**Title**: Can we identify older people most vulnerable to living in cold homes during winter?

**Authors’ names and affiliations**

Claudio Sartini1 \*, Peter Tammes2, Alastair D Hay2, Ian Preston3, Daniel Lasserson4, Peter H Whincup5, S Goya Wannamethee1, and Richard W Morris2

1 University College London, Department of Primary Care & Population Health, London, UK

2 Centre for Academic Primary Care, School of Social and Community Medicine, University of Bristol, Bristol, UK

3 Centre for Sustainable Energy, Bristol, UK

4 Nuffield Department of Medicine, University of Oxford, UK

5 Population Health Research Institute, St George's University of London, UK

\* Corresponding author  
Email: c.sartini@ucl.ac.uk

**Abstract  
Words: (now 188, max 200)**

**Purpose**: Living in a cold home increases the risk of dying in winter, especially in older people. However, it is unclear which individual factors predict whether older people are living in cold homes.

**Methods**: 1402 Men aged 74-95 from a UK population-based study reported difficulties in keeping warm during winter answering four simple “yes/no” questions. Associations between individual’s characteristics and each of the four self-reported measures of cold homes were estimated using logistic regression models. Next, we investigated whether measures of cold homes predict mortality over the subsequent 2.1 years.

**Results**: Manual social class, difficulties making ends meet, and not being married were each associated (p<0.05) with each of the four measures of cold homes (adjusted odds ratios ranged from 1.61 to 4.68). Social isolation, poor respiratory health and grip strength were also associated with reports of cold homes. 126 men died; those who reported the presence of at least three measures cold homes had increased mortality [adjusted hazard ratios 2.85 (95%CI 1.11-7.30, p=0.029)].

**Conclusions:** Older people who find it hard to keep warm in winter, and have an elevated mortality, could be identified using a self-report questionnaire.

**Word count of manuscript text:** 2442 words (+ 3 tables embedded in this file)

**Background**

Excess winter mortality in the United Kingdom (UK) has been partially attributed to cold housing ([1](#_ENREF_1), [2](#_ENREF_2)), with an extra 5500 more deaths occurring annually in the coldest homes than would occur if those homes were warm ([3](#_ENREF_3)). Greater susceptibility of older people to cold has been suggested ([4](#_ENREF_4)) as they have worse cardiovascular and respiratory profiles at lower indoor ([5](#_ENREF_5)) and outdoor ([6](#_ENREF_6)) temperatures. However, it is unclear how to identify older people who particularly find it hard to keep warm in winter ([7](#_ENREF_7)). Existing evidence including qualitative ([8-10](#_ENREF_8)) and quantitative ([1](#_ENREF_1), [9](#_ENREF_9), [11](#_ENREF_11), [12](#_ENREF_12)) study designs and different measures of cold homes (e.g. self-reported ([8](#_ENREF_8), [9](#_ENREF_9)) and indoor temperature ([5](#_ENREF_5), [11](#_ENREF_11))), do not identify factors related to living in cold homes.

Using data from a UK population-based study of older men, we aim to highlight factors independently associated with living in cold homes to identify vulnerable older people who find it hard to keep warm ([13](#_ENREF_13)). We investigate the associations between (i) socio-demographic measures, (ii) health factors, (iii) behavioural factors, (iv) other personal circumstances, and (v) house characteristics with four self-reported measures of cold homes during winter. As it is unclear which measures of cold homes best predict those at risk of death ([11](#_ENREF_11)), we also investigated whether reports of cold homes in our study relate to mortality.

**Material and methods**   
  
*Sample*  
The British Regional Heart Study (BRHS) is a prospective, population-based cohort study following up 7735 men (99% Caucasian) recruited from primary care practices in 24 British towns in 1978–80. In 2014, 2820 surviving men aged 74-96 years were invited to complete a comprehensive health status and life style questionnaire including self-reported measures of cold homes ([14](#_ENREF_14)). 1655 men responded (99% between April and October) and 1402 had complete data on all covariables of interest; also, depending on both covariables and outcome of interest, the number of observations available for analyses varied from 1385 to 1402. The National Research Ethics Service (NRES) Committee London provided ethical approval. Participants provided informed written consent to the investigation, in accordance with the Declaration of Helsinki.  
  
*Self-reported measures of cold homes*  
Men were asked whether they were (i) having difficulties in meeting the heating/fuel costs; (ii) staying in bed longer in order to stay warm during the previous winter; (iii) unable to keep the living room comfortably warm during the cold winter weather, and (iv) turning the heating off even when cold because of worries about the costs during the previous winter. Having difficulties in meeting the heating/fuel costs was chosen as our main outcome, as an overall proxy measure of cold housing.   
  
