# The effects on health of a publicly funded domestic heating programme: a prospective controlled study

J Walker,[1] R Mitchell,[2] M Petticrew,[3] S Platt[1]

[1] Research Unit in Health, Behaviour and Change (RUHBC), School of Clinical Sciences & Community Health, University of Edinburgh, Edinburgh, UK; [2] Public Health & Health Policy, University of Glasgow, Glasgow, UK; [3] Public & Environmental Health Research Unit, Dept Public Health & Policy, London School of Hygiene & Tropical Medicine, London, UK

Correspondence to:
S Platt, Research Unit in Health, Behaviour and Change (RUHBC), School of Clinical Sciences & Community Health, University of Edinburgh, Teviot Place, Edinburgh EH8 9AG, UK;
steve.platt@ed.ac.uk

Accepted 31 August 2008
Published Online First 18 September 2008

## ABSTRACT

**Objective:** To assess the effect of a publicly funded domestic heating programme on self-reported health.

**Design, setting and participants:** A prospective controlled study of 1281 households in Scotland receiving new central heating under a publicly funded initiative, and 1084 comparison households not receiving new heating. The main outcome measures were self-reported diagnosis of asthma, bronchitis, eczema, nasal allergy, heart disease, circulatory problems or high blood pressure; number of primary care encounters and hospital contacts in the past year; and SF-36 Health Survey scores.

**Results:** Usable data were obtained from 61.4% of 3849 respondents originally recruited. Heating recipients reported higher scores on the SF-36 Physical Functioning scale (difference 2.51; 95% CI 0.67 to 4.37) and General Health scale (difference 2.57; 95% CI 0.90 to 4.34). They were less likely to report having received a first diagnosis of heart disease (OR 0.69; 95% CI 0.52 to 0.91) or high blood pressure (OR 0.77; 95% CI 0.61 to 0.97), but the groups did not differ significantly in use of primary care or hospital services.

**Conclusions:** Provision of central heating was associated with significant positive effects on general health and physical functioning; however, effect sizes were small. Evidence of a reduced risk of first diagnosis with heart disease or high blood pressure must be interpreted with caution, due to the self-reported nature of the outcomes, the limited time period and the failure to detect any difference in health service use.

It is generally recognised that housing conditions are an important determinant of population health.[1] The influence of housing conditions on health inequalities in the UK has been recognised in landmark publications such as the Black Report[2] and the Acheson Report.[3] Links between housing and health are explicitly recognised in the Wanless report on public health policy in England,[4] which states that "… inequalities in health may be due to … … social and environmental factors such as housing and income". A recent review of evidence conducted by the World Health Organization[5] found "… considerable evidence that housing conditions do affect health status". Although uncertainty surrounds the precise pathways via which the domestic environment may impact on residents' health, research on the physiological effects of cold suggests that low temperatures may be implicated in respiratory conditions[6–9] and may be a risk factor for heart disease.[10–12]

In Scotland, the potential public health benefit associated with improving standards of domestic heating is one of the main drivers behind a policy initiative—the Scottish Government Central Heating Programme (CHP)[13] – aimed at providing modern central heating systems to substantial numbers of homes that lack such facilities. During the period covered by the evaluation reported in this paper, those eligible to receive heating under the CHP were: social sector (local authority or housing association) tenants whose home lacked any form of central heating system; and private sector households in which the head of household (or partner/spouse) was aged 60 or over, and whose home either lacked any form of central heating or contained a central heating system that was broken beyond repair.

The intended public health impacts of the CHP include improving the health of the elderly, reducing the number of winter deaths, lowering the incidence of cold-related illness and reducing pressure on the NHS.[14] Relatively few studies have directly considered the associations between cold housing and health.[15] However, recent work indicates that inability to maintain sufficient warmth in the home in winter is associated with poor health,[16 17] though the reverse effect – adverse health consequences due to overheating – has also been suggested by research conducted in North America.[18] Although the nature and strength of causal links between low indoor temperature and ill health remain as yet unclear, the CHP appears to be driven in part by the expectation that improving domestic heating arrangements will lead to better health for residents. In order to assess the health impacts of the CHP, the Scottish Government commissioned an evaluation with the aim of identifying any changes in health status that were attributable to the Programme. The findings reported here are drawn from that evaluation, which is one of relatively few large-scale intervention studies to have considered the specific effect on health of improved domestic heating arrangements.[19] The overall paucity of robust evidence of the health effects of social interventions was recognised in the Wanless report, which concluded that "the major constraint to further progress on the implementation of public health interventions is the weakness of the evidence base for their effectiveness …".[4] The report identified "… the potential of public health programmes for use as natural experiments, where evaluation should be an explicit component of the implementation of new interventions, programmes and policies, and so could inform the evidence base for public health".[4] This study is a practical example of such an endeavour.

