The impact of home energy efficiency interventions and winter fuel payments on winter- and cold-related mortality and morbidity in England

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CONFLICTS OF INTEREST

Dr Chalabi reports grants from National Institute for Health and Care Excellence (NICE), grants from Natural Environment Research Council, grants from Department of Energy and Climate Change, during the conduct of the study;

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Drs Armstrong, Bonnington, Doyle, Goodwin, Green, Hajat, Milojevic, Picetti, Rehill, Shrubsole have nothing to disclose.

Important

A 'first look' scientific summary is created from the original author-supplied summary once the normal NIHR Journals Library peer and editorial review processes are complete. The summary has undergone full peer and editorial review as documented at NIHR Journals Library website and may undergo rewrite during the publication process. The order of authors was correct at editorial sign-off stage.

A final version (which has undergone a rigorous copy-edit and proofreading) will publish as part of a fuller account of the research in a forthcoming issue of the Public Health Research journal.

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SCIENTIFIC SUMMARY
(n=2234)

Background

It has long been recognized that England, and the UK more generally, has a large burden of winter- and cold-related mortality/morbidity by comparison with neighbouring countries of 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 of such home energy efficiency (HEE) interventions (i.e. insulation of roof spaces, cavity and solid walls, floors, and improved (double/triple) glazing) on mortality and morbidity at population level using data from a national database of HEE interventions. Additional analyses focused on long term trends in cold deaths, and on the methods and application of modelling techniques, including the use of Multi-Criteria Decision Analysis, as inputs to assessments of policies on home energy efficiency interventions.

Methods

Assessment of epidemiological trends in cold related deaths was based on a daily time series of deaths for the period 1975 to 2012, linked to meteorological data (daily maximum temperature), weekly reports of influenza A & B cases, as well as national domestic fuel costs, adjusted to 2011 prices, and other data from the UK Housing Energy Fact File. The association between mortality and temperature over lags 0-13 days was analysed using Poisson regression methods adjusted for long term trend and seasonality and reported influenza cases. The annual (July to June) number of cold attributable deaths ***was computed assuming a time-invariant threshold*** of 10 degrees Celsius, and related to the period of Winter Fuel Payments and to annual average domestic fuel costs.

The impact of home energy efficiency interventions, 2002-2010, was based on 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 home energy efficiency characteristics and winter indoor temperatures, combined with building physics modelling, was used to classify intervention dwellings with respect to the impact of their HEE

interventions on indoor temperature. Epidemiological relationships for cold-related mortality and morbidity were then used to quantify the impact of such interventions on a range of health outcomes. Similar assessments were done for impacts on indoor air quality as a result of intervention-related changes in ventilation characteristics.

Building on previous methods, we implemented a model of health impact useful for assessing potential policy options. Methodological analyses were undertaken to address two important areas of uncertainty in such models: estimates of the length of life shortening in cold related mortality, and secondly the potential risk of home energy efficiency interventions for heat mortality. This model incorporates short to long term impacts on physical and mental health arising from changes to the indoor environment (temperature, indoor air quality specifically relating to particles ($PM_{2.5}$) of outdoor and indoor origin, radon, second hand tobacco smoke and mould risk). This model was used to make a comparison of the relative benefits of home energy efficiency interventions by comparison with those of current policy on Winter Fuel Payments.

These model results were also used as inputs to a Multi-Criteria Decision Analysis, used to illustrate its application as an interactive decision-support tool. Comparisons were made of five insulation measures (cavity wall insulation, draught-proofing, 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 respectively) drawn from academia, national/local government, relevant charities, housing organizations/consultancies, public health bodies), and the last workshop entailed interactive demonstration of the MCDA analysis.

We also undertook a series of in-depth interviews with householders (12 household interviews, of 2-4 participants each, and 41 individual interviews), 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: experience of applying for and organising the interventions (or decisions about not to install); narratives of how life in the home was before, immediately after and now in relation to the (considered) intervention; impact on physical and mental health; impact 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 wellbeing; 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, wellbeing, costs and climate change.

The project entailed public involvement of two forms: the involvement of organizations and agencies representing a range of stakeholder interests, including non-governmental and governmental organizations, to reflect their perspectives at local, national and international level (who contributed to discussions of the design of the project and to interpretation, including the Multi-Criteria Decision Analysis); and dialogue with selected members of the public through in-depth interviews.