*Individual factors*   
The individual factors selected in this study were investigated as previous evidence from qualitative ([8-10](#_ENREF_8)) and quantitative ([1](#_ENREF_1), [9](#_ENREF_9), [11](#_ENREF_11), [12](#_ENREF_12)) studies suggested their potential association with cold homes. For example, we hypothesized that an association of proxies of fuel poverty (e.g. social class, making ends meet and marital status) with cold homes could be found as these associations were more consistently reported in the literature ([1](#_ENREF_1)). The factors investigated in this study were categorised consistently with previous published work from the BRHS ([14-19](#_ENREF_14)), and represented five different domains: (i) socio-demographic (age, social class, and region of residence), (ii) general health (number of chronic conditions, respiratory health, mobility limitations outdoors, grip strength, depression, and feeling of social isolation), (iii) behavioural factors (smoking and alcohol consumption), (iv) personal circumstances (having increasing financial difficulties and house ownership), and (v) house characteristics (types of home insulation, heating system). Also, a proxy measure of the house energy efficiency (Energy Efficiency rating ([20](#_ENREF_20)), aggregated from households within participants’ Lower Super Output Area [LSOA]) was linked to each of the BRHS men. Energy Efficiency (EE) rating was investigated using descriptive statistics only; as a graded trend in association with the main outcome of interest was not found, this variable was considered as unimportant and not included in final models.  
*Statistical analyses*We examined the distribution of all variables of interest according to self-reported measures of cold homes. As the Energy Efficiency rating did not show a graded linear relationship with self-reported difficulties in keeping warm, we preferred to include house characteristics collected at individual level (e.g. types of home insulation and heating) in further analysis.  
  
*Logistic regression models*  
Logistic regression was used to estimate the associations of individual factors with each of the cold home measures, firstly unadjusted, then mutually adjusted. The mutually adjusted models were performed to narrow down the list of factors which were independently associated with each of the four self-reported measures of cold homes collected in this study.

*Subsidiary analyses*

As older people are less active in winter ([21](#_ENREF_21)), they are also likely to spend most time at home during this period [7]; therefore, a subsidiary analysis was carried out to find out which individual factors were associated with men both having difficulties in meeting the heating/fuel costs and also being inactive or occasionally active. Physical activity levels were derived from a self-reported questionnaire validated against objectively measured physical activity in a previous study ([15](#_ENREF_15)).  
As it is unclear which measures of cold homes best predict those at risk of death ([11](#_ENREF_11)), we also investigated whether self-reported measures of cold homes, alone or in combination, predicted mortality using Cox proportional hazard models; estimates (hazard ratios) were adjusted for potential confounding factors such as age, social class, marital status, chronic conditions, respiratory health, and region. We were interested in a specific combination of measures of cold homes; the question about men having difficulties in meeting the heating/fuel cost was always included in such combinations as it represented an overall proxy measure of cold housing. This question was combined with the one about “inability of keeping the living room warm”; the living room gets used the most by older people, and therefore it was relevant to the objective. Additionally, we wanted to include the information about the bedroom (“staying in bed longer in order to stay warm”) because it is a further and distinct part of the house. We excluded the fourth measure of cold homes from the combinations we tested (“Turning the heating off because of worries of the costs”) because it was less informative than “having difficulties in meeting the heating/fuel costs” and it did not give any specific information about the room where the heating was turned on or off.   
 **Results**We found (i) 288 (20.7%) men had difficulties in meeting the heating/fuel costs; (ii) 173 (12.4%) stayed in bed longer in order to stay warm; (iii) 47 (3.3%) could not keep comfortably warm in the living room, and (iv) 130 (9.4%) turned heating off because of worries about the costs. Manual social class, increasing financial difficulties, poor health in general, and being not married were more common in men who were having difficulties in meeting the heating/fuel costs (Table 1). Similar findings were found for other self-reported measures of cold homes (results not shown).  
  
*Logistic regression models*  
In unadjusted models (Table 2, left column), many individual factors were associated with having difficulties in meeting the heating/fuel costs. However, in fully adjusted models (Table 2, right column), fewer associations were found. Having increasing financial difficulties showed the strongest association (OR= 4.68, 95%CI 3.74-5.87, p<0.001). Also, men who were of manual social class, not married, feeling socially isolated, having three or more chronic conditions, persistent sputum production, and who were younger were more likely to have difficulties in meeting the heating/fuel costs (all p<0.05).