## METHODS

### Participants

A sample of 1977 households due to receive central heating under the programme was interviewed

**Table 1** Specification of outcome measures, by category (specific symptoms and health conditions, use of primary and secondary health services and self-reported health-related quality of life) and type (continuous, dichotomous)

| Measure | Variable type and comments |
|---|---|
| Specific symptoms and health conditions | |
| Number of reported episodes of cold/flu symptoms in past 6 months | Continuous |
| Whether respondent has ever been diagnosed with *asthma* * | Dichotomous; analysis restricted to those reporting no diagnosis at initial interview |
| As above, diagnosed with *chest problems such as chronic bronchitis, pulmonary disease** | Dichotomous; analysis restricted as above |
| As above, diagnosed with *eczema** | Dichotomous; analysis restricted as above |
| As above, diagnosed with *a nasal allergy such as* hayfever* | Dichotomous; analysis restricted as above |
| As above, diagnosed with *heart disease** | Dichotomous; analysis restricted as above |
| As above, diagnosed with *circulatory problems** | Dichotomous; analysis restricted as above |
| As above, diagnosed with *high blood pressure** | Dichotomous; analysis restricted as above |
| Number of reported attacks of asthma in the past 12 months | Dichotomous (one or more vs zero); restricted to those reporting a diagnosis of asthma at the initial interview |
| Whether respondent has been woken by shortness of breath in the past 12 months | Dichotomous |
| Whether respondent has been woken by tightness in chest in the past 12 months | Dichotomous |
| Whether respondent has experienced wheezing in chest in the past 12 months | Dichotomous |
| Whether respondent experienced coughing or phlegm on most days for a minimum of 3 months a year and for at least 2 successive years | Dichotomous |
| Whether respondent suffers from at least one respiratory health problem | Dichotomous |
| Whether respondent has ever been advised to change diet/lifestyle to reduce blood pressure or avoid having high blood pressure | Dichotomous; analysis restricted to those reporting *no* at initial interview |
| Whether respondent is currently taking action in relation to diet/lifestyle due to high blood pressure | Dichotomous |
| Whether respondent is currently suffering from high blood pressure | Dichotomous |
| Use of primary and secondary health services | |
| Number of GP/nurse encounters in past year* | Continuous |
| Number of hospital outpatient or day bed visits in past year* | Dichotomous (one or more vs zero) |
| Number of overnight hospital stays in past year* | Dichotomous (one or more vs zero) |
| Number of A&E attendances in past year* | Dichotomous (one or more vs zero) |
| Self-reported health-related quality of life (SF-36†) | |
| SF-36 Physical Functioning scale | Continuous |
| SF-36 Role-Physical scale | Continuous |
| SF-36 Bodily Pain scale | Continuous |
| SF-36 General Health scale | Continuous |
| SF-36 Vitality scale | Continuous |
| SF-36 Social Functioning scale | Continuous |
| SF-36 Role-Emotional scale | Continuous |
| SF-36 Mental Health scale | Continuous |
| SF-36 Health Transition item | Continuous |

*Identifies outcome measures of primary interest.
†SF-36 Health Survey (version 2).

shortly before receipt of heating. Recruitment of households was carried out by Local Authorities and Housing Associations (for public sector participants), and by the contractor engaged to manage the heating installations (for privately owned dwellings). No selection criteria were applied – any eligible individual who consented to participate in the study was enrolled.

A comparison group from households not involved in the programme (n = 1872) was also recruited. Identification of appropriately matched comparison households was performed by the commercial survey organisation who carried out all interviews for the study (NFO System 3). The comparison group, matched to heating recipients by tenure, household composition, socioeconomic group and location (postcode sector), cannot be considered a control group in a strict experimental sense, as the allocation of individuals to groups was not random or undertaken by the research team. Rather, this was an ''opportunistic'' sample, reflecting varying degrees of willingness amongst public sector landlords and tenants/householders to participate in the study. Moreover, the comparison group (which would ideally have consisted of households that lacked central heating throughout the period of the evaluation) necessarily included a proportion of homes that possessed central heating systems, for the simple reason that it would have been impossible to find a sufficiently large body of ''heating-less'' households, which were not enrolled in the CHP. In the event, the comparison group included dwellings both with and without central heating. This being so, the comparison group was viewed as a set of households whose status in respect of their domestic heating arrangements was expected to remain broadly static across the period of the evaluation, thus providing a fairly constant base against which any changes experienced by the recipient group could be contrasted. This expectation was not, in the event, wholly met (see below).

