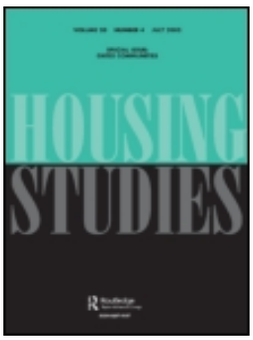

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Keeping Warm and Staying Well. Does Home Energy Efficiency Mediate the Relationship between Socio-economic Status and the Risk of Poorer Health?

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ABSTRACT *This paper discusses the findings of two surveys, undertaken in 2000 and 2001, which investigated relationships between home energy efficiency, socio-economic status and respondent health. Data were collected through interviews with an informant from each household and energy surveys. Respondents were drawn from relatively poor households. The main health measure used in the analysis, respondent-assessed overall health, was statistically significantly related to other health indicators, including SF36 scores, the reported presence of limiting conditions and health care behaviours such as visiting the GP. Worse respondent self-assessed health was statistically significantly related to occupational, wealth and income measures of poorer socio-economic status. However, measures of heating satisfaction and sense of mastery displaced the socio-economic measures when they were included in the predictive logistic regression model for self-assessed respondent health. Objective home energy efficiency, measured by SAP ratings, was associated with health in the model independently of the subjective measure. The findings support other evidence that home energy efficiency makes an important contribution to the relationship between lower socio-economic status and poorer health, and document the combined relationship between objective and subjectively measured home energy efficiency and health.*

KEY WORDS: Energy efficiency, fuel poverty, socio-economic status, health

Introduction

This paper discusses evidence, derived from a series of cross-sectional and longitudinal surveys, for the mediating influence of inefficient home heating and insulation on the well-established relationship between socio-economic status and health. The surveys were undertaken as part of the Warm Homes Project, a research programme funded by the Community Fund of the UK National Lottery, and based in a relatively deprived area

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of North East England. This programme has investigated the health impact of fuel poverty through a combination of four annual surveys, qualitative data collection and a randomised control trial of fuel poverty interventions. The present paper discusses the analysis of survey data collected in the first two years of this four-year project (March/April 2000 and 2001) prior to the provision of home heating and insulation to households found to be in fuel poverty.

The existence of a statistical gradient between relative poverty and poorer health has been established for over a century. This relationship appears to be robustly independent of differences in definition and measurement of the nebulous concepts of poverty and health. However, the causal status of this relationship is contested. Poorer health might, through mediating social processes, 'cause' socio-economic status to decline (Easterlow *et al.*, 2000). Both might be jointly affected by other influences, e.g. genetic differences in fitness. If features linked to socio-economic status do impact causally on population health, many mediating causal pathways can be suggested, including, for example, differences in neighbourhood environment, lifestyle, diet, social exclusion or stresses arising from unfavourable comparisons with others.

Elucidating the processes that drive the established socio-economic status/health gradient has become a research priority (Macintyre, 1997). The present paper will add to a small body of evidence suggesting that living in a fuel inefficient home makes a significant, underestimated contribution to this gradient.

Some research investigating relationships between housing conditions and mental and physical health has been undertaken, reviewed by Dunn (2000), and the BMA (2003). The damaging effects on mental health of overcrowding (e.g. Gabe & Williams, 1993) and high-rise living (e.g. Freeman, 1993) have been documented. With respect to physical health, a number of specific relationships have been documented, for example, between cold and ischaemic heart disease (e.g. Collins, 1993); damp and respiratory problems (e.g. Hopton & Hunt, 1996); indoor pollution and asthma (e.g. Ashmore, 1998); and overcrowding and infectious disease (e.g. Hunt, 1997). Low indoor temperatures, the focus of the present study, damp and indoor pollution are causally associated. Low temperatures cause damp through condensation which, in turn, encourages the growth of mould and dust mites (BMA, 2003, p. 31). However, studies designed to assess the health impact of home improvements have proved inconclusive, and their methodology has been criticised (Thomson *et al.*, 2001).

Child development studies suggest that living in poor housing early in life has a long-term adverse impact, and that this impact is not reversed by living in improved housing during adulthood (Dedman *et al.*, 2001; Marsh *et al.*, 1999). The health damaging effect of poorer housing has been shown to be statistically independent of socio-economic indicators (Ellaway & Macintyre, 1998). Mental and physical health damaging effects associated with housing problems may mutually reinforce each other.

The UK suffers from a greater excess of winter mortality, of around 20 per cent, than do comparable North European countries (Curwen, 1991), despite its warmer winter climate. One possible explanation of this difference is that the relatively poor energy efficiency of British homes exposes a greater proportion of the population, particularly those on low incomes, to living in cold winter conditions. Some studies have found little evidence of a relationship between socio-economic deprivation and excess winter mortality (Lawlor *et al.*, 2000; Shah & Peacock, 1999). However, these studies adopted generalised measures of socio-economic deprivation that did not take into account home energy efficiency.

