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Fuel poverty and human health: A review of recent evidence

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ABSTRACT

The health impacts of tackling fuel poverty are reviewed, drawing primarily on large-scale studies completed in the last 10 years. Although physical health effects on adults appear to be modest, caregivers and children perceive significant impacts on children's respiratory health. There also appear to be significant effects on the physical health of infants, particularly on weight gain and susceptibility to illness. Mental health effects on adults emerge as significant in most studies, as do mental health impacts on adolescents. Mental health effects on children have, as yet, never been systematically assessed. Whilst several studies are methodologically rigorous, with some also based on very large samples, methodological problems remain. In future evaluations of health impacts, clinical outcomes could be more comprehensively augmented with measures that extend beyond physical health. These include measures reflecting quality of life, changes in patterns of social engagement and daily routine, and their concomitant impacts on mental wellbeing, Such measures may provide more rounded insights into the potential health impacts of tackling fuel poverty and—equally as important for policy and practice—the processes by which these impacts become manifest.

0. Introduction

Policymakers worldwide are paying increasing attention to indoor living environments, as a consequence of a growing body of evidence linking buildings—especially housing—to human health (Hood, 2005). In colder climates, living in a comfortably heated home is commonly viewed as protective for human health, and the World Health Organization recommends a minimum temperature of 21 °C in living rooms, and 18 °C in all other rooms (WHO, 2007). In the United Kingdom, households that are unable to maintain these standards of thermal comfort and safety are described as living in *fuel poverty*. Fuel poverty is measured using a complex algorithm, BREDEM-12. This calculates the cost of heating a home and takes into account household income, the current cost of heating fuel, and the energy efficiency of the house. Households which require 10% or more of their income to attain WHO standards are rated as being in fuel poverty (Sefton and Chesshire, 2005). Since relatively few UK households can afford to spend such a substantial proportion of their income on domestic heating, a large percentage of fuel-poor people live in homes that are persistently cold and damp (Liddell, 2008). Living for long periods of time in such cold and damp conditions—rather than being fuel-poor per se—is thought to generate significant health risks.

Elsewhere in the world fuel poverty is described using different terms and different measures. Terms include *energy insecurity* (United States) and *lacking affordable warmth* (a term used in 20 countries coordinated by the Organization for Economic Co-operation and Development). In most regions of the world, *lacking affordable warmth* is measured through household surveys, with items scoping how often households go without heating on cold days, whether other needs are left unfulfilled in order to heat the home, and whether the home energy supply has been disconnected because of debt (e.g. Eurostat, 2005).

The combination of prolonged winters and poor housing stock mean that significant proportions of European and North American households currently live in cold and damp homes. Based on the BREDEM-12 method, 12% of households in England were fuel poor in 2006, 21% in Wales, 24% in Scotland, and 34% in Northern Ireland (NIHE, 2008). At the last estimate, and using the OECDs definition of affordable warmth, 6% of homes in France lacked affordable warmth, 7% in Ireland, 11% in Italy, and 15% in Belgium (EU-SILC, 2005). This makes fuel poverty a common challenge throughout the Northern Hemisphere, and for this reason most countries (as well as the European Union) have recently developed policies intended to reduce fuel poverty, most notably through enhancing the energy efficiency and insulation quality of houses, old and new (e.g. EPEE, 2009).

1. Fuel poverty and mortality risk

Until recently, the primary health risk known to be associated with excess cold was to life itself. Increased rates of mortality during cold weather were first noted many years ago (e.g. Young,

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1924). They have since been confirmed through many studies of "*excess winter mortality*" in which the number of deaths occurring during winter months is compared with deaths during the rest of the year (e.g. Analitis et al., 2008). Broadly speaking, significantly more deaths occur during winter (e.g. Healy, 2003). Cold indoor temperatures are strongly implicated in this effect, in that risks are especially great for residents of poorly insulated homes (Wilkinson et al., 2007). This helps account for countries such as Italy and Greece having significantly higher excess winter mortality rates than do more northerly countries such as Finland and Sweden (Barnett et al., 2005); although the latter group have colder winters, they also have better standards of domestic insulation and lower rates of fuel poverty (Healy, 2004).

Cold-related deaths occur mostly through changes in blood pressure and blood chemistry during cold weather, which in turn increase the risk of catastrophic cardio- or cerebro-vascular events such as strokes, myocardial infarctions or pulmonary embolisms (Crawford et al., 2003). The immune system is also suppressed, increasing the risk of infections (Howieson and Hogan, 2005).

Whilst many studies of excess winter mortality exist, their preponderance should not be taken to imply that the effects of cold temperatures are either catastrophic or non-existent, i.e. that people either die from cold, or survive unharmed. More recently, studies have begun to examine the enduring and potentially cumulative health effects that might be associated with living in cold conditions. These include increased risk of influenza, pneumonia, asthma, arthritis, and accidents at home (WHO, 2007). As evidence for a broader spectrum of health impacts became evident, preventable health impacts became the primary rationale for tackling fuel poverty in many different parts of the world (Wilkinson et al., 2007).

As a consequence, many countries now have policies which protect their more vulnerable citizens from cold-related health risks (see Morgan, 2007). In the UK these policies are collectively known as the UK Fuel Poverty Strategy (BERR, 2001). The Strategy sets out targets and timelines for eliminating fuel poverty, with an overall target to eradicate fuel poverty by 2018. In the first phase (2001–2010), priority has been given to the three groups deemed most vulnerable to the effects of fuel poverty. These are people over 60 years old, people living with disability or long-term illness, and families with children. In the second phase (2010–2018) non-vulnerable groups will be prioritised.

The UK Fuel Poverty Strategy provides funding for improving the energy efficiency of housing stock. It achieves targets through progressively more stringent regulations that govern new buildings, and a programme of retrofitting existing homes (i.e. installing better heating and insulation). Human health is construed as the main beneficiary of the Strategy. This is reflected in the extent to which health features in the 158-page Strategy document—the word "health" appears 238 times—and in the Strategy's declared:

> first priority … to ensure that by 2010 no older householder, no family with children, and no householder who is disabled or has a long-term illness need risk ill health due to a cold home (BERR, 2001, p. 10).

The Strategy begs an obvious question, namely: can policies which invest in actions so indirectly related to human health (the Fuel Poverty Strategy constitutes, after all, a housing regeneration policy) be expected to deliver significant health impacts? The present paper critically reviews the recent evidence base in order to address this question. The question has relevance for a variety of strategic areas, including policies related to energy efficiency, fuel poverty, climate change, health, housing and social justice (Thomson et al., 2009).

2. Fuel poverty and illness—the core studies 2000–2009

Housing intervention studies have seldom produced incontrovertible evidence of significant and sustained human health gains, largely due to small sample sizes and a variety of methodological limitations (Rudge and Gilchrist, 2005). However, 5 recent research evaluations of housing and human health, which form the central focus of the present paper, prove exceptions to the rule. Brief details of them are contained in Table 1. The first two evaluations were integral elements of the UK's Fuel Poverty Strategy, namely the Warm Front evaluation (which monitored the health impacts of retrofits in England and Wales) and the evaluation of the Central Heating Programme (which did the same in Scotland). The third was carried out in New Zealand and consisted of two phases. A home insulation programme was evaluated first, with impacts on adults and children being measured; thereafter homes of children with asthma were given a home heating package and impacts on children's respiratory health monitored. The remaining two studies focused exclusively on children, and were more concerned with the effects of cold and damp housing on health, i.e. they did not address the issue of fuel poverty per se. One compared infant development in low-income USA households which either received, or did not receive, a winter fuel supplement. The other was carried out in England and examined the health correlates of cold and damp housing on child and adolescent wellbeing.