## Data collection

Initial interviews were conducted in respondents' homes, information being given by the head of household or her/his partner. One year after the initial interview, participants were sent a short postal questionnaire. Finally, 1 further year later (2 years after the initial contact), a final interview was held in the home. An identical three-stage data collection regime was

applied to both recipient and comparison respondents. Informed consent to participate in all stages of the study was obtained from all respondents prior to the first interview. The initial wave of interviews was conducted between November 2002 and February 2004, while final interviews were held between December 2004 and March 2006. Results reported here are derived from the first and final interviews. Although the dates of final interviews were not recorded, the survey organisation was specifically instructed to aim for an interval of 1 year between each pair of contacts (i.e. a 2-year period between first and final interviews) and, as far as we are aware, the instruction was followed.

### Outcomes

Seventeen individual outcomes relating to specific symptoms and health conditions, four outcomes representing respondents' use of primary and secondary health services and nine outcomes relating to self-reported health-related quality of life (HRQOL), derived from Version 2 of the SF-36 Health Survey,[20] were examined (see table 1).

Data on perceived adequacy of heating, use of heating and experiences of problems with damp, mould and cold were also gathered to ascertain whether the intervention achieved changes in the domestic environment that could plausibly be related to changes in health status.

### Analysis

Continuous outcomes were analysed via analysis of covariance (ANCOVA), the value of the outcome at the study endpoint being predicted by the age of the respondent (in years); gender; socioeconomic group (four-way scheme: class AB, C1, C2 or DE); household type (seven-way scheme: single pensioner, single adult, single parent, couple without children, couple with children, pensioner couple, multiple adult); housing tenure (dichotomous: owner-occupied vs rented); experience of life events in the year prior to the final interview (group of five binary indicators, representing experience of serious illness, divorce/separation, bereavement, personal unemployment, unemployment suffered by another wage earner in the respondent's household); change in smoking exposure over the study period; and "treatment group" membership (dichotomous: heating recipient vs comparison group household). In addition, the ANCOVA models included as a predictor the value of the outcome at the initial interview point. For these outcomes, confidence intervals for the effect of the intervention were estimated via bootstrapping,[21 22] due to the markedly non-normal distributions of these quantities. Outcomes representing counts (e.g. number of cold/flu episodes) were modelled via Poisson regression. Binary outcomes were analysed via logistic regression, the set of predictors being in most cases identical to that employed for continuous quantities. For one binary outcome – number of reported asthma attacks in the past 12 months (zero vs one or more) – technical considerations stemming from the small number of available cases (n = 183) forced adoption of a more limited predictor set. All analyses were weighted (via inverse propensity scores[23]) to adjust for sample attrition between the initial and final interview points. Analysis was performed with SAS software, Version 9.1 and with R version 2.7.1.

## RESULTS

A total of 3849 households contributed initial interview data, of which 1977 (51.4%) were central heating recipients and 1872 (48.6%) comparison households. Final interviews were achieved with 2365 households, representing 61.4% of the original sample. Of these, 1281 (54.2%) were heating recipients and 1084 (45.8%) from comparison households. All results reported here are based on these 2365 respondents. The comparability of the recipient and comparison groups in the final achieved sample is shown in table 2. Although significant between-group differences are evident for socioeconomic group and property type, these differences are relatively small. Overall, the groups were broadly similar in terms of the variables examined.

Although little change in the heating status of comparison households had been expected (see above), 279 [25.7%]) of the 1084 comparison respondents who provided data at both the initial and final interview were found to have acquired central heating at some point during the follow-up period. Conversely, 92 (7.2%) of the 1281 recipient households who yielded successful interviews at both points may not have received heating, or may have had a central heating installation which

