The impact of home energy efficiency interventions and winter fuel payments on winter- and cold-related mortality and morbidity in England: a natural equipment mixed-methods study

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Scientific summary

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Background

It has long been recognised that England, and the UK more generally, has a large burden of winter- and cold-related mortality/morbidity in comparison with neighbouring countries in continental Europe, despite England's relatively mild (maritime) winter climate. Although many factors may contribute to this, it is probable that improvement in the energy efficiency of England's housing stock may help reduce this impact, while also helping to meet increasingly urgent climate change mitigation and energy security objectives.

This study aimed to quantify the impact that such home energy efficiency (HEE) interventions [i.e. insulation of roof spaces, cavity and solid walls, floors and improved (double/triple) glazing] had on mortality and morbidity at population level using data from a national database of HEE interventions. Additional analyses focused on the long-term trends in cold-related deaths and on the methods and application of modelling techniques, including the use of the multicriteria decision analysis (MCDA), as inputs to an assessment of policies on HEE interventions.

Methods

The assessment of epidemiological trends in cold-related deaths was based on a daily time series of deaths for the period 1975–2012 linked to meteorological data (daily maximum temperature), weekly reports of influenza A and B cases, national domestic fuel costs (adjusted to 2011 prices) and other data from the *United Kingdom Housing Energy Fact File 2013* [Department of Energy and Climate Change. *United Kingdom Housing Energy Fact File 2013.* London: Department of Energy and Climate Change; 2014. URL: www.gov.uk/government/statistics/united-kingdom-housing-energy-fact-file-2013 (accessed 16 September 2016)]. The association between mortality and temperature over lags of 0–13 days was analysed using Poisson regression methods adjusted for long-term trends, seasonality and reported influenza cases. The annual (July–June) number of cold-attributable deaths was computed assuming a time-invariant threshold of 10 °C and related to the period of winter fuel payments (WFPs) and to annual average domestic fuel costs.

The impact of HEE interventions, from 2002 to 2010, was based on an analysis of postcode-level data from the Homes Energy Efficiency Database (HEED), which contains data on the type and date of specific HEE interventions in England with an estimated completeness of 90%. Empirical data on the relationship between HEE characteristics and winter indoor temperatures, combined with building physics modelling, were used to classify intervention dwellings with respect to the impact that the HEE interventions had on indoor temperature. Epidemiological relationships for cold-related mortality and morbidity were then used to quantify the impact that such interventions had on a range of health outcomes. Similar assessments were carried out for the impacts that intervention-related changes in ventilation characteristics had on indoor air quality.

Building on previous methods, a model of health impact was implemented that was useful for assessing potential policy options. Methodological analyses were undertaken to address two important areas of uncertainty in such models: (1) estimates of the length of life shortening in cold-related mortality and (2) the potential risk of HEE interventions for heat mortality. This model incorporates short- and long-term impacts that changes to the indoor environment (temperature, indoor air quality specifically relating to particulate matter of outdoor and indoor origin, radon, second-hand tobacco smoke and mould risk) have on physical and mental health. This model was used to make a comparison of the relative benefits of HEE interventions with those of the current policy on WFPs.

These health impact model results were also used as inputs to a MCDA, which was used to illustrate the model's application as an interactive decision-support tool. Comparisons were made of five insulation measures (cavity wall insulation, draughtproofing, double glazing, loft insulation and solid wall insulation) with regard to seven assessment criteria (mortality, morbidity, NHS costs, energy use and three dimensions of health inequality) using different criteria weightings. The methods and results were discussed in three stakeholder workshops (with 10, 25 and 24 participants) drawn from academia, national/local government, relevant charities, housing organisations/consultancies and public health bodies) and the last workshop entailed an interactive demonstration of the MCDA.