These 5 studies form the centre of this review, being the only ones which:

(a) have been published between 2000 and 2009,
(b) focus explicitly on the impacts of cold and damp housing on human health,
(c) use a rigorous methodology and study design,
(d) have sample sizes exceeding 2000 participant households.

Taken together, these criteria provide stringent constraints and ensure that the review is structured around recent publications of the highest quality. Details of these 5 key studies are given below and are contained on Table 1.

Of course, many other studies concerned with the health impacts of cold and damp housing have been published during the same period, some of them of equal rigour in terms of method and design. However, these were considerably smaller in terms of sample size, geographical focus, and the range of outcomes investigated. In this review, reference to these smaller studies has been woven into the structural framework provided by the 5 larger-scale studies.

2.1. Warm front studies

The UK Fuel Poverty Strategy was implemented under the name Warm Front in England, and in Wales as the Home Energy Efficiency Scheme (HEES). The evaluations which ran alongside the English and Welsh schemes used longitudinal, cross-sectional, and qualitative research designs. The first two capitalised on the natural accumulation of households on waiting lists, and overcame ethical concerns which would have arisen had households being randomly allocated to experimental and control groups (Green and Gilbertson, 2008). A total of 231 households were monitored longitudinally, with a time lapse of approximately 1 year between data collected in the pre- and post-intervention

Table 1
Summary of the 5 large-scale studies.

Study	Warm Front	CHP	HIHS and HHHS	NATCEN	C-SNAP
Location	England and Wales	Scotland	New Zealand	England	5 cities, USA
Date collected	2001–2003	2002–2006	2001–2002	2001–2005	2000–2006
Number of homes and participants	2454 homes 2454 participants	2365 homes 2365 participants	HIHS: 1128 homes 3312 participants HHHS: 349 homes 349 participants	6431 homes 13814 participants	7074 infants from 7074 homes
Method and allocation of participants	(a) All participants assessed before intervention. Then Intervention n=1192 Wait-listed n=1262 (b) Longitudinal n=231 and 1600[a] (c) Qualitative n=49	All participants assessed before intervention. Then Intervention: n=1281 Wait-listed: n=1084	HIHS All participants assessed before intervention. Then Intervention: n=1689 Wait-listed: n=1623 HHHS 349 children with newly insulated homes from Phase 1. Given heaters: n=175 Wait-listed: n=174	Longitudinal panel study	Cross-sectional Receiving winter fuel payments n=1132. No payments n=5942
Interval baseline to follow-up	1 year	2 years	HIHS: 1 year HHHS: 1 year	5-year longitudinal study with annual data collection	n/a
Sample	Adults mainly over 60	Adults mainly over 60	HIHS: Adults and children HHHS: Children	Children	Infants
Health outcomes	Mortality GHQ12 SF-36 Indoor T°'s	22 Self-reported physical health outcomes SF-36	HIHS Self-reported physical health SF-36 HHHS Caregiver and child health reports	Caregiver- and self-reported mental and physical health	Hospital attendance Weight-for-age. Caregiver reports of infant status

[a] Indoor temperature monitoring only.

phases. These were among the earliest recipients of home heating upgrades. A further 1192 homes were monitored pre-intervention as they waited for home upgrading, and 1262 different homes were monitored post-intervention. Forty-nine of the households also participated in the qualitative research arm.

Data were collected between 2001 and 2003. The health impact evaluations focused on the physical and mental health of adults, measured primarily through the General Health Questionnaire (GHQ12) and the Health Survey Short Form (SF-36). Evaluations were confined to impacts on adults, most of them over 60 years old.

Applicants for the English and Welsh schemes were obliged to have house surveys undertaken to assess their eligibility. Taking advantage of the surveys, evaluators also made use of baseline indoor temperature data gathered from 1600 households. These households were then followed-up over two subsequent winters to permit a more explicit evaluation of the relationship between fuel poverty measures, changes in indoor temperature, and human health.

2.2. Scottish Central Heating Programme (CHP)

CHP was evaluated through a study which compared 1281 households that were retrofitted (these were monitored 2 years after the home improvements had been carried out) with 1084 households who remained on the CHP waiting list. Data were collected between 2002 and 2006. As with Warm Front, physical and mental health status was assessed using the SF-36. A wide range of other physical health indicators was also monitored, e.g. self-reports of allergies, blood pressure, use of medications, smoking, drinking, etc. Evaluation was confined to adults, most of them over 60 years old.

2.3. New Zealand studies (HIHS and HHHS)

At the same time as Warm Front and CHP were being evaluated in the UK, a similar project was being evaluated in 1128 New Zealand homes, namely the Housing, Insulation and Health Study (HIHS). New Zealand is at the upper end of the international range for excess winter mortality (Davie et al., 2007), and the average daytime winter temperatures in the retrofit region (16 °C) meant that homes required heating to attain WHO standards of thermal comfort and health. Although no screening for fuel poverty was made in recruiting participants into the study, the sample comprised low-income households living in wooden homes with no insulation; unlike Warm Front and the Scottish CHP, at least one resident per household had a respiratory health problem which meant that the scheme was targeted towards households where there was a known health risk from living in cold and damp conditions. In Phase 1 (HIHS), households were randomly assigned to experimental and control conditions, with the former having insulation and draught-proofing installed. Data were collected from both groups at the start of retrofitting and then a year later (2001 and 2002). Participants included all residents over the age of 11 years; caregivers also completed questionnaires for infants and children. As with the English and Scottish studies, health status was assessed using the SF-36. Days off school, GP's visits, and hospital admissions were also monitored.

Phase 1 was evaluated a year after the retrofit. Thereafter, Phase 2—the Housing, Heating and Health Study (HHHS) began, focusing on homes containing children with asthma. These homes were entered into a randomised controlled trial in which half (n=175) were supplied with a home heating system and followed-up a year later. They were compared with 174 controls. Both groups, having already participated in Phase 1, had insulation measures already in place, but the experimental group went on to receive a heating system.

2.4. NATCEN

The National Centre for Social Research (NATCEN) carried out a longitudinal study of housing conditions and their association with English children's wellbeing between 2001 and 2005 (Barnes et al., 2008). The study gathered data on 6431 children every year for 5 years using caregiver interviews for under 11-year olds, and self-completed questionnaires for adolescents. Fuel poverty was not assessed using the UK convention (i.e. the BREDEM-12 algorithm). Instead, caregivers were asked each year—over 5 consecutive years—whether they had been able to keep the home warm during the previous winter. They were also asked about the presence/absence of damp and mould. This measure resembles the one customarily used in the USA and most OECD countries. In 2005, 5% of caregivers in the NATCEN study reported that they had experienced difficulty heating their home in the previous winter, an estimate which correlates closely with the official fuel poverty rate for England in 2006 which was based on the BREDEM-12 formula (i.e. 6%) (EHCS, 2006).