**Table 2** Comparison of recipient and comparison groups in final achieved sample: sociodemographic characteristics, smoking status and change in smoking status (Scotland, 2002–06)

| | CHP* recipients n = 1281 | Comparison group n = 1084 | |
|---|---|---|---|
| **Characteristic** | **Mean (SD)** | **Mean (SD)** | **p Value** |
| Age: (years) | 61.9 (16.5) | 62.4 (16.8) | 0.26† |
| | n (%) | n (%) | |
| Sex: female | 829 (64.7) | 688 (63.5) | 0.53‡ |
| Socioeconomic group | | | |
| AB (professional/managerial) | 33 (2.6) | 39 (3.6) | 0.04‡ |
| C1 (skilled non-manual) | 191 (14.9) | 186 (17.2) | |
| C2 (skilled manual) | 282 (22.0) | 196 (18.1) | |
| DE (semi-skilled/unskilled manual) | 775 (60.5) | 663 (61.2) | |
| Household composition | | | |
| Single adult | 121 (9.5) | 93 (8.7) | 0.21‡ |
| Single parent | 86 (6.7) | 90 (8.5) | |
| Single pensioner | 458 (35.8) | 397 (37.3) | |
| Couple with no children | 142 (11.1) | 118 (11.1) | |
| Couple with children | 98 (7.7) | 76 (7.1) | |
| Pensioner couple | 286 (22.4) | 242 (22.7) | |
| Multiple adults | 88 (6.9) | 49 (4.6) | |
| Tenure: No. owner–occupier | 544 (42.5) | 441 (40.7) | 0.37‡ |
| Property type | | | |
| Detached house | 175 (13.7) | 161 (14.9) | < 0.001‡ |
| Semi-detached house | 179 (14.0) | 170 (15.7) | |
| Terraced house | 355 (27.7) | 254 (23.4) | |
| Tenement | 288 (22.5) | 208 (19.2) | |
| Four-in-a-block | 158 (12.3) | 169 (15.6) | |
| Flat in converted building | 19 (1.5) | 12 (1.1) | |
| High-rise flat | 3.3 (2.6) | 82 (7.6) | |
| Other | 7.3 (5.7) | 28 (2.6) | |
| Smoking status at baseline | | | |
| No exposure to smoking | 649 (50.7) | 561 (52.0) | 0.23‡ |
| Passive smoking only | 188 (14.7) | 145 (13.5) | |
| Active smoker, no passive exposure | 103 (8.1) | 67 (6.2) | |
| Active smoker and passive exposure | 339 (26.5) | 305 (28.3) | |
| Change in smoking status between baseline and final interview | 329 (25.8) | 277 (25.8) | 0.97‡ |
| Central heating at baseline point (comparison group only) | | 151 (13.9) | NA |

*Central heating programme.
†Mann–Whitney test.
‡Chi-square test.

predated the start of the evaluation. Despite this "contamination" of the two groups, the original classification of respondents as either recipients or comparison group members was retained. This approach corresponds to the "intention to treat" concept applied in clinical trials, under which subjects are retained for analysis purposes in the treatment group to which they were originally allocated, even if they did not in the event receive the intended treatment option. The remit of the evaluation was not to assess the health impact of receiving central heating *in general*, but rather to determine the health-related effects of a specific initiative—the Central Heating Programme—with its own unique client base, and financial and administrative characteristics. One feature of such a real world initiative is that, for a variety of reasons, some intended clients of the programme will not in the event actually receive heating systems. A second feature is that households outside the programme will, via a variety of routes, acquire central heating independently of the initiative. Thus, to assess the specific health impacts of the CHP—as distinct from the more general effects of "receiving central heating"—in the actual context within which it operates, it was considered appropriate to retain the original respondent groupings (even if subject to "contamination") on the grounds that this approach faithfully reflects the experience of the CHP as actually implemented. A further series of analyses (not reported here) was performed to evaluate the effect of "true" receipt of central heating, contrasting those who actually received heating during the study period with those who did not. Effect sizes were found to be broadly similar to those derived via the "intention to treat" approach.

With regard to the home environment, the recipient group was more likely to report satisfaction with home heating (OR 4.96; 95% CI 3.87 to 6.37); less likely to keep more than half of the rooms in the home unheated during cold weather (OR 0.22; 95% CI 0.16 to 0.29); and less likely to report problems with damp, mould and cold (OR 0.39; 95% CI 0.15 to 1.00) than the comparison households. These findings suggest that recipients' home environment was improved through receipt of heating under the programme. Thus, it is legitimate to examine whether there were any corresponding changes in health status.