Wilkinson *et al.* (2001) have linked living in a house built before 1850, poorer thermal efficiency and colder indoor winter temperatures to excess winter mortality data at the small area (post code) level. The relationship they found between socio-economic status and excess winter mortality was eliminated when indoor temperatures were controlled for. Winter home temperature was associated with income only in energy inefficient homes, implying that even relatively poor people can keep their home warm if it is fuel-efficient.

The present study extends understanding of the relationship between socio-economic status, home heating and health by focusing on morbidity rather than mortality, and by relating these factors at an individual rather than aggregated level. The study explores the relative impact on health of objective and subjective measures of socio-economic status and energy efficiency, described in more detail in the next section.

Socio-economic status was assessed objectively through the measurement of income and wealth. It was assumed to be bound up with, but distinct from, a sense of personal control, assessed through the use of the mastery scale (Pearlin *et al.*, 1981). Feelings of powerlessness are an anticipated sequela of relative material deprivation, but may be affected by psychosocial processes, e.g. informal support and coping strategies. Mastery scale scores are modestly associated with socio-economic status (Mizell, 1999; Pearlin *et al.*, 1981; Walford-Kraemer & Light, 1984). Considerable evidence has accumulated that perceived control, as measured by the mastery scale, mediates between a wide variety of stressful environments and harm to mental health (Bengtsson-Tops, 2004; Bullers, 2002; Caputo, 2003; Comijs *et al.*, 1999; Mu *et al.*, 2000; Penninx *et al.*, 1997; Petterson & Friel, 2001; Seilheimer & Doyal, 1996; Smith *et al.*, 2000).

Similarly, the quality of home heating was assessed objectively through SAP ratings, a measure of home energy efficiency and subjectively through a scale measuring home heating satisfaction. Again, use of a subjective and an objective measure allows some differentiation of the health impact of physical home conditions from perceptions.

Methodology

Four longitudinal surveys of respondents from households in potential fuel poverty were carried out in March/April 2000, 2001, 2002 and 2003. Heating and insulation improvements were offered, during the summer of either 2001 or 2002, to households assessed as being in fuel poverty. Households were categorised as being in fuel poverty if they needed to spend more than 7.5 per cent of their disposable income after deduction of tax and housing costs on fuel in order to keep their home adequately heated. This figure, rather than the more usual dividing line of needing to spend 10 per cent of total income excluding tax and housing costs on fuel (DETR, 2000) was used in order to include those in borderline fuel poverty.

The present paper will discuss the findings of the 2000 and 2001 surveys which generated extensive data on self-assessed health, demographic status and satisfaction with home heating. The interview surveys were linked to home energy efficiency assessments undertaken by an external contractor.

Methods

An independent market research company carried out interview surveys with a household respondent in their own home. NHER-qualified energy auditors undertook home energy

efficiency assessments which were used to derive SAP ratings, a standardised measure of energy efficiency on a scale of 1–120, where lower scores indicate poorer energy efficiency. The interviews covered household demographics and income, home tenure, satisfaction with accommodation including home heating, accommodation history, leisure activities, health status, use of health services and energy management knowledge. Respondents were asked to assess their own health, and that of other members of the household, and to report illness-related behaviours for each household member such as visits to the doctor, prescriptions received, days off work and hospital in-patient stays.

Satisfaction with home heating was assessed through an eight-item scale, developed by National Energy Action, which measured satisfaction with the heating system, insulation and the absence of damp. The respondents had to assess, for each of the eight questions, how closely the statements reflected the situation in their home on a scale ranging from 'very closely', 'fairly closely', 'not very closely', to 'not at all closely'. Scores were summed and averaged for the number of questions answered.

Three indicators of socio-economic status were obtained: a classification of the conventionally defined head of household's occupational status, rated during the interview; a wealth measure, based on the household not owning their own home or having use of a private vehicle; and monthly disposable income after tax and housing costs were deducted. Incomes were equivalised as recommended by McClement (DSS, 1992) for the number of persons in the household.

Mastery scale scores were based on a well-validated seven-item scale measuring the extent to which an individual sees their life chances as being under their own control (Pearlin *et al.*, 1981). Each item could be answered on a four-point scale, from 'strongly agree' to 'strongly disagree'.

The main health measure, of overall self-assessed health, was derived from answers to the question 'In general, at the moment, how good is your own health and that of other people in the household?' A separate answer was recorded for up to six household members. However, the present analysis is concerned only with respondent health, rather than with their assessment of the health of other household members. Respondents were invited to rate their own health and that of other household members as 'excellent', 'very good', 'good', 'fair', or 'poor'.