2.5. C-SNAP

Results from the US Children's Sentinel Nutritional Assessment Programme (C-SNAP) yielded valuable insights into the potential impacts of tackling fuel poverty. Data were collected amongst low-income caregivers and their infants in 5 cities between 2000 and 2006. Caregivers (n=7074) were interviewed using a 4-item Home Energy Security Indicator which explored the extent to which homes had foregone heating in the last 12 months. The anthropometric and health status of infants (0–3 years old) was also assessed, and caregivers rated their infant's developmental status. In addition, comparisons were made between two groups of children, viz. those whose homes received a substantial winter heating subsidy (n=1132) and those that did not (n=5942). Whilst all of the children were eligible for subsidy, subsidies were allocated randomly to low-income families until such time as the subsidy fund ran out, approximating a natural experiment.

2.6. Summary

Findings from these 5 recent large-scale studies are collated and reviewed here for the first time, these findings being interwoven with results from smaller but recent studies of comparable methodological rigour where relevant. The aim is to collate an evidence base concerning the potential impacts that tackling fuel poverty may have on human health. The evidence yields insights into both physical and mental health impacts associated with tackling fuel poverty, and maps changes across the age spectrum from infants to senior citizens. In the interests of providing a conservative summary, the review is largely confined to empirical outcomes. An exception has been made when reviewing potential impacts on mortality. None of the studies were powered to detect mortality impacts, these being very small effects which would require much larger sample sizes. However, Warm Front modelled data to estimate potential impacts, and details of this are reported here.

Additionally in the review, only results which were statistically significant at $p \leq 0.05$ are considered to indicate effects (i.e. trends or non-significant patterns which studies sometimes refer to have been ignored).

3. Changes in physical health and tackling fuel poverty: Adults

These were investigated in evaluations of Warm Front, the Scottish Central Heating Programme, and the HIHS in New Zealand.

3.1. Warm front

As just mentioned, none of the 5 studies collected data on mortality, since they were not powered to detect effects of such a relatively small magnitude. However, Warm Front attempted to impute mortality effects based on other UK studies (e.g. Wilkinson et al., 2004). Heating and insulation improvements were estimated to be associated with an average increase of 10 days to the life expectancy of men and 7 days to the life of women (Green and Gilbertson, 2008). The authors concluded:

> These extra few days may seem negligible, but grossed up over many beneficiaries, the impact is thousands of life years saved each year (p. 18).

Further analyses indicated that the effects on mortality depended on whether householders increased their indoor temperatures after retrofitting. Approximately three-quarters of recipients increased their indoor temperatures to levels approximating WHO standards for health and safety (Critchley et al., 2007). These householders subsequently showed no significant increase in mortality risk when outdoor temperatures fell. The remainder of householders—who did not increase their indoor temperatures after improvements—had an increased mortality risk of 2.2% for every 1 °C that temperatures fell outdoors (Green and Gilbertson, 2008). These findings highlight the importance of being able to assess whether the occupants of retrofitted homes invest energy efficiency savings in improved warmth or not. If savings are used in other ways (for example to purchase food or other goods), then improvements in physical health and mortality risk may be less likely to emerge. The same 2.2% increase in mortality risk per 1 °C had been previously noted in a retrospective study using the 1979–1998 mortality database of Northern Ireland (Crawford et al., 2003).

The Warm Front evaluation found little in the way of any other detectable impacts on the physical health of adults. A rare exception was a significant difference in one of 4 self-assessed physical health measures from the SF-36 (i.e. *general health*). The evaluators point out that most retrofitted homes had only had home improvements installed a year previously, which may have limited the study's potential to detect physical health effects. They concluded, therefore, that the research "*signals probable improvements in physical health further down the timeline*" (Green and Gilbertson, 2008, p. 15). There is room for scepticism concerning this conclusion. Adverse effects of living in poor housing are cumulative over time and become progressively more difficult to treat as people age (Marsh et al., 1999). Health problems might have already become entrenched and intractable in the predominantly elderly sample that participated in the Warm Front evaluation.

3.2. Scottish Central Heating Programme (CHP)

Here, participants were monitored for self-reported physical health outcomes 2 years after intervention. Compared with the wait-listed control group, the intervention group had significantly different scores on 4 of 22 health outcomes, namely fewer first diagnoses of heart disease and fewer first diagnoses of high blood pressure, as well as better scores on two sub-scales of the SF-36. One of the SF-36 differences was for self-assessed *general health*, corroborating Warm Front's findings. However, this perception was not corroborated by participants' responses to questions about incidence of colds/influenza, other respiratory problems, eczema, or use of health services, all of which failed to distinguish between recipients of CHP and those still on the waiting list. The incidence of longstanding illnesses, disabilities, drinking, smoking, and use of medications was also the same across the two groups. Self-assessed *physical functioning* scores (from the SF-36) were better amongst CHP recipients however, which suggested that recipients of the CHP intervention might have been experiencing better mobility and levels of activity post-intervention. This possibility seems to be borne out by the results of a smaller study undertaken in 2 communities in Northern Ireland, where the self-reported constraints imposed by arthritis and rheumatism were significantly reduced following the installation of insulation and heating (Shortt and Rugkåsa, 2007). Nevertheless, taken overall, the results led CHP evaluators to conclude that it was "*prudent to regard the direct impact of the CHP on health as limited*" (Platt et al., 2007, p. 42).

3.3. HIHS New Zealand

In common with Warm Front and CHP, the New Zealand HIHS reported improvements in SF-36 scores for self-assessed *general health*. In addition, the self-reported incidences of wheezing and colds/influenza halved. Respondents also reported significantly fewer days off work. Fewer visits to GP's were self-reported too, although this proved difficult to corroborate when GP consultation records were reviewed later on (Howden-Chapman et al., 2007).

3.4. Summary

It is possible that the studies were not sufficiently powered to detect changes in the physical health of adults, which may be a problem of sample size, compounded by the many confounders and variations that prevail in natural experiments of this kind. This possibility is strongly supported by larger-scale population-based research studies, in which hospital episodes across whole countries, cities or boroughs are monitored as a function of temperature. Here strong effects emerge. In a World Health Organization study carried out in 23 countries, for example, UK sites (Belfast and Glasgow) showed high temperature-related hospital admission rates for coronary events (fatal and non-fatal), with Belfast showing the highest temperature-related incidence of all the countries monitored. The authors conjecture that this effect may be largely a function of poor housing conditions (Barnett et al., 2005). Similarly, in a study examining 3378 emergency hospital admissions for respiratory illness in the London borough of Newham, rates of admission showed a highly significant association with season (Rudge and Gilchrist, 2005), with the association being strongest in output areas that had the highest prevalence of fuel poverty risk. Despite the poorer quality of their fuel poverty measures, these large-scale epidemiological studies may have greater potential to detect associations between fuel poverty and health, by virtue of their larger sample size and their explicit focus on episodes of cold-related ill health which require hospital treatment.

4. Changes in physical health and tackling fuel poverty: Young people

These were investigated in both of the New Zealand studies (HIHS and HHHS), as well as in NATCEN and C-SNAP.

4.1. New Zealand HIHS

In the first phase of the New Zealand intervention (HIHS), when homes were insulated, caregivers reports suggested that children had 15% fewer days off school than did wait-listed control children. The authors speculate that this might be attributable to respiratory ailments being less prominent once cold, damp conditions had improved (Howden-Chapman et al., 2007). Findings from an earlier evaluation of tackling fuel poverty, which monitored a small group of English children (n=72), corroborated this: fewer days off school were accounted for exclusively by decreases in cold-related ailments, and not by ailments such as diarrhea or summer hay fever (Somerville et al., 2000).