Results for all health outcomes are shown in table 3. The values given represent the estimated effect of receiving central heating under the CHP, relative to being in the comparison group, after adjusting for covariates. The table shows (from left to right) the estimate type (O = odds ratio [for binary variables], P = Poisson coefficient [for count data]; R = ANCOVA regression coefficient [for continuous outcomes]); the point estimate; the 95% confidence interval for the estimate; the effective number of responses from which the result is derived; and the associated p value. No p values are shown for continuous outcomes—as previously stated, the confidence limits for these were estimated via boostrapping. At the conventional 5% level, heating recipients were significantly less likely to report receiving a first diagnosis of heart disease (OR 0.69; 95% CI 0.52 to 0.91) or of high blood pressure (OR 0.77; 95% CI 0.61 to 0.97), and more likely to receive a first diagnosis of nasal allergy (OR 1.52; 95% CI 1.05 to 2.20). Recipients were also found to record significantly higher scores on the SF-36 Physical Functioning scale (estimated difference 2.51 units; 95% CI 0.67 to 4.37 units) and the SF-36 General Health scale (estimated difference 2.57 units; 95% CI 0.90 to 4.34 units). No significant effect of the programme was observed for the remaining 25 measures investigated.

## DISCUSSION

Although housing and the domestic environment are now generally accepted as important determinants of health and health inequalities,[24] relatively few large-scale intervention studies have considered the specific effect on health of improved domestic heating arrangements.[19] This large study investigated the influence of improved heating on a total of 30 individual outcomes representing specific symptoms and health conditions (primarily focused on cardiorespiratory conditions), use of health services and self-reported health-related quality of life. Of the 30 measures considered, five exhibited statistically significant associations with the receipt of central heating under the CHP.

The most striking findings are those that suggest heating provision is associated with a reduced probability of receiving a first diagnosis of heart disease or of high blood pressure. These findings are consistent with current understanding of the pathways via which low indoor temperatures may influence cardiovascular health. For example, it has been established that entering a cold room can cause transient hypertension,[10] and that low temperatures are associated with increased blood viscosity (a risk factor for ischaemic heart disease).[12] However, the results reported here must be treated circumspectly for three reasons. First, the evaluation only examined respondents' experiences across a relatively short time period (2 years), and without further research it cannot be stated whether the observed reductions in the incidence of heart disease/high blood pressure would be sustained in the longer term. Indeed, it is questionable whether de novo coronary disease would reduce materially over such a short time period as a result solely of improved heating. Second, it is paradoxical that the apparently reduced experience of these two classes of condition among heating recipients was not matched by corresponding reductions in the use of health services, which is what might reasonably have been expected. Third, the outcome measures representing diagnosis with heart disease and high blood pressure were based on the respondent's self-report, rather than being drawn from an objective clinical sources such as GP or hospital records. A degree of uncertainty or imprecision therefore attaches to the outcomes. For example, one respondent might report a recent diagnosis of angina as "heart disease", while a second might not. These factors—the limited time period examined, the absence of effect on respondents' use of health services, and the self-reported nature of the outcomes—suggest that the apparently positive effect of the CHP on cardiovascular health, while interesting and potentially important, must be viewed with reservation.

Receipt of heating under the CHP was found to exert a positive influence on health-related quality of life (SF-36 Physical Functioning and General Health scales) and reduction in odds of self-reported nasal allergy. This is broadly consistent with the findings of a recent randomised controlled trial of insulation retrofitting in New Zealand, where adults in insulated homes had half the odds of having fair or poor self-rated health after the intervention, and about half the odds of respiratory symptoms.[25] However, in the present case the observed effects—while statistically significant—are small (around 2.5 units on scales with a 100-point range). The effects observed here may be compared with those reported in a recent published comparison of SF-36 scores for adults (aged 15 years or more) with and without asthma.[26] This source estimates that the mean Physical Functioning score for asthmatics is around 10 scale points lower than the mean score for non-asthmatics, whereas the corresponding difference for the General Health

**Table 3** Covariate-adjusted* associations between "treatment group" membership (heating recipient vs comparison group household) and health outcomes (Scotland, 2002–06)