Overall, only three individual factors showed consistent associations with each of the four outcomes of interest: manual social class, having increasing financial difficulties, and being not married (see Table 2 and supplementary Table 2). Other less consistent associations were found in fully adjusted models: poor respiratory health (persistent sputum production), lower grip strength and social isolation were associated with at least two out of four measures of cold homes. Increasing age and drinking alcohol daily (vs occasionally) were also inversely associated with cold homes (Table 2 and supplementary Table 2). The absence of cavity/solid wall insulation in the house increased the odds of living in cold homes, (adjusted OR=1.87, 95%CI 0.98-3.55, p=0.057 for inability to keep the living room comfortably warm, and OR=1.47, 95%CI 0.97-2.22, p=0.072 for turning the heating off when cold because of worries about costs, see supplementary Table 2 – Part C). Overall, other factors such as smoking, region of residence, and heating system were not consistently associated with cold home reports.

*Subsidiary analyses*

129 (9.5%) men had both difficulties in meeting the heating/fuel costs and were inactive or occasionally active. Three individual factors showed statistically significant associations with this outcome: having mobility limitations (OR=3.60, 95%CI 2.15-6.04), persistent sputum production (OR=2.07, 95%CI 1.31-3.27), and having increasing financial difficulties (OR= 3.77, 95%CI 2.78-5.11). No associations were found between other individual factors and this outcome (results not shown).  
  
126 men died after completing the questionnaire (median follow-up period of 2.12 years, interquartile range 2.15-2.25 years). Single self-reported measures of cold homes were not associated with mortality in unadjusted cox proportional hazard models (Table 3). However, assenting to having difficulties in meeting the heating/fuel costs, staying in bed longer in order to stay warm, and inability to keep the living room comfortably warm vs not, n=21, predicted all-cause mortality in unadjusted models (unadjusted Hazard Ratio [HR]=2.90, 95%CI 1.18-7.09, p=0.020; adjusted HR=2.85, 95%CI 1.11-7.30, p=0.029). Additional adjustment for social isolation, financial difficulties, grip strength and other factors did not alter the magnitude of this association (results not shown).

**Discussion**

To our knowledge, this is the most comprehensive investigation of associations of individual factors (socio-demographic, economic, health, and house conditions) with self-reported measures of cold homes in older men, and reports of cold homes related to mortality.

*Overall findings*

Our findings showed that identifying older people who find it hard to keep warm in winter is possible using a self-report questionnaire designed in the BRHS. First, we narrowed down the list of factors which were independently associated with each of the four self-reported measures of cold homes collected in this study; we thought it was important to assess whether an individual factor remained significantly associated with reports of cold homes after mutual adjustment for other individual factors. As expected these factors were increasing financial difficulties, manual social class, and being not married (e.g. living alone) which are known determinants of fuel poverty ([1](#_ENREF_1)). Nevertheless, men having more chronic conditions (three or more vs none), who persistently produced sputum in winter (a marker of chronic lung disease or respiratory infection), with lower grip strength (a marker of physical frailty ([22](#_ENREF_22))), and who were feeling socially isolated (an indicator of reduced quality of life ([23](#_ENREF_23))) were also more likely to live in cold homes. There was also a suggestion that presence of mobility limitations particularly increased the odds of having difficulties in meeting the heating/fuel costs if the men were also inactive (or occasionally active). As most participants lived in a centrally heated home, absence of cavity or solid wall insulation in the house appeared more relevant to cold housing. With these analyses we have gone beyond findings reported in previous qualitative and quantitative studies which merely listed factors linked with living in cold homes.

*Measures of cold homes and mortality*

Those who reported cold homes had also increased mortality rates. However, only a specific combination of three measures of cold homes predicted mortality, while single measures of cold homes did not. This means that to identify an exhaustive measure of cold homes is very complex. Keeping the living room warm was more strongly related to mortality than other single measures, possibly because the living room gets used the most by older people.

*Comparison with previous studies*

Consistent with our main findings, previous studies identified highest levels of fuel poverty in households occupied by a single person over 60 years old (vs couples over 60) with low income ([12](#_ENREF_12)). The English Longitudinal Study of Ageing (ELSA) also found that age in older adults was inversely associated with living in cold homes; the authors reported that ELSA participants under 80 years who were living in cold homes had a worse cardiovascular risk profile including higher blood pressure, and were less likely to have blood pressure checked ([5](#_ENREF_5)). Interestingly, we also found that men who were drinking alcohol daily (vs occasionally) were less likely to stay in bed longer in order to stay warm, and less likely to turn the heating off because of worries of the costs. To our knowledge these findings were not previously reported and may indicate reduced sensitivity of alcohol consumers to cold ([24](#_ENREF_24)) or an indicator of greater financial resources. It is also plausible that daily drinkers spent more time outside and thus required less home heating.