4.2. NATCEN

NATCEN results lend further weight to the association between children's respiratory health and tackling fuel poverty. When many other factors had been accounted for (e.g. age, gender, ethnicity, SES, and caregiver characteristics such as work status, health status, and education) respiratory problems were more than twice as prevalent in children that lived for 3 years or longer in homes that lacked affordable warmth (15%), compared with children who had never lived in homes that were hard to heat during the previous 5 years (7%). For children who had lived at least 3 years in homes that were cold and damp, 15% had respiratory problems compared with 6% of children that had never lived in homes that were cold and damp (Barnes et al., 2008).

4.3. New Zealand HHHS

Phase 2 of the New Zealand programme shed further light on these findings. Children who had a medical history of asthma were entered into a second randomised controlled trial, in which half received a new non-polluting heating system at home whilst 174 did not. At follow-up a year later, caregivers of the experimental group reported significant improvements in 14 of 28 measures (e.g. coughing, wheezing, use of inhalers, visits to doctor or pharmacist for asthma). Despite this, no difference could be found when the 2 groups were compared on clinical measures of lung function (i.e. peak expiratory flow rate and forced expiratory volume in 1 s). The authors of the study caution against pitting self-report against clinical evidence in the context of asthma, citing evidence that self-report measures have been found to be better discriminators of control than peak flow measures (Juniper et al., 2000). In addition, it is possible that clinical changes in children's lung function may take longer than a single winter to emerge. Nevertheless the authors are cautious in their interpretation of these findings, concluding that "*a possibility remains that no effect exists*" (Howden-Chapman et al., 2008, p. 6).

4.4. C-SNAP

Less doubtful perhaps are findings from the C-SNAP study of infants and children under 3 years old. When many other factors had been accounted for (e.g. mother's education, ethnicity, marital status, employment, etc.), infants from low-income families who received a winter fuel subsidy had significantly higher weight-for-age scores and lower nutritional risk for depressed growth than did those from homes without a fuel subsidy. They also had lower odds for attending emergency paediatric units on the days when data collection was taking place, and were rated by caregivers as being in better health and of more advanced developmental status (Frank et al., 2006).

Since infancy is a period of rapid growth, it is also a period of high calorific need. It has long been known that infants living in cooler homes require more calories than average in order to keep warm whilst growing normally (e.g. Clifford, 1950). Additional evidence from the C-SNAP study suggested that children in homes without winter fuel subsidy consumed fewer calories than subsidised infants (Cook and Frank, 2008). This corroborated a previous piece of research, which had used data from the USA National Health and Nutrition Examination Survey to examine winter resource shifts, i.e. the extent to which drops in temperature were associated with changes in how much households spent on food and heating (Bhattacharya et al., 2003). During winter, low-income households showed significant decreases in calorie intake in both adults (147 fewer calories a day), and children (197 fewer calories a day). For both groups, this equated with a 10% reduction in food intake. Eating less saved an average of US$11 on monthly household expenditure, and offset the corresponding increase in heating costs, which was US$37. By contrast, higher-income households increased their spend on both heating and food during temperature shortfalls, maintaining the same levels of food intake year-round.

4.5. Summary

Taken together, effects on infant and child physical health seem more measurable than those amongst adults or older children. In addition to a reduced calorie intake carrying special risk during a developmental period when calories are especially vital, several other factors may account for their greater sensitivity to fuel poverty. Infants and young children spend most of a 24-h cycle indoors (Makri and Stilianakis, 2007), and are also less likely to be mobile. In addition, their immaturity means they are less able to correct thermal stress themselves (e.g. by putting on warmer clothes), or to articulate the need for this to others.

It remains a matter of conjecture whether exposure to cold and damp living conditions during infancy and childhood affects longer-term health. However, several studies beyond the fuel poverty literature suggest that early living conditions remain predictive of health risk in later life, even after other concurrent and subsequent life experiences (both social and economic) are accounted for. Furthermore, this is particularly so in a domain of morbidity most closely associated with fuel poverty, viz. cardiovascular disease (e.g. Elford et al., 1991; Rahkonen et al., 1997).

5. Changes in mental health and tackling fuel poverty: Adults

Warm Front, the Scottish CHP, and the first phase of the New Zealand intervention (HIHS) assessed mental health impacts.

5.1. Warm front

Comparing the effects of Warm Front on the mental and physical health of adults, evaluators concluded that effects were more prominent in the mental health domain. After adjustment for principal covariates, the GHQ12 scores of participants living in homes that were warmer post-intervention indicated lower levels of anxiety and depression. In real terms:

> …prevalence of anxiety or depression fell from 300 to about 150 per 1000 occupants after Warm Front measures. This is a significant impact. For every 10,000 properties (with two adults) improved by Warm Front about, 3000 occupants will be relieved of anxiety or depression (Green and Gilbertson, 2008, p. 18).

However, no changes were found for the 4 mental health subscales of the SF-36 in the evaluation of Warm Front, and it was concluded that mental health effects were confined to measures of borderline anxiety and depression, which were more readily captured with the GHQ12 scale.

5.2. Scottish CHP Programme

This also used the SF-36 scale, and corroborated the findings of Warm Front, in that no changes were found for the 4 mental health sub-scales.

5.3. New Zealand HIHS

By contrast, the New Zealand HIHS reported significant gains in scores for all 4 mental health sub-scales of the SF-36 (Howden-Chapman et al., 2007). This difference could be accounted for by the fact that the New Zealand households were all at clinical risk before intervention, since each household had at least 1 resident with a diagnosable respiratory problem. It is possible that the joint effects of fuel poverty and ill health (especially if one is perceived to exacerbate the other) generate a significantly greater toll on mental health than might be evident in a more diverse range of healthier households.

5.4. Interpreting mental health impacts

Effects on mental health were greater than had been anticipated by some of the research teams (Green and Gilbertson, 2008), and led to speculation on how such impacts had been brought about. If heating becomes more affordable, Warm Front evaluators argued, householders might obtain significant relief from the stress associated with debt or the threat of it. This, in turn, could significantly reduce vulnerability to borderline anxiety and depression. Based on these findings, the Warm Front evaluators concluded that a reduction in perceived financial strain was likely to be the "…*main route from Warm Front to health gain*" (Green and Gilbertson, 2008, p. 19). The CHP programme had in fact measured perceived financial strain, and reported significant improvements in it.

However, two findings suggest that "perceived" financial strain is perhaps the best descriptor for this effect. First, although self-reported difficulty paying fuel bills fell by 40% post-intervention among Warm Front participants (Green and Gilbertson, 2008), data on actual consumption levels indicated an average increase in expenditure on heating (Hong et al., 2006). It could be that mental wellbeing gains came about because Warm Front householders viewed their homes as more energy efficient post-intervention, and hence perceived greater value for money from their expenditure on heating. Increased value for money, and a greater sense of control over how heat is "spent" (i.e. efficiently) may have made the cost of heating a home seem less problematic.

Results from the New Zealand HIHS study also contradict the assertion that relief from financial strain may be the principal route to mental health gain. Householders did save money (domestic heating costs were reduced by 19% in the retrofit group) but the cheapness of domestic energy in New Zealand at the time of the intervention meant a financial saving of only UK£2 per month. Despite this, significant mental health gains accrued in the experimental group across all 4 mental wellbeing dimensions of the SF-36 (Howden-Chapman et al., 2007).