| Measure | Type† | Estimate‡ (95% CI) | n | p |
|---|---|---|---|---|
| Specific symptoms and health conditions | | | | |
| Number of reported episodes of cold/flu symptoms in past 6 months | P | 1.02 (0.88 to 1.17) | 2268 | 0.83 |
| Whether respondent has ever been diagnosed with asthma | O | 0.92 (0.63 to 1.34) | 2061 | 0.65 |
| Whether respondent has ever been diagnosed with bronchitis, etc. | O | 1.29 (0.97 to 1.72) | 1983 | 0.09 |
| Whether respondent has ever been diagnosed with eczema | O | 1.43 (0.89 to 2.28) | 2223 | 0.14 |
| Whether respondent has ever been diagnosed with nasal allergy | O | 1.52 (1.05 to 2.20) | 2136 | 0.03 |
| Whether respondent has ever been diagnosed with heart disease | O | 0.69 (0.52 to 0.91) | 1928 | 0.01 |
| Whether respondent has ever been diagnosed with circulation problems | O | 1.06 (0.83 to 1.34) | 1903 | 0.64 |
| Whether respondent has ever been diagnosed with high blood pressure | O | 0.77 (0.61 to 0.97) | 1340 | 0.02 |
| Number of reported attacks of asthma in the past 12 months (one or more vs zero) | P | 0.96 (0.77 to 1.20) | 183 | 0.74 |
| Whether respondent woken by shortness of breath in past year | O | 1.14 (0.94 to 1.37) | 2256 | 0.18 |
| Whether respondent woken by tightness in chest in past year | O | 1.20 (0.79 to 1.83) | 1639 | 0.39 |
| Whether respondent has experienced wheezing in chest in past year | O | 0.96 (0.72 to 1.28) | 1506 | 0.78 |
| Whether respondent experienced coughing or phlegm on most days | O | 0.86 (0.71 to 1.04) | 2311 | 0.11 |
| Whether respondent suffers from at least one respiratory health problem | O | 1.03 (0.88 to 1.20) | 2325 | 0.74 |
| Whether respondent advised to change diet/lifestyle due to high blood pressure | O | 0.87 (0.71 to 1.07) | 1787 | 0.20 |
| Whether respondent currently taking action in relation to diet/lifestyle | O | 0.99 (0.84 to 1.17) | 2297 | 0.93 |
| Whether respondent is currently suffering from high blood pressure | O | 1.05 (0.87 to 1.28) | 2144 | 0.61 |
| Use of primary and secondary health services | | | | |
| Number of GP/nurse encounters in past 12 months | P | 0.95 (0.84 to 1.07) | 2223 | 0.40 |
| Number of hospital outpatient or day bed visits in past 12 months (one or more vs zero) | P | 0.96 (0.79 to 1.15) | 2280 | 0.63 |
| Number of overnight hospital stays in past 12 months (one or more vs zero) | P | 0.74 (0.54 to 1.03) | 2309 | 0.08 |
| Number of A&E attendances in past 12 months (one or more vs zero) | P | 1.16 (0.90 to 1.50) | 2310 | 0.24 |
| Self-reported health-related quality of life (SF-36¶) | | | | |
| SF-36 Physical Functioning scale | R | 2.51 (0.67 to 4.37) | 2171 | NA |
| SF-36 Role-Physical scale | R | 1.96 (−0.34 to 4.41) | 2265 | NA |
| SF-36 Bodily Pain scale | R | −1.09 (−3.33 to 1.05) | 2302 | NA |
| SF-36 General Health scale | R | 2.57 (0.90 to 4.34) | 2314 | NA |
| SF-36 Vitality scale | R | 0.02 (−1.81 to 1.87) | 2219 | NA |
| SF-36 Social Functioning scale | R | 0.28 (−1.91 to 2.35) | 2269 | NA |
| SF-36 Role-Emotional scale | R | −0.23 (−2.68 to 2.14) | 2258 | NA |
| SF-36 Mental Health scale | R | −0.22 (−1.88 to 1.30) | 2210 | NA |
| SF-36 Health Transition item | R | −0.02 (−0.08 to 0.03) | 2319 | NA |

*Adjusted for age of the respondent, gender, socioeconomic group, household type, housing tenure, experience of life events in the year prior to the final interview and change in smoking exposure over the study period. The ANCOVA models also included as a predictor the value of the outcome at the initial interview point.
†O, odds ratio; P, Poisson regression coefficient; R, regression coefficient (ANCOVA).
‡Shows effect of central heating receipt relative to membership of the comparison group.
¶SF-36 Health Survey (version 2).

scale is around 11 points. When compared with these findings, the small differences observed in the present study are arguably of little practical or clinical importance.