Sampling

The surveys were conducted in a relatively poor area of Tyne and Wear in North East England. Recruitment was undertaken in two waves. In the first wave, 6500 households were contacted by telephone. A member of 2199 households agreed to participate in a telephone screening survey. Of these, 540 met the initial screening criteria for fuel poverty, and 301 respondents were eventually interviewed (wave 1). In view of the high rate of attrition, a second wave of recruitment (wave 2) was undertaken through direct house-to-house calling in areas where fuel poverty was likely to occur. Respondents from 234 of 538 households thus approached were successfully recruited into the study. Among the 535 households recruited overall, 44 per cent were judged to be in fuel poverty according to the study criteria on the basis of the more detailed information obtained in the interview survey.

A small but statistically significant difference between the two waves in the prevalence of fuel poverty was found, with 49 per cent (146) of wave 1 respondents and 38 per cent (91)

of wave 2 respondents meeting the study criteria ($p = 0.02$, Fisher's exact test, two-tailed). This finding suggests that telephone screening surveys may provide a slightly more efficient way of identifying households in fuel poverty than does neighbourhood targeting. Two-thirds of respondents (66 per cent, 354) were female, with a very similar gender mix between waves 1 and 2. Because of the sampling difference between waves 1 and 2, and the sampling bias towards female respondents, statistical analyses were re-run for the two waves and respondent genders separately, in order to check for consistency. Only minor differences from the main analyses were found.

The recruitment methods outlined above sampled a relatively poor target population who either telephone screened as potentially living in fuel poverty or lived in areas of likely poverty. The achieved sample allowed comparisons of the health status of relatively poor households in and not in fuel poverty to be carried out. Median sample total household income after tax but before housing costs was £7800 ($n = 472$) in 2000, and median disposable household income was £5460 ($n = 472$). Only 25 per cent of sample households had a total income of over £12 000, whilst 25 per cent had a total of £5000 or below. (Sample size variations result from missing data.) Because of the restricted income range sampled, study findings cannot be generalised to the overall population. However, the study does allow the antecedents of better or worse health within a more or less socially disadvantaged population to be explored in detail.

All year 1 respondents who had been classified as being in fuel poverty together with a 50 per cent, randomly selected subsample of year 1 survey respondents who were found to not be in fuel poverty were invited to participate in the year 2 survey. Retention rates of 87 per cent and 85 per cent respectively were obtained with these two samples. In view of the high proportion of potential survey respondents who were not successfully recruited, the achieved sample may not be representative of the population surveyed. Replication of analyses with subsamples, reported in the paper, suggest that the findings about relationships between variables were not sensitive to variation in sample parameters, however.

Statistical Methods

Relationships between categorical variables were analysed with Chi-squared and Fisher's exact tests. Spearman's correlation was used to examine the relationship between home heating satisfaction and SAP rating. Logistic regression modelling and analysis of co-variance were employed to analyse multivariate predictors of health status, health behaviours, income and satisfaction with home heating. Analysis was based primarily on the larger, year 1 dataset. Prospective analyses of relationships between year 1 and year 2 variables will be briefly reported.

For the purpose of logistic regression, respondents were dichotomised into two groups who rated their health as excellent or very good versus those who rated their health as good, fair or poor. This division was selected on the grounds that those who assessed their health as 'good' or worse did not consider themselves to be in the best of health. This criterion divided the sample into two roughly equal groups. Similarly, respondents were categorised into two groups, depending on whether they were below or above median satisfaction with home heating for the logistic regression analysis of this variable.

The pattern of relationships between predictors of overall self-assessed health was explored inductively, via path analysis using the AMOS software package.

Data Analysis

The analysis was organised in terms of three linked causal models, as represented by the boxes with thick lines in Figure 1, below.

The thickly marked boxes in Figure 1 reference three dependent variables which were related to predictor variables through multivariate modelling. Overall health will be affected by a range of factors, some of which may be associated with home energy efficiency (analysis 1). Health care behaviour will be influenced by another set of factors which includes overall health (analysis 2). This relationship is presumed to be mediated by specific health problems made more likely by more general health-damaging processes, e.g. resulting from chronic stress or impairment to the immune system. However, this mediating influence is not documented in the analyses outlined below because the numbers of respondents reporting specific conditions was too small. Finally, subjective satisfaction with home heating, a predictor of overall health, will be linked to a third set of variables (analysis 3).

Multivariate models derived from the above analyses are summarised below. The other causal processes represented in Figure 1 can be expected to attenuate or magnify these relationships. For example, the impact of specific health problems caused by extraneous factors might lead respondents to assess their overall health less favourably. Insofar as housing quality is affected by social drift, poor health may cause people to live in colder homes, rather than vice versa. The black box represents all the causal processes, mostly unknown, which may impact directly on, or be affected by, those which were analysed.