5.5. Summary

Whatever the reasons participants perceived improvements in their mental wellbeing, these improvements merit considerable attention. A recent international review of the impacts of improved mental wellbeing on lifespan development concluded that mental health was one of the primary drivers of healthy development from birth onwards (Beddington et al., 2008). The review created a phrase to encapsulate the value of mental wellbeing for people's physical health and social engagement, namely The Mental Wealth of Nations, and estimates a potential for savings of £77 billion if the mental health of all citizens in the UK could be maintained at optimal levels.

Whilst the value of tackling fuel poverty for mental health might be modest in the grander scale of a Mental Wealth of Nations perspective, the following quote from a qualitative study of 49 households in Warm Front illustrates the range of mental health effects that participants perceived:

> There were reports of improved family relations, an expansion of the domestic space used during cold months, greater use of kitchens and improved nutrition, increased privacy, improved social interaction, and an increase in comfort and atmosphere within the home. Greater warmth and comfort also enhanced emotional security, and recipients were more content and at ease in their homes (Gilbertson et al., 2006).

This account underlines the broader social and emotional significance which fuel poverty has for people who experience it, over and above the impacts it may or may not have on their physical wellbeing. Outcomes related to mental health, wellbeing and quality of life may need to be more comprehensively monitored in future empirical trials.

6. Changes in mental health and tackling fuel poverty: Young people

To date, only the NATCEN study has considered the potential impacts of fuel poverty on the mental health of the young.

6.1. NATCEN

After adjustment for covariates (including maternal education, income, multiple deprivation index, family composition, and ethnicity), living in homes which lacked affordable warmth was significantly associated with "*multiple mental health risk*". This was defined as an adolescent manifesting 4 or more negative mental health symptoms (Barnes et al., 2008). Among adolescents who had lived for long periods in homes that lacked affordable warmth, 28% were classified as having a multiple mental health risk, compared with 4% of children who had always lived in homes that had affordable warmth. When broken down into specific symptoms, 13% had truanted (compared with 3% in homes with affordable warmth), 10% had been expelled/excluded from schools (compared to 3% in homes with affordable warmth), and 7% had been in trouble with the police (2% in homes with affordable warmth).

How might these surprising results be explained? More than most other age groups, teenagers seek time away from family members, either for solitude (Larsen, 1997) or to spend private time with their peers. One of the more common consequences of fuel poverty is that families confine heating to rooms which are used by most of the household most of the time, e.g. kitchens and living rooms (Lawlor et al., 2002), a phenomenon referred to as spatial shrink (e.g. Farrell et al., 2008). Where heating is limited to public spaces, and family members cluster together in them, there may be fewer opportunities for privacy and personal space. Intergenerational relationships often come under strain during adolescence (Kwak, 2003), which could make crowding especially challenging at this age too. Evidence in support of this speculation can be found in some of NATCEN's other findings. Children in homes that lacked affordable warmth were less likely to have a quiet place to do homework, reflecting increased clustering of family members into fewer rooms. In addition 10% of the adolescents in homes that lacked affordable warmth felt unhappy in their family compared with 2% in the group that had affordable warmth. They were also more than twice as likely to have run away from home (Barnes et al., 2008). Factors such as these may lead to adolescents from hard to heat homes choosing to seek privacy and respite in public spaces such as parks, shopping precincts, or sports halls. These are venues where they may be more vulnerable to anti-social behaviour and other mental health risks (Wells et al., 2005). The finding that 27% of teenagers from homes without affordable warmth were worried about bullying and mugging, compared with 15% of teenagers who lived in warmer homes (Barnes et al., 2008), lends some support to this possibility.

7. Methodological issues in the recent evidence base.

Bonnefoy (2007) asserts that "*the largest challenge in the field of housing and health seems to be the collection of clear and straightforward evidence*" (p. 415). Despite this, Nutbeam and Boxall (2008) have remarked that housing policy and planning, more than most other domains in social science, have a history of relying on the evidence base of the day—regardless of its quality. For this reason, reviews of the evidence which give due consideration to quality are important. Given the topical nature of fuel poverty and its impacts, and the growing interest which many governments are taking in strategies for combating it, it seems particularly apposite to critique the studies reviewed here.

7.1. Health risk was not always a criterion for participant enrolment

Government policies around tackling fuel poverty are explicitly formulated around the need to protect human health, and prioritise those whose health is most vulnerable to the effects of cold and damp (e.g. BERR, 2001 for the UK, and Ministry of Social Development, 2005 for New Zealand). However, many of the participants enrolled in the studies reviewed here had no clinical health risk. It is perhaps not surprising that limited impacts on physical health were found at 1- or 2-year follow-up in the fuel poverty intervention studies, since relatively few of the participants in these schemes were at clinical risk at baseline. Even in Phase 1 of the New Zealand study, where all homes had at least one at-risk resident, *all* residents of the households were included in the evaluation. Many may have been in good mental and physical health, yielding a potential ceiling effect.

In Phase 2 of the New Zealand study, by contrast, where all homes contained an asthmatic child, and outcome measures were confined to ones which concerned the child, a much wider range of significant effects was noted: 8 of 18 parent-reported physical health outcomes showed significant improvement, as did 6 of 10 outcomes based on children's diary logs of symptoms. In a smaller retrofit study carried out in a single housing estate in Torquay England, and in which children were not selected on the basis of a pre-existing respiratory condition, there were no significant differences between intervention and wait-listed control children across 8 measures of symptoms related to asthma (Barton et al., 2007).

In addition to many participants *not* being at health risk, a group of vulnerable participants who demonstrably *were* at health risk do not appear at all in the evidence base, namely people living with physical and mental disabilities. This is particularly surprising, given that a wide variety of disabilities impair people's capacity for regular activity, and confine them to living at home for long periods at a time. It should not be assumed that impacts on their health are readily equated with those of senior citizens.

7.2. *Participants were not always in fuel poverty*

Recent audits of the UK's Fuel Poverty Strategy have indicated high levels of inaccurate targeting. In Scotland, for example, as many as 50% of homes targeted by CHP were not fuel poor even though they passed all eligibility criteria (Scottish Executive, 2008); in Northern Ireland 30% of homes that participated in a programme similar to Warm Front were not fuel poor (NIAO, 2008). Poor targeting is likely to have compounded the potential for ceiling effects, at least in the UK studies.

7.3. *Implementation of an intention to treat design*

Problems of poor targeting were compounded in all three studies which tackled fuel poverty directly (Warm Front, CHP and the New Zealand HIHS) by the use of an intention to treat design for assessing effects. This meant that all participants who were assigned to the non-treated condition were assumed to remain untreated, whilst all participants assigned to treatment were assumed to have received a retrofit. Amongst wait-listed control households in the CHP programme, however, 26% installed insulation and heating measures before they were followed-up. Additionally 7% of the intervention group did not, ultimately, receive heating and insulation. All of them remained in their respective control and experimental groups for the purposes of statistical analyses (Platt et al., 2007).

Further contamination in the 3 intervention studies also occurred as a result of so-called "thermal resisters", i.e. householders who chose to retain low indoor temperatures after insulation and heating measures were installed. As already mentioned, 25% of Warm Front households maintained temperatures at least 2 °C lower than WHO recommended levels after treatment (Critchley et al., 2007). In New Zealand, 16% of treated households elected not to increase their indoor temperatures after retrofitting (Howden-Chapman et al., 2009).