Two further factors suggest that the findings of this study should be interpreted with caution. The first is that, as a result of the dilution of the distinction between "treatment" groups, estimation of the (unknown) "true" effects of the intervention is less precise than would be the case if the integrity of the groups had been preserved. The presence of central heating recipients in the comparison group is likely to result in an underestimation of any effects attributable to the intervention. Although this situation is suboptimal, it represents the best that may be achieved in a research context where a true experiment is not practically feasible. The approach is justified on the grounds that findings will be conservative—that is, will incline towards understatement of the unknown true effects of the intervention—and any risk of spurious positive results is minimised. There were a number of reasons why subjects may have ended up "misclassified", but these reasons are not generally indicative of data management problems. First, some intended recipients of the heating intervention did not eventually receive it for practical reasons (eg no mains gas supply in the street/block), or because they underwent a change of heart. With regard to the latter, a number of actual instances were reported of recipients (especially older people) deciding that they did not wish to endure the disruption of a full central heating installation. Second, some recipients may have indicated that they had a pre-existing central heating system because the terms of the initiative permitted a new heating system to be provided (for private sector households) where existing central heating was broken beyond economical repair. Third, a proportion of control households would, naturally, acquire central heating over the duration of the study as a normal home improvement measure.

A second consideration is that, with 30 individual outcomes under investigation, the possibility of Type I ("false-positive") errors must be recognised—at the conventional 5% level, 1.5 of these outcomes would be expected to yield a spuriously significant result due to the random play of chance. These factors, together with the specific limitations discussed earlier, mean that the striking findings relating to heart disease and high blood pressure—while interesting and consistent with current knowledge relating to the physiological effects of cold—provide insufficient evidence to make a claim for causality.

Although seasonality was not adjusted for in analysis, data collection for the study was conducted throughout the year and

## What is already known on this subject

- It is widely recognised that housing conditions are an important determinant of population health and health inequalities.
- However, relatively few large-scale intervention studies have considered the specific effect on health of improved domestic heating arrangements.
- There is a relative lack of robust evidence of the health effects of public policy interventions; greater use should be made of "natural experiments" which will inform the evidence base for public health.

## What this study adds

- The study provides the kind of public health evidence, derived from a public policy "natural experiment", which was called for in the Wanless report.
- The provision of central heating under the Central Heating Programme in Scotland was associated with significant positive effects on general health and physical functioning; however, effect sizes were small.
- Evidence of a reduced risk of first diagnosis with heart disease or high blood pressure must be interpreted with caution, due to the self-reported nature of the outcomes, the limited time period covered by the study and the failure to detect any difference in health service use.

## Policy implications

While investment in disease prevention (eg by funding housing improvement) may eventually reduce demand on health services, the study findings suggest that the effects may be fewer than anticipated.

individual sampling waves were spaced at an approximately uniform interval of 2 years between the first and final interviews. Therefore, it is unlikely that the observed results were influenced to any great degree by seasonal effects.

This study provides the kind of public health evidence that was called for in the Wanless report.[4] However, the study also illustrates the difficulties in collecting evidence from natural experiments where the researcher does not have control over delivery of the intervention. Despite its limitations, the study does raise one very important point. While the expectation of many commentators and policymakers is that investment in disease prevention (eg by funding housing improvement) may eventually reduce demand on health services,[14] our findings suggest that the effects may be fewer than anticipated. As always, more robust evidence collected over a longer time period is needed. Some of this may come from RCTs and, while such genuinely experimental investigations are difficult to realise in the field of housing and health, at least one such study has recently been successfully implemented.[27]

**Acknowledgements:** The conduct of the evaluation relied on the assistance and co-operation of a large number of individuals and bodies. Above all, thanks are due to the tenants and householders who volunteered to take part—without any tangible incentive or gain to themselves—in a time-consuming schedule of interviews. Without the data provided by these respondents, the evaluation would have been impossible. We also acknowledge the efforts of the TNS fieldworkers who conducted the interviews. Several Local Authorities and Housing Associations assisted in the identification of tenants included in the Central Heating Programme, who were potential candidates for the recruitment into the evaluation. The corresponding function was provided for private sector households by Eaga Group. We express our thanks to staff in all these organisations. We are also grateful to Nevil Pierse of The University of Otago (New Zealand), whose guidance on statistical matters was of immense value.

**Funding:** The research on which this paper draws was funded by the Scottish Government.

**Competing interests:** None.

**Ethics approval:** The study protocol was approved by the Faculty of Law, Business and Social Science Ethics Committee at the University of Glasgow.

Disclaimer: The views expressed in the publication are those of the authors and do not necessarily represent those of Scottish Ministers.