*Strengths and limitations*

Previous investigations of cold homes have been at household levels ([12](#_ENREF_12)), while the current study was a large population-based study of older men, thus applying at individual level. We were able to account for confounding between individual factors, and estimated independent associations of these factors with measures of cold homes. To our knowledge, this analysis was not carried out elsewhere. Moreover, the self-reported measures of cold homes we used were similar to the ones collected in other quantitative studies ([4](#_ENREF_4), [25](#_ENREF_25)), but never used to predict mortality in survival models. A specific combination of three measures of cold homes was associated with a threefold increased mortality risk. Other factors potentially related to cold homes and mortality, for example respiratory infections, objectively measured respiratory function, and biological markers of inflammation (e.g. Interleukin-6 and C-Reactive protein) were not available during the relevant data collection phase. Further studies, which take these variables into account, will need to be undertaken to better understand the mechanism which relates cold homes to mortality The follow-up period for survival analysis was relatively short and the statistical power reduced due to a low number of deaths observed. Future studies with longer follow-up and repeated measures of cold homes over time are required.

The study lacked an objective measure of cold homes, such as indoor temperature (a better marker of thermal efficiency of the dwellings). Also, we observed that a higher EE rating of the house measured at LSOA level did not correspond to less difficulties in meeting the fuel costs in the BRHS; there is a suggestion that such broad measure of EE is not suitable in studies were the information is collected at individual level as in the BRHS. However, we acknowledge its relevance in other studies on cold homes at household or macro-area level.   
  
A further minor limitation is the inclusion of only male participants; in the UK and in comparison to men, a higher proportion of the female population are aged 75 and over (9%, compared with 7% of males in 2013 ([26](#_ENREF_26))), so we would expect a higher absolute number of women exposed to cold weather, and so cold housing, than men. We would expect that a cold homes-mortality relationship could be found in the female population; previous reports found that women were more likely to suffer fatal events in a cold period than men ([1](#_ENREF_1), [4](#_ENREF_4)). However, such finding could not be confirmed by our study. Lastly, although our measure of grip strength was self-reported, our finding was consistent with one from a previous study ([5](#_ENREF_5)).   
  
We also acknowledge the potential importance of factors which were not measured nor reported in our study, such as biological markers of inflammation and influenza rates. This is a limitation of our study; to measure those factors could have helped in understanding the biological pathways linking cold homes with mortality ([5](#_ENREF_5)). Larger studies may explore this important scientific questions in the future. However, our work makes an important contribution to the literature and enhance the understanding of which profiles of older men live in cold homes, and the implications for their future mortality.

*Implications*

Our findings suggest that experiencing increasing financial difficulties and lower social class, known to be strongly associated with fuel poverty ([27](#_ENREF_27)), are not the only factors which increase older people’s difficulties in keeping warm during winter. With an aging population, UK policies should acknowledge the detrimental contribution of multiple risk factors which increase with age and are more common in people living in cold homes such as social isolation, poor respiratory health or lower physical function in general. Interventions developed at address these could also reduce winter mortality, as well as interventions to lower fuel payments.

Our findings also suggest that a few simple questions, such as the ones on grip strength and persistent sputum production, may be a useful tool in identifying those who find it hard to keep warm in winter in primary care. Present studies are already evaluating the feasibility of implementing grip strength measurement into routine clinical practice, because it is inexpensive and simple to measure ([22](#_ENREF_22)). Other factors related to cold homes in our study are already collected in primary care (e.g. chronic conditions, marital status, and alcohol consumption), while others can be potentially routinely collected in the future (e.g. spirometry to measure lung function ([28](#_ENREF_28)), or a single item question rather than a complex score to measure social isolation ([29](#_ENREF_29))), as part of an admission procedure during winter. This would help primary care teams in identifying, or improving the assessment of heating needs of, older people who find it hard to keep warm without visit them at home, as the National Institute for Health and Care Excellence (NICE) have recommended in England ([2](#_ENREF_2), [13](#_ENREF_13)).

**Conclusions**

Identifying older people who find it hard to keep warm in winter and have an increased mortality risk is possible. Increasing financial difficulties and lower social class are not the only factors which increase older people’s difficulties in keeping warm during winter. With an increasing aging population, UK policies need to tackle the adverse effect of multiple risk factors which increase with age and are more common in people living in cold homes, such as social isolation, poor respiratory health and physical frailty.

**AUTHORS CONTRIBUTIONS**   
CS processed the data, performed statistical analyses, drafted and revised the manuscript, and incorporated revisions of co-authors. RWM contributed to the study design and supervised the statistical analyses. SGW, PHW, and RWM contributed to the BRHS design and the acquisition of data. IP contributed to the acquisition of the data from the Centre of Sustainable Energy. All authors provided an important intellectual contribution to the work, revised the manuscript, and approved the final version.

**Acknowledgements**

This paper presents independent research funded by the National Institute of Health Research School for Primary Care Research (NIHR SPCR grant reference number 281). The NIHR programme grant was awarded to RWM, and supported CS and PT. DSL is funded by the NIHR Oxford Biomedical Research Centre. The British Regional Heart study is supported by a British Heart Foundation (BHF) programme grant (RG/13/16/30528). The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and the decision to submit the manuscript for publication. The views expressed in this publication are those of the author(s) and not necessarily those of the NIHR, the Department of Health, the NHS or BHF.