Results

Reliability and Validity of Measures

The home heating satisfaction scale was internally reliable (alpha $= 0.82$). Home energy efficiency was assessed in two ways, subjectively, through interview questions, and

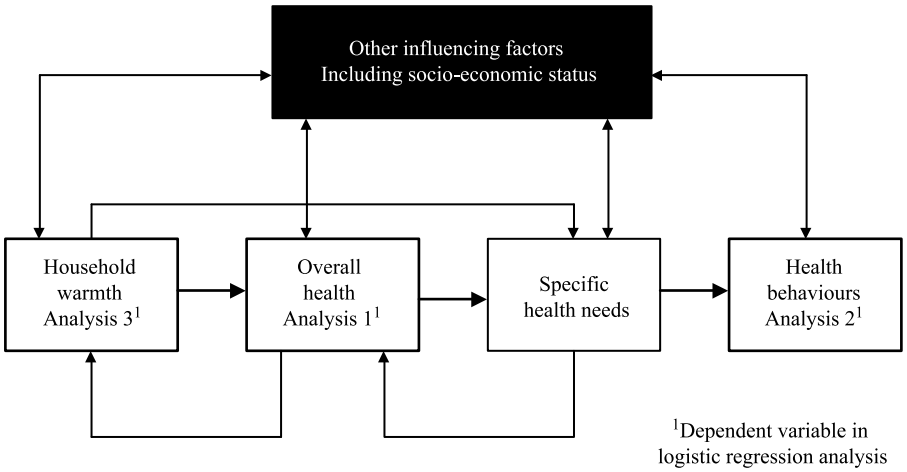

Figure 1. A conceptual model of the relationship between household warmth and health

objectively, through SAP ratings. These two measures were statistically significantly but weakly associated (rho $= 0.186$, $p < 0.001$).

The three socio-economic measures were modestly but statistically significantly associated. For example, occupational status explained 32 per cent of the variance of income equivalised for household composition when respondent age was controlled for ($F_{5,426} = 36.78$, $p < 0.001$). The reliability and validity of the widely used mastery scale have been demonstrated by Grenyer (2002).

Evidence for the validity of the general health measure comes from its close relationship to two others, the presence of long-standing conditions and SF36 scores. Logistic regression analysis showed that respondents who rated their health as good, fair or poor were, with respondent age controlled for, 7.4 times as likely to report limiting conditions as were those who described their health as very good or excellent ($p < 0.001$). Scores on the SF36 scale, a widely used questionnaire measure of physical and mental health, were also closely associated with overall health ratings with respondent age controlled for ($p < 0.001$), for total scores and for all but one of the subscales, including physical functioning, mental health and energy and vitality. The only relationship with subscales which did not achieve statistical significance was for social functioning.

Analysis 1: Predictors of Respondent Overall Self-assessed Health

Two logistic regression analyses using the measure of overall self-assessed health as the predicted variable will be presented below, first with only objective predictor variables (SAP, the household wealth and income measures and respondent age, smoking and socio-economic status). The final logistic regression model is shown in Table 1. The effects of adding the subjective variables, namely mastery scale scores and satisfaction with home heating, summarised in Table 2 below, will then be discussed.

As can be seen in Table 1, respondent age, being a smoker, SAP and household income all contributed statistically significantly and independently to the prediction of respondent self-assessed health status. Home tenure (owner occupied, council or privately rented) was not statistically significantly associated with respondent health. Respondent gender was not selected into the logistic regression model when the variables selected into the model

Table 1. Logistic regression model for objective predictors of poorer respondent self-assessed health*, $n = 333$**

Predictor	Odds	95% confidence intervals	Significance
Respondent age (per year)	1.04	1.03–1.05	< 0.001
Respondent smokes			
No	1		
Yes	2.25	1.35–3.73	0.002
SAP rating (per unit)	1.03	1.00–1.05	0.02
Household income (per £100)	1.00	1.00–1.00	0.04

*Respondents were dichotomised into two groups in terms of whether they indicated that their health was excellent or very good (40 per cent) rather than good, fair or poor (60 per cent).
**Total year 1 sample $n = 535$. 202 respondents were excluded from the analysis on account of missing data.