In addition, a series of in-depth interviews with householders (12 household interviews, with 2–4 participants in each interview, and 41 individual interviews) was undertaken which were conducted in three geographical regions. These interviews were included to gather accounts of how home energy practices are integrated into everyday household decisions across a range of household types. Interviews used a topic guide to explore the experience of applying for and organising the interventions (or decisions about what not to install); narratives of how life in the home was before, immediately after and now in relation to the (considered) intervention; the impact the intervention had on physical and mental health; the impact the intervention had on fuel costs; comparisons with neighbours/family members in similar homes without energy interventions; views of the importance of energy efficiency interventions compared with other potential benefits to improve health and well-being; and underlying values and beliefs relating to domains such as indoor temperature, ventilation, fuel use and responsibilities for climate change. Interviews were recorded, transcribed and analysed using inductive analysis, as well as a more deductive content analysis around the key themes of interventions in the context of health, well-being, costs and climate change.

The project entailed public involvement in two forms: (1) in the involvement of organisations and agencies representing a range of stakeholder interests, including non-governmental and governmental organisations, to reflect their perspectives at local, national and international levels (contributing to discussions of the design of the project and to interpretation, including the MCDA) and (2) dialogue with selected members of the public through in-depth interviews.

The study had approval from the Research Ethics Committee of the London School of Hygiene and Tropical Medicine and the National Research Ethics Service (15/SC/0494).

Results

Changes over time

The number of cold-related deaths per year has declined steadily since the mid-1970s, which is probably a continuation of a trend of decreasing winter-/cold-related mortality going back over many decades. The factors contributing to this decline are not understood in detail but are likely to include a wide range of factors associated with improving socioeconomic conditions and health care and protection.

There is evidence that, since the introduction of WFPs in 1997, the gradient of association between outdoor cold and mortality is somewhat weaker than in earlier years: the per cent increase in mortality for each degree Celsius fall in temperature below the 'cold threshold' was 2.37% [95% confidence interval (CI) 2.22% to 2.53%] before WFP and 2.00% (95% CI 1.74% to 2.28%) after WFP. However, an interpretation of this association must recognise that many other potentially protective factors have changed over a similar period. There is also evidence that years with higher than average domestic fuel prices have shown a somewhat stronger relationship between low outdoor temperatures and mortality [per cent increase in mortality per degree Celsius fall in temperature 2.49% (95% CI 2.32% to 2.66%)] than years of below-average fuel prices (1.97%, 95% CI 1.77% to 2.18%), a result that is compatible with high fuel prices increasing the number of cold deaths..

Impact of recent home energy efficiency interventions

Home energy efficiency measures that were installed in the English housing stock from 2002 to 2010 have had a relatively modest impact in improving the indoor environment, specifically with respect to winter indoor temperatures (with an average increase of around 0.09 °C) and air quality. The small gains in winter temperatures arise because most of the energy efficiency interventions have been relatively modest and the shape of the empirical relationship between energy efficiency and indoor temperature shows a relatively shallow increase in temperatures, with improved energy efficiency and a plateau effect at around 500 watts/K *E*-value, a value close to the average energy efficiency of the English stock. Further improvement of energy efficiency beyond this point appears to result in little or no change in average winter indoor temperatures and hence in little or no reduction in cold-related deaths from direct exposure to cold.

These changes in indoor temperature are associated with an estimated initial reduction of around 280 cold-related deaths nationally and an eventual maximum impact of 4000 life-years gained per year. This figure is broadly consistent with the ONS analysis[15] of the change in the annual burden of excess winter deaths in the population.

These cold impacts may be appreciably smaller than those relating to changes in indoor air quality. Building physics models of expected changes in ventilation characteristics that are associated with HEE interventions suggests that the impacts these changes have on health could be positive or negative and potentially greater by as much as an order of magnitude than those related to indoor temperatures. The balance of ventilation-related harms and benefits depends on many assumptions and varies by area, dwelling type and occupants. Ventilation can be maintained for health with appropriate design, implementation and maintenance of control measures (including the use of trickle vents and, for some dwellings, mechanical ventilation with heat recovery), but device failure/suboptimal operation are likely to be common.