**Conflict of interest statement**

The authors report no relationships that could be construed as a conflict of interest

**Table 1** – Descriptive statistics of individual characteristics in BRHS men collected on one occasion during 2014 (left column), and descriptive statistics stratified by having difficulties in meeting the fuel costs.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | All (n=1399) 7 | Men having difficulties in meeting the heating/fuel costs | | |
| Yes  (n=288, 20.7%) | No  (n=1111, 79.3%) | p-value |
| *Socio-demographic characteristics* |  |  |  |  |
| Age (years), mean (SD) | 81.0 (4.3) | 80.5 (4.2) | 81.1 (4.3) | 0.025 |
| Social class: |  |  |  |  |
| Manual, n (%) | 633 (45.3) | 183 (63.5) | 450 (40.5) | <0.001 |
| Non-Manual, n (%) | 731 (45.3) | 100 (34.7) | 631 (56.8) |  |
| HMF, n (%) | 35 (2.5) | 5 (1.7) | 30 (2.7) |  |
| Region, n (%) |  |  |  | 0.511 |
| South | 493 (35.2) | 97 (33.7) | 396 (35.6) |  |
| Midlands | 196 (14.0) | 39 (13.5) | 157 (14.1) |  |
| North | 555 (39.7) | 113 (39.2) | 442 (39.8) |  |
| Scotland | 155 (11.8) | 39 (13.5) | 116 (10.4) |  |
| *General health* |  |  |  |  |
| Chronic conditions 1, n (%) |  |  |  | <0.001 |
| None | 589 (42.1) | 99 (34.4) | 490 (44.1) |  |
| One/Two | 700 (50.0) | 150 (52.1) | 550 (49.5) |  |
| Three or more | 110 (7.9) | 39 (13.5) | 71 (6.4) |  |
| Chronic obstructive pulmonary disease (COPD) 2: Yes, n (%) | 90 (6.4) | 31 (10.7) | 59 (5.3) | 0.001 |
| Persistent sputum production: Yes, n (%) | 349 (25.0) | 108 (37.5) | 241 (21.7) | <0.001 |
| Mobility limitations in getting about outdoor: Yes, n (%) | 539 (38.5) | 157 (54.5) | 382 (34.4) | <0.001 |
| Grip strength 3: fair/poor vs good/very good, n (%) | 256 (18.4) | 82 (28.5) | 174 (15.7) | <0.001 |
| Depression: Yes vs no, n (%) | 145 (10.4) | 46 (16.0) | 99 (8.9) | <0.001 |
| Feeling isolated from others: Sometimes/often vs rarely/not, n (%) | 311 (22.2) | 101 (35.1) | 210 (18.9) | <0.001 |
| *Behavioural factors* |  |  |  |  |
| Smoking: Yes vs no, n (%) | 47 (3.4) | 11 (3.8) | 36 (3.2) | 0.627 |
| Alcohol consumption, n (%) |  |  |  | 0.008 |
| Occasionally | 719 (51.4) | 165 (57.3) | 554 (49.9) |  |
| None | 208 (14.9) | 48 (16.7) | 160 (14.4) |  |
| Daily | 472 (33.7) | 75 (26.0) | 397 (35.7) |  |
| *Personal circumstances* |  |  |  |  |
| Finance managing 4, n (%) |  |  |  | <0.001 |
| Very well | 748 (53.5) | 42 (14.6) | 706 (63.6) |  |
| Quite well | 456 (32.6) | 127 (44.1) | 329 (29.6) |  |
| Alright or not well | 195 (13.9) | 119 (41.3) | 76 (6.8) |  |
| House ownership 5: Renting/Other vs owner, n (%) | 145 (10.4) | 40 (13.9) | 105 (9.5) | 0.028 |
| Present circumstances, n (%) |  |  |  | 0.015 |
| Married | 1007 (72.0) | 196 (68.1) | 811 (73.0) |  |
| Single/Alone/Divorced/Separated | 97 (6.9) | 31 (10.7) | 66 (5.9) |  |
| Widowed | 295 (21.1) | 61 (21.2) | 234 (21.1) |  |
| *House characteristics* |  |  |  |  |
| House centrally heated: No vs Yes, n (%) | 146 (10.4) | 34 (11.8) | 112 (10.1) | 0.394 |
| Cavity/solid wall insulation: No vs Yes, n (%) | 461 (33.0) | 93 (32.3) | 368 (33.1) | 0.789 |
| House energy efficiency rating 6 |  |  |  | 0.012 |
| 1 – Lowest energy efficiency | 103 (10.3) | 29 (14.4) | 74 (9.2) |  |
| 2 | 173 (17.3) | 34 (16.9) | 139 (17.3) |  |
| 3 | 371 (37.0) | 77 (38.3) | 294 (36.7) |  |
| 4 | 143 (14.3) | 34 (16.9) | 109 (13.6) |  |
| 5 – Highest energy efficiency | 213 (21.2) | 27 (13.4) | 186 (23.2) |  |

