</sup>			Improvement <sup>h</sup>

Continued

TABLE 2—Continued

Eick et al. <sup>34</sup> (2004) <sup>b</sup>	Randomized controlled trial	C	Unclear/mixed effects**	C	41	4–12 mo	Improvement***, 2 outcomes
Winder and Armstrong <sup>35</sup> (2003) <sup>a</sup>	Prospective uncontrolled study	C	Improvement <sup>b</sup>	C	72	14 mo	Unclear/mixed effects <sup>b</sup>
Caldwell et al. <sup>36</sup> (2001) <sup>c</sup>	Prospective controlled study	C	Improvement* <sup>d</sup>	C	302/110	6–12 mo	Improvement*** <sup>e</sup>
Green and Gilbertson <sup>37</sup> (1999)	Retrospective controlled study	C	Improvement <sup>b</sup>	C	111/94	~2–4 y	Unclear/mixed effects*, 3 outcomes
Iversen et al. <sup>38</sup> (1986)	Prospective controlled study	C	Improvement <sup>b</sup>	B	106/535	3–6 mo	Improvement* 3 outcomes
<b>Rehousing or retrofitting with or without neighborhood renewal (after 1995)</b>							
Kearns and Petticrew <sup>39</sup> (2008) <sup>c</sup>	Prospective controlled study	A	Improvement**	C	262/284	24 mo	Improvement* Deterioration*
Thomson et al. <sup>40</sup> (2007)	Prospective controlled study	A	Improvement**	B	50/50	12 mo	Improvement*, 2 outcomes
Critchley et al. <sup>41</sup> (2004) <sup>f</sup>	Prospective controlled study	A	Improvement <sup>b</sup>	B	246	1–12 mo	Unclear/mixed effects <sup>d,h</sup>
Thomas et al. <sup>42</sup> (2005) <sup>f</sup>	Prospective controlled study	B	Improvement**	C	585/759	22 mo	Unclear/mixed effects*** <sup>e</sup>
Barnes <sup>43</sup> (2003)	Prospective controlled study	B	Unclear/mixed effects**	C	45/45	18 mo	Improvement*, 4 outcomes
Evans and Layzell <sup>44</sup> (2002)	Prospective controlled study	B	Unclear/mixed effects <sup>b</sup>	C	17/17	6–18 mo	Improvement* Deterioration <sup>a,h</sup>
Halpern <sup>45</sup> (1995)	Prospective uncontrolled study	B	Improvement**	C	27	10 mo	Improvement** 2 outcomes
Blackman and Harvey <sup>46</sup> (2001) <sup>c</sup>	Prospective uncontrolled study	C	Unclear/mixed effects <sup>b</sup>	C	166	5 y	Deterioration*, 2 outcomes
Wells <sup>47</sup> (2000)	Prospective uncontrolled study	C	Improvement**	B	31	2–3 y	Improvement**
Ambrose <sup>49</sup> (2000)	Prospective uncontrolled study	C	Improvement**	C	227	4 y	Unclear/mixed effects*, 2 outcomes
<b>Provision of basic housing needs/developing country intervention</b>							
Cattaneo et al. <sup>51</sup> (2007) <sup>b,f</sup>	Retrospective controlled study	B	Improvement**	A	1980/2112	2–4 y	Improvement*** <sup>d</sup> , 2 outcomes