## REFERENCES

1. **Lowry S.** *Housing and health*. London: British Medical Journal, 1991.
2. **Black D.** *Inequalities in health: report of a research working group*. London: DHSS, 1980.
3. **Acheson D.** *Independent inquiry into inequalities in health report*. London: The Stationery Office, 1998.
4. **Wanless D.** *Securing good health for the whole population: Final Report*. London: HMSO, 2004.
5. **Bonnefoy XR,** Annesi-Maesano I, Aznar LM, *et al*. *Review of evidence on housing and health: background document for the Fourth Ministerial Conference on Environment and Health, Budapest 2004*. World Health Organisation; 2004 Apr. Report No.: Eur/04/5046267/BD/1.
6. **Strachan DP,** Sanders CH. Damp housing and childhood asthma: respiratory effects of indoor air temperature and relative humidity. *J Epidemiol Community Health* 1989;**43**:7–14.
7. **Rasmussen F,** Borchsenius L, Winslow J, *et al*. Associations between housing conditions, smoking habits and ventilatory function in men with clean jobs. *Scand J Respir Dis* 1978;**59**:264–76.
8. **Ross A,** Collins M, Sanders C. Upper respiratory tract infection in children, domestic temperatures, and humidity. *J Epidemiol Community Health* 1990;**44**:142–6.
9. **Hyndman SJ.** Housing dampness and health amongst British Bengalis in east London. *Soc Sci Med* 1990;**30**:131–41.
10. **Tochihara Y,** Ohnaka T, Nagai Y, *et al*. Physiological responses and thermal sensations of the elderly in cold and hot environments. *J Therm Biol* 1993;**18**:355–61.
11. **Woodhouse PR,** Khaw KT, Plummer M. Seasonal variation of blood pressure and its relationship to ambient temperature in an elderly population. *J Hypertens* 1993;**11**:1267–74.
12. **Keatinge W,** Coleshaw S, Cotter F. Increases in platelet and red cell counts, blood viscosity and arterial pressure during mild surface cooling: factors in mortality from coronary and cerebral thrombosis in winter. *BMJ* 1984;**291**:1405–8.
13. **The Scottish Executive**. *The Scottish Executive's Central Heating Programme and the Warm Deal: Annual Report 2001/02*. Edinburgh: The Scottish Executive, 2002.
14. **The Scottish Executive**. *Free central heating for pensioners and families (Scottish Executive Press Release SE2497/2000)*. Edinburgh: The Scottish Executive, 2000.
15. **Hopton J,** Platt S, Macleod L. Housing conditions and health consequences. In: Gill P, de Wildt G, editors.*Housing and health: the role of primary care*. Oxford: Radcliffe Medical Press Ltd., 2003:17–45.
16. **Evans J,** Hyndman S, Stewart-Brown S, *et al*. An epidemiological study of the relative importance of damp housing in relation to adult health. *J Epidemiol Community Health* 2000;**54**:677–86.
17. **Gemmell I.** Indoor heating, house conditions, and health. *J Epidemiol Community Health* 2001;**55**:928–29.
18. **Brugge D,** Rice PW, Terry P, *et al*. Housing conditions and respiratory health in a Boston public housing community. *New Solutions* 2001;**11**:149–64.
19. **Thomson H,** Petticrew M, Morrison D. Health effects of housing improvement: systematic review of intervention studies. *BMJ* 2001;**323**:187–90.
20. **Ware JE,** Kosinski M, Dewey JE. *How to score Version 2 of the SF-36® Health Survey*. Lincoln, RI: QualityMetric Incorporated, 2000.
21. **Efron, B**. Bootstrap methods: another look at the jacknife. *Annals of Statistics* 1979;**7**:1–26.
22. **Efron B,** Tibshirani R. Bootstrap methods for standard errors, confidence intervals, and other measures of statistical accuracy. *Statistical Science* 1986;**1**:54:77
23. **Little RJA,** Rubin DB. *Statistical Analysis with Missing Data*. New York: John Wiley, 2000.
24. **Olsen NDL.** Prescribing warmer, healthier homes (editorial). *BMJ* 2001;**322**:748–9.
25. **Howden-Chapman P,** Matheson A, Crane J, *et al*. Effect of insulating existing houses on health inequality: cluster randomised study in the community. *BMJ* 2007;**334**:460–4.
26. **Australian Centre for Asthma Monitoring**. *Asthma in Australia 2005 (AIHW Asthma Series 2)*. Canberra: Australian Institute of Health and Welfare, 2005.
27. **Howden-Chapman P,** Crane J, Matheson A, *et al*. Retrofitting houses with insulation to reduce health inequalities: aims and methods of a clustered, randomised community-based trial. *Social Science & Medicine* 2005;**61**:2600–10.