Debate continues about the appropriateness of intention to treat models for assessing health interventions of a social nature (e.g. Thomson et al., 2003), but it is certain that ceiling and contamination effects reduced the likelihood of health impacts being identified in these fuel poverty evaluations. In fact, the NATCEN and C-SNAP studies—whilst not studies concerned with tackling fuel poverty per se—probably comprise more robust studies for assessing impacts since they are based on a more reliable designation of participants as either experiencing or not experiencing a specified condition (a cold damp home or a fuel subsidy, respectively). It is noteworthy that the health impacts identified in these 2 studies—both physical and mental—appear stronger.

7.4. *Variations in the extent of retrofit*

Amongst Warm Front participants interventions ranged from the installation of full central heating, to the draught-proofing of a few doors (Green and Gilbertson, 2008). In the New Zealand HIHS, the extent of retrofit also varied considerably across households: whilst all received ceiling insulation, only 30% received the full insulation package (Howden-Chapman et al., 2007). Future analyses of the fuel poverty intervention data could perhaps incorporate dose–response investigations, through which a more enriched understanding of effects might be ascertained. Since a wide range of investments were made across households involved in Warm Front and CHP (from £100 per household to more than £4000 per household), there is ample opportunity to explore dose–response effects.

7.5. *Limitations of the outcome measures.*

More generic housing and health studies have tended to focus on a wider range of physical ailments, including colds, sore throats, headaches, gastric and duodenal ulcers. The most recent evidence from large-scale WHO investigations suggest that all of these are significantly related to thermal comfort and mould/dampness, after many other contributory factors have been accounted for (e.g. Ezratty et al., 2009). There is, therefore, scope for a widening of focus in terms of physical health impacts.

In addition, a different choice of mental health measures might help unravel how mental health gains are made. The GHQ12 and SF-36 are mental health instruments of unparalleled generic utility. Tackling fuel poverty seems to be associated with rather more specific domains of mental health, probably involving anxiety, mood, and coping. Mental health measures which focus more specifically on these domains might be helpful in future studies. In addition, there is scope for the incorporation of measures which capture potential changes in participants' social engagement and daily living patterns, which Warm Front's small qualitative study highlighted (Gilbertson et al., 2006). A wider implementation of qualitative methodologies, ranging from interviews and focus group work, through to grounded hermeneutics and participatory appraisal, would almost certainly add insights—not least of all to the understanding of the *processes* by which impacts become manifest. Without an understanding of process, it remains difficult to understand what exactly causes change, and therefore how it can be brought about more cost-effectively in future (Giles et al., 2005).

Given the consistency of mental health impacts amongst adults and adolescents, it is also regrettable that young children's mental health has not been monitored. The mental health impacts evident in teenagers may have been related to household crowding in fuel-poor homes, and it has long been known that household crowding carries particular mental health risks for younger children (e.g. Aiello et al., 1979; Liddell and Kruger, 1989). Children's mental health is also more adversely affected by illness than is the case for adults, particularly when illnesses are chronic and necessitate hospitalization, e.g. chest infections,

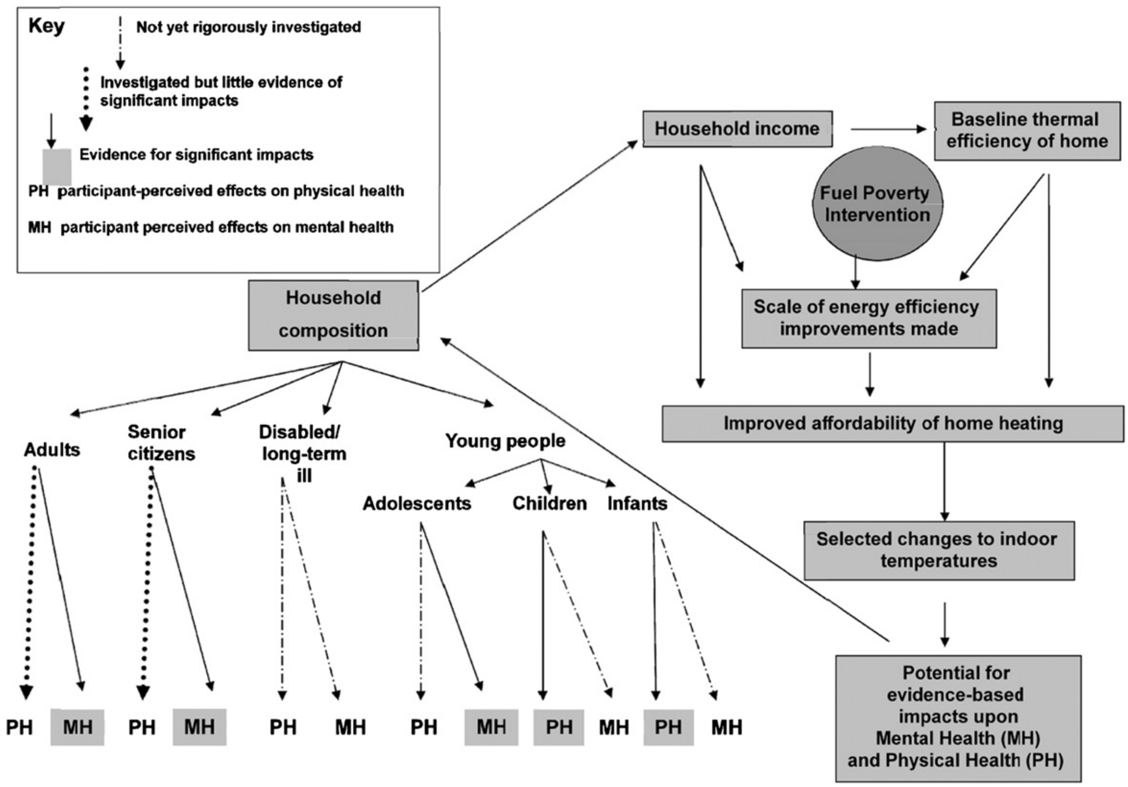

Fig. 1. Hypothesised pathways linking fuel poverty interventions to participant-perceived impacts on human health.

asthma, etc. (Powell and Brazier, 2004). These sorts of conditions are particularly common amongst children living in fuel poverty (Barnes et al., 2008).

7.6. Narrowness of focus

Fuel poverty studies have been contextualised in frameworks that resemble the medical model, associating a single "treatment" (retrofitting) with individual effects (illness or mental health scores). It could be argued that these interventions are more appropriately conceptualised as systemic in nature, and therefore better suited to a public health model for evaluating impact. As illustrated in Fig. 1, the effects of making a home more energy efficient will depend on baseline levels of energy efficiency and thermal comfort, the scale of efficiency improvements, whether these make home heating more affordable or not, and whether the household chooses to "take" savings in improved heating or some other consumable. All of these will contribute to the potential for an energy efficiency intervention to generate changes in mental and physical health, with the extent and type of changes being—in turn—dependent on the age and baseline health status of the residents. Such a sequence or path is more suited to the analytic treatments endorsed by public health models, which hypothesise routes or processes through which interventions may generate systemic changes, implicating many diverse and inter-dependent factors along the way (Byrne and Keithley, 1993).

Insights from analyses of this kind would offer valuable information for both policy and implementation strategies. It is important to note that all 5 of the key studies reviewed here collected data that are amenable to path analyses and similar systemic exploration, so there is potential for more integrated reviews of both impact and process from the current evidence base.