Table 2. Logistic regression model for all predictors of poorer respondent self-assessed health[*], $n = 370$[**]

Predictor	Odds	95% confidence intervals	Significance
Respondent age (per year)	1.05	1.04–1.07	< 0.001
Mastery scale score			
Higher locus of control	1		
Lower	2.89	1.74–4.80	< 0.001
Satisfaction with home heating			
More positive	1		
Less positive	2.40	1.39–3.96	0.002
Respondent smokes			
No	1		
Yes	2.34	1.38–3.96	0.002
SAP rating (per unit worse)	1.03	1.01–1.05	0.01

[*]Respondents were dichotomised into two groups in terms of whether they indicated that their health was excellent or very good (40 per cent) rather than good, fair or poor (60 per cent).
[**]Total year 1 sample $n = 535$. 165 respondents were excluded from the analysis on account of missing data.

were taken into account. The wealth and occupational socio-economic status measures were included only if income was taken out of the analysis.

When interaction effects were included in the model, a statistically significant interaction between SAP rating and household income replaced the separate effects of these variables. This effect was anticipated on the grounds of evidence that poorer people find it particularly difficult to maintain the warmth of an energy inefficient home (Wilkinson *et al.*, 2001). However, the interaction was in the opposite direction, showing that respondents from households with higher incomes and better home SAP ratings were much more likely to report better health than other groups. This finding suggests that, within the relatively poor population sampled, higher income does not compensate for fuel inefficiency. Instead, energy efficiency and relative affluence may work together to produce better health. This possibility will be considered further in the Discussion.

The full logistic regression model, including the subjective measures of mastery and satisfaction with home heating, is summarised in Table 2.

As shown in Table 2, worse respondent health was significantly and independently associated with their older age, being a smoker, weaker sense of mastery over their life, lower satisfaction with home heating and worse SAP rating. The occupational, wealth and income measures of household poverty were not selected into the final logistic regression model, although all were significantly associated with the health indicator.

The generalisability of the above conclusions was tested with the year 2 data, and with year 1 subsamples. Similar findings were obtained when the year 1 predictor variables were related to respondent self-assessed health in year 2, except that smoking was not included in the final model. These results suggest that the pattern of relationships identified was stable over a one year time period. This pattern was found in both sample waves and for male and female respondents, indicating that sampling bias arising from the recruitment methods used in the two sample waves or from the over-representation of female respondents was not affecting the findings.

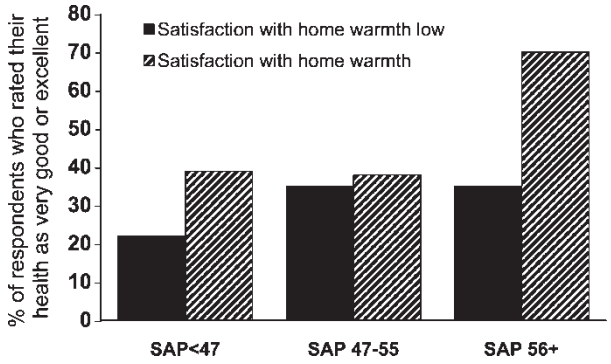

Figure 2. Respondent self-assessed health in relation to satisfaction with home warmth and energy efficiency (SAP rating) ($n = 370$)

The above findings suggest that the relationship between poverty and health within a relatively deprived population could be better explained statistically in terms of the mediating influences of having a sense of mastery and satisfaction with home heating. Objective energy efficiency (SAP ratings), in contrast, was associated with overall health independently of income, wealth, mastery or satisfaction with home heating. As will be shown below (analysis 3), objective home energy efficiency, not surprisingly, was statistically significantly related to satisfaction with home heating. Objective home energy efficiency may affect health in two ways, directly and through influencing satisfaction with one's living conditions which, in turn, impacts on overall health. One interpretation of these findings is that the relationship between poverty and health may be mediated by perceptual factors related to home energy efficiency, at least among the poorer segment of the population sampled in this study. This important qualification and alternative explanations for the findings will be returned to in the Discussion.

Overall, these results suggest that health perceptions are closely related to social psychological and socio-economic variables, particularly those associated with home energy efficiency. The latter finding implies that measures which make it easier for poorer people to keep their home warm may provide an effective investment in health gain. The powerful combined association of objective and subjective measures of energy efficiency with overall self-assessed health is illustrated in Figure 2.

Analysis 2: Health Care Behaviours Associated with Respondent Self-assessed Health

This analysis was concerned with relationships between overall respondent self-assessed health and the frequency of reported health care behaviours, namely visiting the GP, receiving prescriptions, attending hospital and taking time off work on account of sickness. Demonstration of such relationships both provides evidence for the construct validity of the overall health measure, and suggests that measures that improve overall health may also yield health-economic benefits such as reduced demand for health services and absence from work. The results of these analyses, with respondent age included as a covariate, are summarised in Table 3.