1 Men were asked if their doctor had ever diagnosed chronic conditions including angina, heart attack, heart failure, claudication, stroke, diabetes, cancer, chronic kidney disease, osteoporosis, Parkinson´s disease.   
2 Doctor’s diagnosis of COPD   
3 Rating in comparison with men of same age

4 Men were asked to describe how they were managing financially at present  
5 Renting from local authorities or privately. Category other included living in residential or nursing home (n=5 men), or living in sheltered accommodation (n=9 men), or unspecified accommodation (n=24 men)

6 The rating was not self-reported by the BRHS men, but aggregated from households within participants’ Lower Super Output Area [LSOA]).  
7 Descriptive statistics in this table were from 1399 men with complete data on all variables and who answered the question about difficulties in meeting the heating/fuel costs

**Table 2** - Cross-sectional associations from logistic regression models between individual characteristics and difficulties in meeting the heating/fuel costs in BRHS men (aged 74-95) who completed a questionnaire in 2014. Per each of the individual characteristics the associations are reported as Odds Ratios (ORs) in comparison to the reference category. The statistically significant results are reported in bold.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Difficulties in meeting your heating/fuel costs? Yes vs No | | | |
|  | Unadjusted model 6 | | Full adjusted model 7 | |
|  | OR (95%CI) | p-value | OR (95%CI) | p-value |
| *Socio-demographic characteristics* |  |  |  |  |
| Age (years) | **0.97(0.94,1.00)** | **0.026** | **0.94(0.90,0.98)** | **0.003** |
| Social class: Non-manual (ref.) | 1 |  | 1 |  |
| Manual | **2.57(1.95,3.37)** | **<0.001** | **1.66(1.20,2.31)** | **0.002** |
| HMF | 1.05(0.40,2.77) | 0.919 | 1.00(0.34,2.91) | 0.998 |
| Region: South (ref.) | 1 |  | 1 |  |
| Midlands | 1.01(0.67,1.54) | 0.947 | 1.00(0.61,1.64) | 0.999 |
| North | 1.04(0.77,1.41) | 0.782 | 0.89(0.62,1.28) | 0.541 |
| Scotland | 1.37(0.90,2.10) | 0.144 | 1.03(0.62,1.72) | 0.903 |
| *General health* |  |  |  |  |
| Chronic conditions 1: None (ref.) | 1 |  | 1 |  |
| One/Two | **1.35(1.02,1.79)** | **0.037** | 1.21(0.87,1.70) | 0.261 |
| Three or more | **2.72(1.74,4.25)** | **<0.001** | **2.13(1.19,3.82)** | **0.011** |
| COPD 2: No (ref.) | 1 |  | 1 |  |
| Yes | **2.15(1.36,3.39)** | **0.001** | 1.00(0.54,1.86) | 0.994 |
| Persistent sputum production: No (ref.) | 1 |  | 1 |  |
| Yes | **2.17(1.64,2.86)** | **<0.001** | **1.83(1.29,2.59)** | **0.001** |
| Difficulties in getting outdoor: None (ref.) | 1 |  | 1 |  |
| Yes | **2.29(1.76,2.97)** | **<0.001** | 1.22(0.85,1.74) | 0.274 |
| Grip Strength 3: Good/Very good (ref.) | 1 |  | 1 |  |
| Fair/Poor | **2.13(1.58,2.89)** | **<0.001** | 1.25(0.85,1.82) | 0.253 |
| Depression (van Marwijk score): No (ref.) | 1 |  | 1 |  |
| Yes | **1.94(1.33,2.83)** | **0.001** | 1.03(0.62,1.71) | 0.896 |
| Feeling isolated from others: No/rarely (ref.) | 1 |  | 1 |  |
| Sometimes/often | **2.32(1.74,3.08)** | **<0.001** | **1.61(1.10,2.37)** | 0.014 |
| *Behavioural factors* |  |  |  |  |
| Smoking: No (ref.) | 1 |  | 1 |  |
| Yes | 1.19(0.60,2.36) | 0.627 | 0.60(0.25,1.43) | 0.249 |
| Alcohol consumption: Occasionally (ref.) | 1 |  | 1 |  |
| None | 1.01(0.70,1.45) | 0.969 | 0.81(0.52,1.26) | 0.344 |
| Daily | **0.63(0.47,0.86)** | **0.003** | 0.82(0.57,1.18) | 0.294 |
| *Personal circumstances* |  |  |  |  |
| Finance managing (score 1-3) 4: Well/Quite well/alright or not well | **5.10(4.15,6.28)** | **<0.001** | **4.68(3.74,5.87)** | **<0.001** |
| House ownership: Owner (ref.) | 1 |  | 1 |  |
| Renting/Other 5 | **1.55(1.05,2.28)** | **0.029** | 0.64(0.39,1.05) | 0.076 |
| Present circumstances: Married (ref.) | 1 |  | 1 |  |
| Single/Alone/Divorced/Separated | **1.94(1.23,3.06)** | **0.004** | **2.20(1.25,3.89)** | **0.006** |
| Widowed | 1.08(0.78,1.49) | 0.645 | 1.10(0.72,1.68) | 0.653 |
| *House characteristics* |  |  |  |  |
| House centrally heated, Yes (ref.) | 1 |  | 1 |  |
| No | 1.19(0.79,1.79) | 0.394 | 0.96(0.57,1.61) | 0.874 |
| Cavity/solid wall insulation, Yes (ref.) | 1 |  | 1 |  |
| No | 0.96(0.73,1.27) | 0.789 | 1.07(0.76,1.50) | 0.690 |