In this context, fuel poverty studies, both past and present, need more explicit embedding in the broader scientific evidence base concerning health and housing, from which many insights might emerge. As this broader literature makes clear, improvements in home heating and insulation generate many highly correlated changes in housing quality, including improvements in thermal comfort, ventilation, and a reduction in dampness and mould. The multiple collinearity of impacts makes it difficult, but not impossible, to disentangle the individual and combined contributions of correlated factors, and research programmes such as the WHO's LARES project (Larger Analysis and Review of European Housing and Health Studies) have contributed significantly to understanding in this domain (Ormandy, 2009). The broader, generic literature on health and housing has, as yet, a relatively unutilised potential for informing the fuel poverty debate at empirical, theoretical and strategic levels.

8. Conclusions

What emerges from the present review is that, despite relatively few published studies, they show considerable heterogeneity in their aims, participants, methods, and statistical treatments. This makes drawing conclusions difficult, except at the most generic of levels (Herbert, 2007). Formal meta-analyses are certainly premature at this stage, largely because so few studies of sufficient size and rigour exist, which is compounded by their multi-level heterogeneity. What is more feasible is a "narrative synthesis" (Thomson et al., 2009, p. S681), which is what has been presented in this review. Whilst lacking the rigour of regression-based meta-analyses, narrative synthesis can be useful in contexts where the development of policy is unlikely to be held back awaiting a final meta-analytical verdict.

In the UK, the potential benefits of tackling fuel poverty were initially construed as pertaining to the physical health of vulnerable people (e.g. BERR, 2001; Scottish Executive, 2008). Although the potential for finding such effects may have been weakened by methodological limitations in the evaluations carried out thus far, it is safest to conclude that these anticipated physical health impacts from tackling fuel poverty have been relatively modest. Even in the New Zealand study where children's homes were supplied with heating, and where all children had a doctor-diagnosed asthmatic condition, clinical effects such as improved lung function could not be detected. This should not detract, however, from the evidence related to improvements in the children's school attendance, and diary-reported improvements in the severity and frequency of the children's symptoms. It seems safe to conclude that, a year or two after improvements have been made to people's homes, gains are largely confined to adult *perceptions* of physical wellbeing, since all 3 studies which used the SF-36 reported significant gains in people's self-assessed general health. *Clinical* impacts on adult physical health may take longer to emerge, if they emerge at all. That being said, some impacts on mortality are almost certain at population level, even though none of the studies were sufficiently powered to detect these.

By contrast, significant effects on the physical health of the young were more evident, especially in terms of infants' weight gain, hospital admission rates, and caregiver-rated developmental status. Additionally, mental health impacts emerged as surprisingly strong amongst both adults and adolescents. Viewed in historical context, this pattern of results corroborates what was found in a previous review of housing improvement studies (1975–2001). Of 10 studies which assessed mental health impacts, nine indicated significant gains, although physical health impacts were sparse and inconsistent (Thomson et al., 2003).

Several new insights emerge from this narrative synthesis. There are strong empirical grounds for widening the assessment of potential impacts to a broader range of physical ailments than has hitherto been customary. The review also highlights the important distinction which needs to be made between *perceived* improvements in physical health (which are frequently found) and *demonstrable* improvements, i.e. clinical changes in symptoms, changes in prescribing patterns, or reduced reliance on medical services (which are rare). In addition, the review suggests that a wider range of mental health impacts merits investigation, spreading across the lifespan from children and teenagers through to senior citizens, and incorporating measures of quality of life and mental wellbeing. It is possible that mental health effects act as the principle catalyst for perceived gains in physical health, which is a hypothesis yet to be explored. Impacts on perceived mental wellbeing may even have the potential over time to translate into clinical improvements in physical health, in line with those reported in the Mental Wealth of Nations review (Beddington et al., 2008). Longer-term monitoring will be essential if hypotheses about process are to be tested. Understanding process will be fundamental for building better models of intervention in the future.

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References

Aiello, J.R., Nicosia, G., Thompson, D.E., 1979. Physiological, social, and behavioral consequences of crowding on children and adolescents. Child Development 50, 195–202.

Analitis, A., Katsouyanni, K., Biggeri, A., Baccini, M., Forsberg, B., et al., 2008. Effects of cold weather on mortality: results from 15 European cities within the PHEWE project. American Journal of Epidemiology 168, 1397–1408.

Barnes, M., Butt, S., Tomaszewski, W., 2008. The dynamics of bad housing: the impact of bad housing on the living standards of children. National Centre for Social Research, London.

Barnett, A.G., Dobson, A.J., McElduff, P., Salomaa, V., Kuulasmaa, K., Sans, S., 2005. Cold periods and coronary events: an analysis of populations worldwide. Journal of Epidemiology and Community Health 59, 551–557.

Barton, A., Basham, M., Foy, C., Buckingham, K., Somerville, M., 2007. The Watcombe Housing Study: the short term effect of improved housing conditions on the health of residents. Journal of Epidemiological and Community Health 61, 771–777.

Beddington, J., Cooper, C.L., Field, J., Goswami, U., Huppert, F.A., Jenkins, R., Jones, H.S., et al., 2008. The mental wealth of nations. Nature 455, 1057–1060.

BERR, 2001. The UK fuel poverty strategy. Department for Business Enterprise and Regulatory Reform, London.

Bhattacharya, J., DeLeire, T., Haider, S., Currie, J., 2003. Heat or eat? Cold weather shocks and nutrition in poor American families. American Journal of Public Health 93, 1149–1154.

Bonnefoy, X., 2007. Inadequate housing and health: an overview. International Journal of Environment and Pollution 30, 411–429.

Byrne, D., Keithley, J., 1993. Housing and the health of the community. In: Burridge, R., Ormandy, D. (Eds.), Unhealthy Housing: Research, Remedies, and Reform. Taylor & Francis, London.

Clifford, M.L., 1950. Well babies and hot weather. American Journal of Nursing 50, 459–460.

Cook, J., Frank, D., 2008. Food security, poverty, and human development in the United States. Annals of the New York Academy of Sciences 1136, 193–209.

Crawford, V.L.S., McCann, M., Stout, R.W., 2003. Changes in seasonal deaths from myocardial infarction. Quarterly Journal of Medicine 96, 45–52.

Critchley, J., Gilbertson, J., Grimsley, M., Green, G., 2007. Living in cold homes after heating improvements: evidence from Warm-Front, England's Home Energy Efficiency Scheme. Applied Energy 84, 147–158.

Davie, G.S., Baker, M.G., Hales, S., Carlin, J.B., 2007. Trends and determinants of excess winter mortality in New Zealand: 1980–2000. Public Health 7, 263–272.

EHCS, 2006. English House Condition Survey. Communities and Local Government Printer, London.

Elford, J., Whincup, P., Shaper, G., 1991. Early life experience and adult cardiovascular disease: longitudinal and case control studies. International Journal of Epidemiology 20, 833–844.

EPEE (2009). The fuel poverty infrastrusture. Summary Report. European Fuel Poverty and Energy Efficiency Partnership, Brussels.

Eurostat, 2005. Material Deprivation in the European Union. European Commission, Luxembourg.

EU-SILC, 2005. EU Survey on Income and Living Conditions. Eurostat, Luxembourg.

Ezratty, V., Duburcq, A., Emery, C., Lambrozo, J., 2009. Liens entre l'efficacité énergétique du logement et la santé des residents: resultats de l'étude européenne LARES. Environement, Risques & Santé 8, 497–506.