As can be seen in Table 3, four respondent health care behaviours, getting prescriptions from the doctor, visiting the doctor, attending hospital as an in-patient and taking sick

Table 3. Analysis of variance models for relationships between respondent self-assessed health* and the frequency of health care behaviours**

Mean (better health)	Mean (poorer health)	Significance	Age covariance significance	Overall significance	Adjusted R^2
	Number of prescriptions in the last 4 months ($n = 534$)				
0.8	3.2	< 0.001	< 0.001	< 0.001	0.04
	Number of respondent visits to the doctor in the last 4 months ($n = 445$)				
0.6	1.6	< 0.001	0.86	< 0.001	0.04
	Number of days as a hospital patient in the last 6 months ($n = 503$)				
0.02	0.5	0.04	< 0.001	< 0.001	0.01
	Number of days off work in the last 6 months ($n = 159$)				
0.6	5.8	0.04	0.41	0.06	0.02

*Respondents were dichotomised into two groups in terms of whether they indicated that their health was excellent or very good (40 per cent) rather than good, fair or poor (60 per cent).
**Total year 1 sample $n = 535$. The number of respondents included in each analysis is shown in the Table. The analysis of days off work was confined to respondents in employment.

leave from work, were statistically significantly associated with poorer self-assessed overall health. Respondent age was controlled for as a covariate in the above analyses, and cannot, therefore, account for the findings. Those who assessed their health as poorer were also more likely to attend an accident and emergency ward, but this association was not statistically significant. The overall model for absence from work does not quite attain the conventional 0.05 threshold for statistical significance, but the relationship with overall respondent health was highly significant when the non-significant relationship with respondent age was excluded from the analysis.

The adjusted values for R^2 show that the combination of respondent age and overall health assessment provides only weak predictive power, accounting for 2–5 per cent of the variance in the four health care behaviours. Nevertheless, the findings cannot be explained by chance, and suggest that a person's overall health assessment influences a wide range of health care behaviours to some extent. Similar findings were obtained for the two sample waves and for male and female respondents. Prospective analysis, with year 1 respondent self-assessed health related to year 2 health behaviours generated statistically significant relationships for number of visits to the GP, in-patient visits to a hospital and prescriptions received. These findings suggest that a person's assessment of their own health may impact on their future health care behaviour.

Analysis 3: Predictors of Satisfaction with Home Heating

Satisfaction with home heating was assessed through an eight-item scale completed by the respondent, as discussed in relation to analysis 1. The results of the logistic regression relating this year 1 variable to year 1 predictors are presented in Table 4.

Table 4 shows that respondent dissatisfaction with home heating was significantly and independently associated with poorer SAP ratings, living in rented accommodation, mastery scores and older respondent age. A similar pattern of relationships was found when year 2 satisfaction with home heating was predicted, within the two sample waves, and for male and female respondents. These findings suggest that the relationships which

Table 4. Logistic regression model predictors of perceptions of lower satisfaction with home heating[*] in year 1 ($n = 371$) [**]

Predictor	Odds	95% confidence intervals	Significance
SAP rating (per unit worse)	1.03	1.02–1.05	< 0.001
Home rented			
No	1		
Yes	4.8	2.99–7.75	< 0.001
Older respondent age (per year)	1.02	1.01–1.03	0.005
Mastery scale score			
Higher locus of control	1		< 0.001
Lower	2.89	1.62–4.29	< 0.001

[*]Respondents were dichotomised into two groups in terms of their satisfaction with home heating, as for analysis 1.
[**]Total sample $n = 535$. 164 cases were excluded from the analysis on account of missing data.

emerged from statistical modelling endured over time and were not affected by the above two sample features. The occupational social status, wealth and income poverty indicators were included in the initial analysis but not the final model. However, occupational social status was almost accepted into the model ($p = 0.07$). Respondent gender was unrelated to satisfaction with home heating.

Taken together, the findings of analyses 1 and 3 imply that objective energy efficiency, as measured by SAP ratings, may play a double role, affecting satisfaction with home fuel inefficiency which in turn influences health, as well as directly impacting on health.

Path Analysis

Path analysis was used to explore the overall set of relationships outlined above. Overall self-assessed health was best predicted by the saturated model which included the relationship between every predictor variable. Non-saturated models varied slightly, depending upon the statistical criteria used to judge predictive accuracy. One such model is presented in Figure 3.