Continued

TABLE 2—Continued

Choudhary et al. <sup>52</sup> (2002) <sup>b</sup>	Retrospective controlled study	B	C	197/168	20 y	Improvement <sup>h</sup>
Aga Khan Health Service <sup>53</sup> (2001)	Retrospective controlled study	B	C	438/921	>1 y	Improvement**
Spiegel et al. <sup>54</sup> (2003)	Retrospective controlled study	C	C	896/807	1–4 y	Unclear/mixed effects**
Aiga et al. <sup>55</sup> (1999) <sup>b</sup>	Retrospective uncontrolled study	C	B	184/189	1–8 y	Improvement**
Wolff et al. <sup>56</sup> (2001) <sup>b</sup>	Retrospective controlled study	C	C	240/289	2.5 y	Improvement* Improvement** <sup>c</sup> ; 3 outcomes
<b>Rehousing from slums (before 1965)</b>						
Wilner et al. <sup>58</sup> (1960)	Prospective controlled study	A	B	1891/2893	<1 y	Improvement* <sup>d</sup> ; Deterioration* <sup>d</sup> ; 2 outcomes
McGonigle and Kirby <sup>60</sup> (1936) <sup>c,d</sup>	Prospective controlled study	B	C	152/289	5 y	Deterioration <sup>h</sup>
Ferguson and Pettigrew <sup>61</sup> (1954)	Retrospective controlled study	C	C	52/52	10–27 y	Improvement <sup>h</sup> , 4 outcomes
Chaplin <sup>62</sup> (1938)	Prospective uncontrolled study	C	B	23	8–19 mo	Improvement <sup>h</sup>

Note. Number of outcomes within each category synthesis is 1 unless otherwise indicated. For statistical tests, unless otherwise indicated, controlled studies tested for the difference between control and intervention groups at follow-up and uncontrolled studies tested for change since baseline. Synthesis of multiple outcomes within same outcome category: where multiple outcomes all report an effect in the same direction and with same level of statistical significance, we report the effect direction and indicate the overall level of statistical significance. Where direction of effect varies across multiple outcomes, we report the direction of effect and statistical significance where 70% of outcomes report similar direction and statistical significance; if more than 70% of outcomes report consistent direction of effect, we report no clear effect/conflicting findings. Where statistical significance varies, if the direction of effect is similar and more than 60% of outcomes are statistically significant, we report it as statistically significant; if one conflicting outcome is judged to be distinct from other outcomes or of less value or validity, we do not include the outcome or we report it separately.

<sup>a</sup>Narrative only, no data reported.

<sup>b</sup>Children only.

<sup>c</sup>Data for children also available.

<sup>d</sup>Difference in change between control and intervention group.

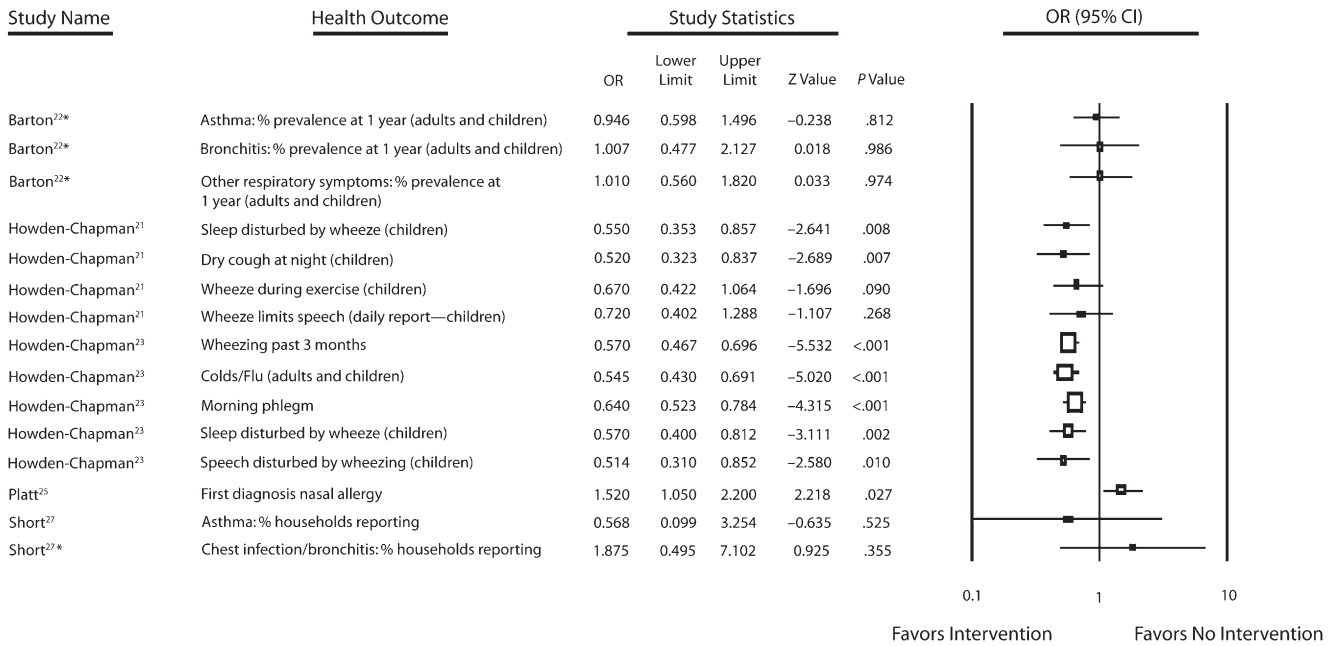
<sup>e</sup>Change within intervention group only.