1 Men were asked if their doctor had ever diagnosed chronic conditions including angina, heart attack, heart failure, claudication, stroke, diabetes, cancer, chronic kidney disease, osteoporosis, Parkinson´s disease.   
2 Doctor’s diagnosis of COPD   
3 Rating in comparison with men of same age

4 Men were asked to describe how they were managing financially at present  
5 Renting from local authorities or privately. Category other included living in residential or nursing home (n=5 men), or living in sheltered accommodation (n=9 men), or unspecified accommodation (n=24 men)

6 Variables included one at a time. Number of observation in all models = 1399  
7 All listed variables included in the model. Number of observation = 1399

**Table 3** – Prospective associations between self-reported measures of cold homes with all-cause mortality in men aged 74-96 years from the BRHS. Results were reported as Hazard Ratios (HR) with 95% Confidence Intervals (CI) from Cox proportional hazard models. Statistically significant HRs are marker in bold.

|  |  |  |
| --- | --- | --- |
|  | All-cause Mortality 1 | |
|  | Model 1 | Model 2 |
|  | Unadjusted Model | Full adjusted model 2 |
|  | HR (95% CI) | HR (95%CI) |
| *Self-reported measures of cold homes during previous winter* |  |  |
| (1) Having difficulties in meeting the heating/fuel costs | 1.14 (0.75, 1.73)  p=0.547 | 1.04 (0.67,1.60) p=0.861 |
| (2) Staying in bed longer in order to stay warm | 1.15 (0.69, 1.91)  p=0.601 | 1.05 (0.62, 1.78)  p=0.857 |
| (3) Can’t keep the living room comfortably warm | 1.81 (0.84, 3.88)  p=0.127 | 1.38 (0.64, 3.01)  p=0.406 |
| (4) Turning the heating off because of worries about the costs | 0.69 (0.33, 1.40)  p=0.302 | 0.62 (0.30, 1.29)  p=0.202 |
| *Combination of measures* |  |  |
| Assenting to (1) and (2) vs others 3 | 1.47 (0.80, 2.74)  p=0.217 | 1.34 (0.71, 2.54)  p=0.372 |
| Assenting to (1) and (3) vs others 4 | 2.22 (0.98, 5.04)  p=0.056 | 1.80 (0.77, 4.18)  p=0.172 |
| Assenting to (1), (2) and (3) vs others 5 | **2.90 (1.18, 7.09)**  **p=0.020** | **2.85(1.11, 7.30)**  **p=0.029** |

1 Median follow-up period of 2.12 years during years 2014-2016; 126 men died during this period (the total number of men included in each of the survival models was 1385).

2 Adjusted models for age, social class, region, marital status, number of chronic conditions, and persistent sputum production

3 Men assenting to (1) and (2) were n=89

4 Men assenting to (1) and (3) were n=34

5 Men assenting to (1), (2) and (3) were n=21

References

1. Marmot Review Team. The Health Impacts of Cold Homes and Fuel Poverty. 2011. Available from <https://www.foe.co.uk/sites/default/files/downloads/cold_homes_health.pdf>.

2. National Institute for Heath and Care Excellence (NICE) guidelines. Excess winter deaths and illness and the health risks associated with cold homes. Published date: March 2015. Available from <https://www.nice.org.uk/guidance/ng6/chapter/1-Recommendations>

3. Dear KB, McMichael AJ. The health impacts of cold homes and fuel poverty. BMJ. 2011;342:d2807.

4. Wilkinson P, Pattenden S, Armstrong B, Fletcher A, Kovats RS, Mangtani P, et al. Vulnerability to winter mortality in elderly people in Britain: population based study. BMJ. 2004;329(7467):647-53.