The model reproduces the causal sequences outlined in the paper. In particular, the relationship between occupational status and health is mediated by satisfaction with

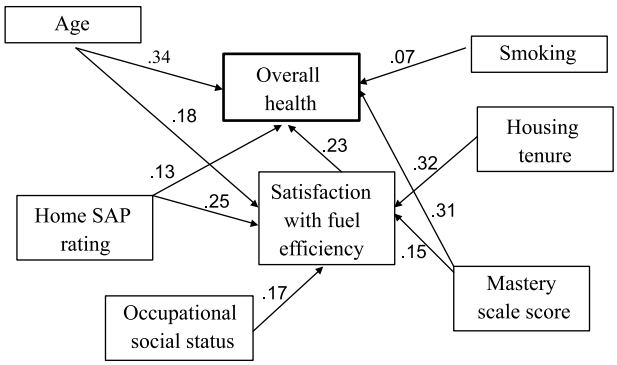

Figure 3. Path analysis for predictors of respondent overall self-assessed health ($n = 349$)

heating, whilst SAP ratings predict both the latter and overall health. Although the variables included do not predict overall respondent health powerfully, they offer suggestive signals about causal processes.

Discussion

The study discussed in this paper is affected by the usual limitations of cross-sectional and longitudinal surveys with respect to sample generalisability, the validity of measures and the causal status of statistically significant but predictively weak relationships. Recruiting relatively poor people into the study proved more difficult than anticipated even though all were offered free energy efficient light bulbs, and the prospect of valuable, free home improvements if their household met the study criterion for fuel poverty. Possible reasons for the low recruitment rate include reluctance to endure the disruption associated with the implementation of energy efficiency measures, lack of interest in the long-term state of rented accommodation, and fear that property improvement might lead to rent increases.

Because the survey sample was self-selected, the findings can be generalised from only tentatively. However, statistical modelling with subsamples based on the two sample waves and male and female respondents suggests that the findings are robust, at least with respect to the recruitment methods used and respondent gender. The finding that statistical relationships identified with the year 1 dataset were also found when used to predict health and satisfaction with home heating in year 2 provides evidence of consistency over time in these relationships.

The targeting of relatively poor households, through telephone screening and direct recruitment in poorer areas, meant that the sample was drawn from a socio-economically disadvantaged population. Extrapolation from one national survey (DTI/DEFRA, 2003), with allowance for differences in the treatment of housing costs, suggests that roughly 14 per cent of the population would have been classified as in fuel poverty in terms of the study definition. (This proportion is expected to increase (Klein, 2003, p. 15) as a result of anticipated fuel price increases.) The screening procedures led to about 40 per cent of those interviewed being classified as being in fuel poverty. Although a substantial increase on the underlying rate was achieved, the failure to eliminate over half those who were not in fuel poverty attests to the complexity of making this assessment. Research which improves the accuracy of screening methods will enable people in fuel poverty to be targeted more efficiently. Sensitivity (i.e. the proportion of fuel poor households detected through screening) as well as selectivity will need to be addressed.

Measuring social and health variables by means of survey questions raises methodological issues about their validity. Medical assessments of respondent health will not fully correspond with self-assessed health. On the other hand, it can be argued that health is a subjective concept which survey questions can tap into. The overall health measure was closely related to the reported presence of limiting conditions, and to SF36 scores. The finding of statistically very significant, although predictively weak, relationships between overall self-assessed health and a range of reported health care behaviours suggests that the former was measuring subjective health, at least, with some degree of validity. The weakness of the relationships between overall self-assessed health and reported health behaviours might be expected as use of health services will result from relatively minor health problems and efforts at health promotion as well as from limiting conditions. Nevertheless, if the relationship between home energy efficiency and overall

self-assessed health is causal, a cost saving to health services should result from improving the former.

The study documents the importance of home energy efficiency as a factor mediating the relationship between socio-economic status and health. This finding is consistent with the conclusion of Ellaway & Macintyre (1998) that the association of poor housing with worse health is independent of socio-economic status. Within a relatively disadvantaged population living in one of the coldest areas of England, inefficient heating, assessed objectively and subjectively, predicted overall respondent health better than measures of occupational socio-economic status, wealth or income. The data support the conclusion that the health-damaging effects of poorer socio-economic status are mediated by differences in energy efficiency.

Socio-economic status was held fairly constant within the relatively poor population sampled. The findings are particularly relevant to the prospects of energy efficiency improvements generating health gains among the more socially disadvantaged. They attest to the health impact of home energy efficiency for this social group, but have to be interpreted with the usual cautions about cross-sectional survey data. First, home energy efficiency may be associated and confounded with other causally significant factors, e.g. the quality of the local environment. Second, energy efficiency measures provide only a current snapshot of historical exposure, whilst health effects might be expected to accumulate over a lifetime (Dedman *et al.*, 2001; Marsh *et al.*, 1999). The first methodological limitation might result in the health impact of energy efficiency being overestimated, whilst the second might lead to underestimation.