<sup>f</sup>Subgroup analysis (presented in favor of main population alone).

<sup>g</sup>Area-level data not relating to study population alone.

<sup>h</sup>No statistics/data reported.

\* $P > .05$ ; \*\* $P < .05$ .



Note. CI = confidence interval; OR = odds ratio.

FIGURE 2—Forest plot of standardized effects on respiratory outcomes from controlled studies of warmth and energy efficiency improvements.

a new neighborhood was not part of this intervention. Although it is likely that measures for improvement of warmth were part of the intervention in each study, only 4 studies specifically reported that the intervention included upgrading or installing heating and energy efficiency measures.<sup>41,42,44,46</sup> Nine studies assessed changes in housing conditions, 6 studies reported improved conditions, and 3 studies reported no change.<sup>43,44,46</sup> Levels of intervention integrity (see the box available as a supplement to the online article at <http://www.ajph.org>) were often unclear, and it is likely that there was considerable variation within studies with respect to the extent of intervention delivered and improved conditions experienced.

All the UK interventions were area based, targeting deprived neighborhoods. The US study targeted individual homeowners on low incomes and with families.<sup>47</sup> Only 1 study reported impacts for children as well as adults.<sup>46</sup> A narrative synthesis of health impact data from the 10 UK studies of similar programs of housing-led neighborhood renewal is presented in the following paragraphs.<sup>39–49,63</sup>

**General health impacts.** Six studies reported general health impacts. Impacts on general health

outcomes were unclear. The better-quality studies (grade A or B) either reported small improvements that were not statistically significant<sup>39,40,43</sup> or were not accompanied by supporting data or statistics.<sup>41,44</sup> One study (grade C) reported a statistically significant increase in self-reported poor health (+12.3%) among adults but not children.<sup>46</sup>

**Respiratory health impacts.** Three studies (grade B or C) assessed respiratory impact across a number of outcomes.<sup>39,46,49,67</sup> There was little evidence of improvements in respiratory health, and in each of these studies some of the respiratory outcomes were better in the control group following the intervention.

**Mental health impacts.** Nine studies assessed mental health impacts. Each of these studies assessed changes in mental health. In the 3 more rigorous studies (grade A),<sup>39–41</sup> there was no clear impact on Short Form-36 measures of mental health, whereas in the less rigorous studies, statistically significant positive impacts were reported across a range of measures.<sup>42–46,49</sup>

**Other illness or symptom impacts.** Three studies assessed other types of health or illness impacts. The range of outcomes assessed was diverse; a mix of positive and negative impacts

was reported, and there was no clear overall indication of benefit or harm.<sup>39,43,44</sup>

**Socioeconomic impacts.** Three studies reported socioeconomic impacts. In 2 studies (one grade A and one grade B), residents reported that they were more able to afford basic essentials, suggesting reduced financial strain.<sup>39,41</sup> No other studies reported socioeconomic impacts attributable to the improvement.