Modelling

Two methodological analyses were undertaken to improve the evidence inputs for models of the health impacts of HEE interventions. In a time-series regression analysis of annual deaths in relation to annual summaries of cold and heat, an association of cold with mortality (an increase of 2.3%, 95% CI 0.7% to 3.8%, for each additional 1 °C of cold during the year) was observed, which was broadly similar in magnitude to that found in published daily studies [e.g. by the Eurowinter Group (The Eurowinter Group. Cold exposure and winter mortality from ischaemic heart disease, cerebrovascular disease, respiratory disease, and all causes in warm and cold regions of Europe. *Lancet* 1997;**349**:1341–6) and Pattenden *et al.* (Pattenden S, Nikiforov B, Armstrong BG. Mortality and temperature in Sofia and London. *J Epidemiol Commun Health* 2003;**57**:628–33)], suggesting that most deaths caused by cold were among individuals who would not have died in the next 6 months and, thus, were not mainly attributable to very short-term 'harvesting'. The estimated association with heat was more imprecise (effect estimate 1.7%, 95% CI –2.9% to 6.5%).

Analyses of mortality in relation to housing characteristics provided weak but plausible evidence that the risk of heat-related death is greater in homes with higher than average indoor temperatures during hot weather. Specifically, for each degree Celsius heat anomaly of daytime bedroom temperature compared with the regional average, the risk of mortality in relation to high outdoor temperature is increased by 1.34% (95% CI 0.37% to 2.32%). Given that energy efficiency tends to increase indoor temperatures, this suggests a potential adverse consequence of HEE interventions that may become increasingly important to take into account in the context of climate change.

A model for quantifying the range of health effects associated with changes in the indoor environment from HEE interventions was implemented. This model indicates the potential importance of medium- and longer-term impacts on health by HEE measures, which are not observed in short-term studies. As an illustrative case study of its use in policy comparison, it was found that HEE improvements of similar annualised cost to current WFPs achieve greater improvements in health [while also reducing rather than increasing carbon dioxide (CO_2) emissions]. This suggests that replacing policies (WFP) that incentivise

additional fuel consumption for home heating with a rapid full-scale programme of energy efficiency could help transform the housing stock (with both health and climate change benefits) without substantial financial burdens to the public purse.

Multicriteria decision analysis

The MCDA suggests that, when HEE improvements are accompanied by compensatory ventilation, double glazing is the 'optimal' option when all assessment criteria are given equal weight, but boiler replacement scores highest when greater weight is given to energy savings and reducting health inequalities. As the MCDA's use as an interactive tool with stakeholders demonstrated, the results were sensitive to personal preferences for weightings and also to whether or not purposed provided ventilation was assumed. Although stakeholders could see the value of the MCDA as a useful framework and interactive tool for comparing policy options relating to HEE programmes, there was a view that the transparency and robustness of model evidence relating to the impacts of interventions on the indoor environment and, in particular, on impacts consequent to changes in ventilation characteristics are critical to any such assessment.

In-depth interviews

From our qualitative study of households in England, four distinct householder framings of HEE interventions were identified, which have different implications for future uptake rates. These were home improvement, home maintenance, subsidised public goods and contributions to sustainability. These do not dovetail with current UK national policy, which frames HEE more explicitly in consumerist terms. Although consumerist framings might improve short-term uptake rates, they could have significant costs in the longer term of eroding the 'common good' of commitment to environmental sustainability.

Conclusions

The impact that HEE programmes since around 2000 have had on the population health in England has been relatively modest and remains partly unknown because of limited empirical data on the long-term consequences of changes to dwelling ventilation.

Much larger-scale changes are required to the housing stock if the full potential benefits for improving health and for reaching increasingly important climate change mitigation targets are to be realised. This will require efforts to dovetail national and local policy objectives with those of householders.

Given the relevance of housing to several key strategic objectives (winter- and cold-related mortality/morbidity, climate change mitigation and energy security), it would be prudent to seek the greater integration of policy development across all relevant policy domains. This may be important not only for efficiency of actions, but also to ensure that specific policy initiatives are aligned towards the same strategic goals and do not, in part, act against each other.

There remain important areas of uncertainty with regard to the impact that housing and housing improvements have on health. Those relating to changes in ventilation characteristics, which could be either positive or negative depending on the context, merit further research as a matter of priority given the scale of housing improvements planned for the coming decades. Such research should include a large-scale programme of monitoring to record changes to the indoor environment following the installation of routine energy efficiency measures. This would provide a very important input to help improve current health impact models of HEE interventions as a guide to policy development.

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