The finding that objective and subjective energy efficiency measures, themselves associated, predicted health status independently of each other can be explained in three non-exclusive ways. First, the health impact of fuel inefficiency might be partly mediated by differences in expectation, apparent in the qualitative arm of the study. The qualitative data showed that individual tolerance of living in a cold home varies substantially, and is influenced by cultural, biographical and personal factors, as well as by circumstances such as caring for a young child or the presence of a sick relative. In consequence, distress about fuel inefficiency might exacerbate the health-damaging effect of the inefficiency itself. Although the idea of psychosocial mediation of physical conditions remains plausible, two alternative explanations must be acknowledged. First, the subjective measure might pick up aspects of home energy efficiency which SAP ratings do not detect, offering a more accurate assessment of objective conditions. For example, draughts affect body surface cooling, but poorly fitting windows and doors, which cause draughts, do not affect SAP ratings greatly. Second, as shown in the lower part of Figure 1, people with worse health may find coping with cold more difficult. Even if energy efficiency, within the range sampled in this study, impacts on health indirectly, this conclusion does not downgrade the importance of material conditions that impact strongly on perceptions of home warmth.

The findings suggest that a sense of personal mastery, rather than material conditions as measured by household income, wealth and socio-economic status, determines health, with material circumstances affecting health only indirectly by making it more likely that people in poverty will feel unable to control their lives. As noted above, this conclusion only applies in relation to the relatively disadvantaged population sampled. If a wider range of incomes had been sampled, a direct effect of this variable might have been demonstrated. In addition, the cautions mentioned with respect to subjective assessments of household warmth apply equally to the mastery variable. First, this measure may simply

detect more subtle aspects of material circumstances, e.g. instrumental support networks, not captured by the income measure. Second, as shown in Figure 1, poorer health may cause feelings of powerlessness. As noted in relation to energy efficiency, even if household relative poverty affects health only through psychosocial processes, its indirect impact remains real and significant.

The well-off can afford to mitigate the impact of fuel inefficiency by spending more on fuel. Wilkinson *et al.* (2001) found, at the aggregate level, that cold indoor temperatures were particularly associated with the combination of low income and fuel inefficiency. However, the present findings suggest that, within the relatively poor population sampled, poorer health is associated with low SAP ratings and/or low income, whilst the combination of relative affluence with good home energy efficiency predicted reduced risk of poorer health. One possible explanation of these findings is that, within this relatively poor population, those who spend more on heating their homes on account of their fuel inefficiency experience other forms of relative deprivation and exclusion. As the qualitative arm of the present study illustrated, coping with fuel poverty can involve different strategies of accepting lower temperatures combined with giving up or reducing other types of expenditure, e.g. on holidays, social activities or even food. The health consequences of home fuel inefficiency are mediated by such coping strategies.

Although these complexities and ambiguities must be acknowledged, the findings are consistent, at least, with the hypothesis that home energy efficiency plays an important, underestimated role in the processes through which lower socio-economic status 'causes' poorer health. The present study extends previous work in this field by documenting the relationship between living in a cold home and poorer health at the individual as against the aggregate level, assessing overall health rather than mortality or specific forms of morbidity, and including both objective and subjective measures of energy efficiency.

The findings have two important policy implications. Although not conclusive, they contribute to a growing body of evidence that home fuel inefficiency makes a significant contribution to the maintenance of health inequalities. As this problem can be ameliorated relatively easily through well-defined interventions, government actions designed to improve home energy efficiency should provide an exceptionally good return in terms of health gain in return for the needed investment. Second, the take-up of energy efficiency schemes needs to be maximised through careful attention to their design. It should not be assumed that families, e.g. those living in privately rented accommodation, will necessarily welcome such schemes simply because they are free.

Inevitably, research into complex issues raises more questions than it contributes to answering. The key question of the extent to which low energy efficiency causes health problems can only be answered directly through randomised controlled trials, as noted above. Survey data make a different kind of contribution to knowledge, generating hints about processes underlying any causal relationship. Four questions arising from the findings described in the present paper are worth further investigative consideration.

First, the complex responses of household members to fuel inefficiency, and their health consequences, should be mapped in more detail through surveys which include home temperature measurement and qualitative research. Second, it might be expected that the relatively affluent can more easily mitigate fuel inefficiency by spending more on fuel. The expected interaction might be found if similar surveys are conducted with a wider range of socio-economic groups, not just the relatively poor, as noted above. Third, the finding that objectively and subjectively measured home heating efficiency were independently and

additively associated with overall self-assessed health could be further investigated. In particular, the perspectives of deviant cases, i.e. those who were satisfied with the heating of their homes despite low SAP ratings or dissatisfied despite good SAP ratings could be further explored. Differences in expectation might explain the apparent discrepancies in judgement shown by these two groups, as suggested above. Alternatively, detailed investigation of their circumstances might point up problems with SAP ratings themselves. Fourth, family decision-making about accepting energy efficiency interventions should be investigated, so that barriers to their take-up can be identified and minimised.

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