### Provision of Basic Housing Needs in Developing Countries After 1990

Six studies from the developing world were identified that assessed provision of basic housing needs.<sup>51–56</sup> The interventions ranged from replacing mud floors with cement to the provision of warmth and energy efficiency measures. The diversity of the interventions prevents an appropriate synthesis of the health impact data within this intervention category; however, it would appear that the investment in providing basic housing needs can lead to significant reductions in illness among adults and children. Some of these impacts may be long-term, benefiting the next generation of residents. No adverse impacts were reported in these studies. Improvements to basic housing amenities

have also been associated with improvements in socioeconomic opportunities.<sup>52,55</sup>

### Rehousing From Slums Before 1965

Four studies assessed the health impacts of rehousing residents from slum conditions. The studies were carried out over 40 years ago in the United Kingdom<sup>60,61</sup> and the United States.<sup>58,62</sup> None of the reported impacts were statistically significant, and no 2 studies assessed similar outcomes. One study (grade A) reported beneficial impacts on mental health but an increase in disability and illness episodes.<sup>58</sup> Another study reported adverse impacts on adult mortality but not infant mortality. Impacts on housing conditions were not clearly reported in this study, but rent was reported to have doubled, causing severe financial hardship among residents.<sup>60</sup>

### Association Between Study Quality and Reported Impacts

Overall, study quality or other specific methodological characteristics of the studies did not appear to be related to types or directions of effects reported. However, the small number of studies within each intervention category and the extreme heterogeneity in study methods make it difficult to detect a relationship between reported outcomes and study methods.

## DISCUSSION

Since our previous review, published in 2001, there has been both an increase in the quantity of data in this field and an improvement in the quality of available data. In particular, the available evidence on the health impacts of improvements in warmth and energy efficiency has improved. Most of the evidence comes from the United Kingdom; only 3 studies from North America were identified.<sup>47,58,62</sup>

Improvements in general, respiratory, and mental health were reported following warmth and energy efficiency improvements; reports of worsening health were rare. Significant health improvements were reported in 2 large randomized controlled studies of energy efficiency retrofitting in New Zealand; however, health impacts following similar retrofitting in the United Kingdom were less obvious. There were few well-conducted studies of housing-led neighborhood renewal programs. A mix of conflicting (positive and negative) and unclear

impacts was reported regardless of study quality, suggesting that the size and type of health impacts following programs of housing-led neighborhood renewal remain unknown.

Interventions to provide basic housing amenities in the developing world may generate health improvements, especially among children.

Few studies assessed the impacts of housing interventions on socioeconomic determinants of health. There is some suggestion that improvements in warmth and energy efficiency lead to reduced heating costs, less time off from school or work, and increased use of the home for studying and leisure, and may also increase privacy and improve relationships between household members. Although none of the studies reported differential impacts by socioeconomic status, all but 4 studies (Health Action Calderdale Kirklees and Wakefield, unpublished data, 2005)<sup>27,32,38</sup> focused on low-income households. Our findings, therefore, are of particular relevance to housing policies aiming to contribute to wider strategies to improve the health of the worst off and reduce health inequalities.

### Strengths and Limitations

The increased quantity and improved quality of studies identified in this review increased the utility of the synthesis. It was possible to review distinct groups of interventions and also to group them by developing versus developed country context and by time period. Despite improvement in the quality of studies assessing the health impacts of housing interventions, the quality of evidence in this field remains variable: only 8 studies (19%) were judged to have minimal sources of bias (overall methodological grade A).

Details of intervention implementation, intervention integrity, and contamination of control group were rarely reported; these are likely to be important sources of bias. In 7 studies, authors reported that some houses in the control group had received the intervention.<sup>34–36,41,42,51,58</sup> In around half of studies that reported housing conditions at baseline (7 of 15), most of the intervention households reported having no housing problems at baseline.<sup>27,38,40,44,46,50,67</sup> Contamination of the control group and the wide within-study variation in the housing improvements delivered (i.e., in the intervention integrity) probably limited the ability to detect impacts,

and this may have led to an underestimate of the efficacy of housing improvement on health. Subgroup analyses examining the impacts on those experiencing the greatest improvement in housing conditions would be valuable, but this is rarely possible because of small sample sizes.