Farrell, C., McAvoy, H., Wilde, J., 2008. Tackling Health Inequalities: An All-Ireland Approach to Social Determinants. Combat Poverty Agency, Dublin.

Frank, D., Neault, N.B., Skalicky, A., Cook, J.T., Wilson, J.D., Levenson, S., et al., 2006. Heat or eat: the low income home energy assistance program and nutritional and health risks among children less than 3 years of age. Pediatrics 18, 1293–1302.

Gilbertson, J., Stevens, M., Stiell, B., Thorogood, N., 2006. Home is where the hearth is: grant recipients' views of England's Home Energy Efficiency Scheme (Warm Front). Social Science and Medicine 63, 945–956.

Giles, M., Liddell, C., Bydawell, M., 2005. Condom use in African adolescents: the role of individual and group factors. AIDS Carem 17, 729–739.

Green, G., Gilbertson, J., 2008. Health impact evaluation of the Warm Front Scheme. Sheffield Hallam University, Centre for Regional Social and Economic Research.

Healy, J.D., 2003. Excess winter mortality in Europe: a cross country analysis identifying key risk factors. Journal of Epidemiology and Community Health 57, 784–789.

Healy, J.D., 2004. Housing, Fuel Poverty and Health: A Pan-European Analysis. Ashgate Publishers, Aldershot.

Herbert, R., 2007. Dealing with heterogeneity in clinical trials. Manual Therapy 12, 1–2.

Hong, S.H., Oreszczyn, T., Ridley, I., 2006. The impact of energy efficient refurbishment on the space heating fuel consumption in English dwellings. Energy and Buildings 38, 1171–1181.

Hood, E., 2005. Dwelling disparities: how poor housing leads to poor health. Environmental Health Perspectives 113, A310–A317.

Howden-Chapman, P., Matheson, A., Crane, J., Viggers, H., Cunningham, M., Blakely, T., et al., 2007. Effect of insulating existing houses on health inequality: cluster randomised study in the community. British Medical Journal 334, 460–464.

Howden-Chapman, P., Pierse, N., Nicholls, S., Gillespie-Bennett, J., Viggers, H., Cunningham, M., et al., 2008. Effects of improved home heating on asthma in community dwelling children: randomised controlled trial. British Medical Journal 337, 852–855.

Howden-Chapman, P., Viggers, H., Chapman, R., O'Dea, D. Free, S., O'Sullivan, K., 2009. Warm homes: drivers of the demand for heating in the residential sector in New Zealand. Energy Policy 37, 3387–3399.

Howieson, S.G., Hogan, M., 2005. Multiple deprivation and excess winter deaths in Scotland. Perspectives in Public Health 125, 18–22.

Juniper, E.F., O'Byrne, P., Ferrie, P., King, D., Roberts, J., 2000. Measuring asthma control clinic questionnaire or daily diary? American Journal of Respiratory Critical Care Medicine 162, 1330–1334.
Kwak, K., 2003. Adolescents and their parents: a review of intergenerational family relations for immigrant and non-immigrant families. Human Development 46, 115–136.
Larsen, R.W., 1997. The emergence of solitude as a constructive domain of experience in early adolescence. Child Development 68, 80–93.
Lawlor, D.A., Maxwell, R., Wheeler, B.W., 2002. Rurality, deprivation, and excess winter mortality. Journal of Epidemiology and Community Health 56, 373–374.
Liddell, C. (2008). The impact of fuel poverty on children. Save The Children, Belfast.
Liddell, C., Kruger, P. 1989. Activity and social behavior in a crowded South African township nursery: a follow-up study on the effects of crowding at home. Merrill Palmer Quarterly 35, 209-226.
Makri, A., Stalianakis, N.I., 2007. Vulnerability to air pollution health effects. International Journal of Hygiene and Environmental Health 211, 326–336.
Marsh, A., Gordon, D., Pantazis, C., Heslop, P., 1999. Home Sweet Home?, The Impact of Poor Housing on Health. Polity Press, London.
Ministry of Social Development, 2005. Statement of Intent 2005/6. Ministry of Social Development, Wellington, New Zealand.
Morgan, E., 2007. Energy Poverty in the EU. European Parliament, Cardiff.
NIAO, 2008. Warm Homes: Tackling Fuel Poverty. Northern Ireland Audit Office, Belfast.
NIHE, 2008. Northern Ireland House Condition Survey. Northern Ireland Housing Executive, Belfast.
Nutbeam, D., Boxall, A.M., 2008. What influences the transfer of research into health policy and practice? Observations from England and Australia. Public Health 122, 747–753.
Ormandy, D. (Ed.), 2009. Housing and Health in Europe: the WHO LARES Project Oxford, Routledge, UK.
Platt, S., Mitchell, R., Walker, J., Hopton, J., 2007. The Scottish Executive Central Heating Programme: Assessing Impacts on Health. Scottish Executive, Edinburgh.
Powell, C., Brazier, A., 2004. Psychological approaches to the management of respiratory symptoms in children and adolescents. Paediatric Respiratory Reviews 5, 214–224.
Rahkonen, O., Lahelma, E., Huuhka, M., 1997. Past or present? Childhood living conditions and current socioeconomic status as determinants of adult health. Social Science and Medicine 44, 327–336.
Rudge, J., Gilchrist, R., 2005. Excess winter morbidity among older people at risk of cold homes: a population-based study in a London borough. Journal of Public Health 2, 353–358.
Scottish Executive, 2008. Review of Fuel Poverty in Scotland. Department of Housing, Edinburgh.
Sefton, T., Chesshire, J., 2005. Peer Review of the Methodology for Calculating the Number of Households in Fuel Poverty in England. DTI, London.
Shortt, N., Rugkåsa, J., 2007. "The walls were so damp and cold" fuel poverty and ill health in Northern Ireland: results from a housing intervention. Health & Place 13, 99–110.
Somerville, M., Mackenzie, I., Owen, P., Miles, D., 2000. Housing and health: does installing heating in their homes improve the health of children with asthma? Public Health 114, 434–439.
Thomson, H., Petticrew, M., Douglas, M., 2003. Health impact assessment of housing improvements: incorporating research evidence. Journal of Epidemiology and Community Health 57, 11–16.
Thomson, H., Thomas, S., Sellstrom, E., Petticrew, M., 2009. The health impacts of housing improvements: a systematic review of intervention studies from 1887 to 2007. American Journal of Public Health 99, S681–S692.
Wells, S., Graham, K., Speechley, M., Koval, J.J., 2005. Drinking patterns, drinking contexts and alcohol-related aggression among late adolescent and young adult drinkers. Addiction 100, 933–944.
WHO, 2007. Housing, Energy and Thermal Comfort. World Health Organization, Copenhagen.
Wilkinson, P., Pattenden, S., Armstrong, B., Fletcher, A., Kavats, R.S., Mangtani, P., McMichael, A., 2004. Vulnerability to winter mortality in elderly people in Britain: a population-based study. British Medical Journal 329, 647–651.
Wilkinson, P., Smith, K., Beevers, S., Tonne, T., Oreszczyn, T., 2007. Energy, energy efficiency, and the built environment. The Lancet 370, 1175–1187.
Wilkinson, P., Smith, K., Joffe, M., Haines, A., 2007. A global perspective on energy: health effects and injustices. The Lancet 370, 965–978.
Young, M., 1924. The influence of weather conditions on the mortality from bronchitis and pneumonia in children. Journal of Hygiene 23, 151–175.