The project ISRCTN is 15/SC/0494.

Results

Changes over time

The number of cold deaths per year has declined steadily since the mid 1970s, probably continuing a trend of reducing 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 socio-economic conditions, and health care and protection.

There is evidence that since the introduction of Winter Fuel Payments in 1997 the gradient of association between outdoor cold and mortality is somewhat weaker than in earlier years: percent increase in mortality for each degree Celsius fall in temperature below the 'cold threshold' was 2.37% (95% CI 2.22, 2.53%) pre-WFP, and 2.00% (1.74, 2.28%) post-WFP. However, interpretation of this association must recognize 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 (percent increase in mortality per degree Celsius fall in temperature 2.49% (2.32, 2.66%)) compared with years of below average fuel prices (1.97% (1.77, 2.18%)), a result compatible with high fuel prices having a detrimental effect on cold deaths.

Impact of recent home energy efficiency interventions

Home energy efficiency measures installed in the English housing stock, 2002-10, have had relatively modest impact in improving the indoor environment specifically with respect to winter indoor temperatures (an average increase of around 0.09 degree Celsius) and air quality. The small gains in winter temperatures arise because most of the energy efficiency interventions have been relatively modest and because of the shape of the empirical relationship between energy efficiency and indoor temperature – which 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 little or no reduction in cold-related death due to direct exposure to cold.

These changes in indoor temperature are associated with an estimated initial reduction of around 280 cold deaths nationally and an eventual maximum impact of 4000 life years gained/year. This figure is broadly consistent with our own and other published evidence on the change in annual burden of cold 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 associated with HEE interventions suggest that the impacts on health could be positive or negative and potentially greater by as much as an order of magnitude as those related to indoor temperatures. The balance of ventilation-related harms and benefits depend on many assumptions, and vary by area, dwelling type and occupants. Ventilation can be maintained for health with appropriate design, implementation and maintenance of control measures (including use of trickle vents and, for some dwellings, mechanical ventilation with heat recovery), but device failure/sub-optimal 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, we observed an association of cold with mortality (an increase of 2.3% (95% CI 0.7 to 3.8%) for each additional 1 degree of cold across the year), which was broadly similar in magnitude to that found in published daily

studies, suggesting that most deaths due to cold were among individuals who would not have died in the next six months – and thus 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* 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, 2.32%). Given that energy efficiency tends to increase indoor temperatures, this suggests a potential adverse consequence of HEE interventions which may become increasingly important to take into account in the context of climate change.

We implemented a model for quantifying the range of health effects associated with changes in the indoor environment from HEE interventions. This model indicates the potential importance of medium and longer-term impacts on health of home energy efficiency measures, which are not observed in short term studies. As an illustrative case study of its use in policy comparison we found that home energy efficiency improvements of similar annualized cost to current Winter Fuel Payments achieve greater improvements in health (while also reducing rather than increasing CO_2 emissions). This suggests that replacing policies (WFP) that incentivize 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.

MCDA

The Multi-Criteria Decision Analysis analyses suggest that, where home energy efficiency improvements are accompanied by compensatory ventilation, double glazing was the 'optimal' option when all assessment criteria were given equal weight, but boiler replacement scored highest when greater weight was given to energy savings and reduction in health inequalities. As its use as an interactive tool with stakeholders demonstrated, the results were sensitive to personal preferences for weightings, and also to whether purposed provided ventilation was assumed. Although stakeholders could see the value of the Multi-Criteria Decision Analysis as a useful framework and interactive tool for comparing policy options relating to home energy efficiency programmes, there was a view that critical to any such assessment is 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.

In-depth interviews

From our qualitative study of households in England, we identified four distinct householder framings of HEE interventions, which have different implications for future uptake rates. These were: home improvement; home maintenance; subsided 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 might have significant costs in the longer term of eroding the 'common good' of commitment to environmental sustainability.

Conclusions

The impact on population health in England of home energy efficiency programmes since around 2000 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, 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 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 of housing and housing improvements on health. Those relating to changes in ventilation characteristics, which could be either positive or negative depending on 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 home energy efficiency interventions as a guide to policy development.