### Short-Term Health Impacts Following Housing Improvement

Housing improvement addresses only one aspect of deprivation, and it may not be realistic to expect to see health improvement in the relatively short time frame of most evaluations. However, the varying levels of potential for benefit and of control for confounding factors described here may have led many studies to underestimate the full potential for health improvement.

The use of more-rigorous study methods has previously been associated with underestimates of effect size,<sup>68</sup> but in the studies reviewed here, 2 of the better-quality studies reported larger effects.<sup>21,23</sup> Further scrutiny may offer an explanation for the clearer health improvements reported in the New Zealand studies compared with the less-rigorous UK studies. The New Zealand studies targeted individuals with existing respiratory disease, and baseline housing conditions were poor across the study population. Despite cold winters and levels of excess winter mortality similar to those in the United Kingdom,<sup>69</sup> insulation and central heating are rare in New Zealand and many houses are constructed from poorly insulated weatherboard.<sup>23</sup> In addition, in contrast to the UK studies, the New Zealand team had strong links with housing agencies, allowing a measure of control over intervention implementation and ensuring recruitment of eligible participants.<sup>70</sup>

### Implications of Available Evidence From Intervention Studies

The greatest potential for investment in housing as a health improvement strategy appears to lie in targeting improvements in warmth at vulnerable individuals who have poor health and live in poor housing. Area-based investment, which targets area need rather than individual need, may benefit those in most need within the area, but the benefits may be concealed when assessed at an area level. National- or state-level data on housing

conditions—for example, the US housing survey<sup>71</sup>—are invaluable resources to help identify the types and locations of households in which improvements in warmth have the greatest potential to generate health gains. Prioritizing the type of housing improvements required will also need to be tailored to local conditions, such as climate, but evidence on the health impacts of interventions that do not include improvements in warmth is sparse.

Many of the studies in this article demonstrate that “naturally occurring” programs (i.e., they represent ongoing opportunities for well-conducted research) of housing improvement can be evaluated to assess health impacts through use of rigorous study designs with comparison groups, including randomized controlled trials. Data from large-scale studies on the extent of change in housing conditions at an individual level are needed to facilitate the investigation of a dose–response effect. This, in turn, could shed light on a possible threshold level for the potential for investment in housing to lead to health improvement. In addition, assessment of socioeconomic impacts associated with housing improvement is needed to investigate the potential for investment in housing to contribute to a longer-term strategy tackling health determinants and reducing health inequalities.

## Conclusions

There is now stronger support for the hypothesis that housing improvement can improve health in the short term than there was at the time of our 2001 review. Improvements in warmth, in particular, can lead to tangible improvements in health, but the potential for health benefits may depend on baseline housing conditions and careful targeting of the intervention. The health impacts of area-based programs of housing improvement remain unclear, but there is little to suggest that housing improvement is detrimental to health. It is important that the uncertainties around the potential for health improvement are not confused with evidence of no health impact. The potential for longer-term health impacts remains but has rarely been investigated. Moreover, other issues of social justice and energy efficiency alone provide justification for providing decent and affordable housing.

Despite improved levels of evidence, large-scale, experimental, and quasi-experimental

studies, including prospective controlled studies, are still needed. These studies need to provide more-detailed data on intervention integrity, differential health impacts by socioeconomic status, and the socioeconomic impacts associated with housing improvement. Such data could provide valuable evidence on the types of housing improvements that are most likely to lead to health improvements and, in the longer term, to reduce health and social inequalities. ■

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## Contributors

H. Thomson prepared the protocol and led each stage of the study. S. Thomas and E. Sellstrom acted as co-reviewers. H. Thomson, E. Sellstrom, and M. Petticrew developed the critical appraisal tool. H. Thomson and S. Thomas tabulated the data and prepared the narrative synthesis, with comments from M. Petticrew. H. Thomson prepared the first draft of the article, and all authors contributed to subsequent drafts.

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No protocol approval was needed for this study.

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