5. Shiue I. Cold homes are associated with poor biomarkers and less blood pressure check-up: English Longitudinal Study of Ageing, 2012-2013. Environmental science and pollution research international. 2016;23(7):7055-9.

6. Sartini C, Barry SJ, Whincup PH, Wannamethee SG, Lowe GD, Jefferis BJ, et al. Relationship between outdoor temperature and cardiovascular disease risk factors in older people. European journal of preventive cardiology. 2017;24(4):349-56.

7. McCartney M. Margaret McCartney: can doctors fix cold homes? BMJ. 2015;350:h1595.

8. Tod A, Lusambili A, Cooke J, Homer C, Abbott J, Stocks A, et al. Barriers to keeping warm in later life. Nursing older people. 2013;25(10):22-9.

9. Burholt V, Windle G. Keeping warm? Self-reported housing and home energy efficiency factors impacting on older people heating homes in North Wales. Energy Policy. 2006;34(10):1198-208.

10. Grey CN, Jiang S, Nascimento C, Rodgers SE, Johnson R, Lyons RA, et al. The short-term health and psychosocial impacts of domestic energy efficiency investments in low-income areas: a controlled before and after study. BMC Public Health. 2017;17(1):140.

11. Wilkinson P, Landon M, Armstrong B, Stevenson S, McKee M. Cold comfort: the social and environmental determinants of excess winter death in England, 1986-1996: Joseph Rowntree Foundation, York; 2001.

12. Department for Business, Energy & Industrial Strategy. Annual fuel poverty statistics report: 2016. Office of National Statistics. Available from <https://www.gov.uk/government/statistics/annual-fuel-poverty-statistics-report-2016>.

13. Kmietowicz Z. GPs should identify and visit people at risk from cold homes, says NICE. BMJ. 2015;350:h1183.

14. Lennon LT, Ramsay SE, Papacosta O, Shaper AG, Wannamethee SG, Whincup PH. Cohort Profile Update: The British Regional Heart Study 1978–2014: 35 years follow-up of cardiovascular disease and ageing. International Journal of Epidemiology. 2015;44(3):826a-g.

15. Jefferis BJ, Sartini C, Ash S, Lennon LT, Wannamethee SG, Whincup PH. Validity of questionnaire-based assessment of sedentary behaviour and physical activity in a population-based cohort of older men; comparisons with objectively measured physical activity data. Int J Behav Nutr Phys Act. 2016;13(1):14.

16. Walker M, Whincup P, Shaper A. The British Regional Heart Study 1975–2004. International Journal of Epidemiology. 2004;33(6):1185-92.

17. Sartini C, Wannamethee SG, Iliffe S, Morris RW, Ash S, Lennon L, et al. Diurnal patterns of objectively measured physical activity and sedentary behaviour in older men. BMC Public Health. 2015;15:609.

18. Shaper AG, Pocock SJ, Walker M, Cohen NM, Wale CJ, Thomson AG. British Regional Heart Study: cardiovascular risk factors in middle-aged men in 24 towns. BMJ. 1981;283(6285):179-86.

19. Jefferis BJ, Sartini C, Lee IM, Choi M, Amuzu A, Gutierrez C, et al. Adherence to physical activity guidelines in older adults, using objectively measured physical activity in a population-based study. BMC Public Health. 2014;14:382.

20. Centre for Sustainable Energy. Mapping domestic energy efficiency in Great Britain. March 2015. Available from <https://www.cse.org.uk/projects/view/1305>.

21. Sartini C, Morris RW, Whincup PH, Wannamethee SG, Ash S, Lennon L, et al. Association of Maximum Temperature With Sedentary Time in Older British Men. J Phys Act Health. 2017;14(4):265-9.

22. Ibrahim K, May C, Patel HP, Baxter M, Sayer AA, Roberts H. A feasibility study of implementing grip strength measurement into routine hospital practice (GRImP): study protocol. Pilot Feasibility Stud. 2016;2(27):2-10.

23. Findlay RA. Interventions to reduce social isolation amongst older people: where is the evidence? Ageing and Society. 2003;23(05):647-58.

24. Freund BJ, Obrien C, Young AJ. Alcohol Ingestion and Temperature Regulation during Cold-Exposure. Journal of Wilderness Medicine. 1994;5(1):88-98.

25. Rudge J, Gilchrist R. Excess winter morbidity among older people at risk of cold homes: a population-based study in a London borough. J Public Health (Oxf). 2005;27(4):353-8.

26. Office of National Statistics (ONS) bulletin. Excess Winter Mortality in England and Wales: 2013-14 and 2012-13. Available from <https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/bulletins/excesswintermortalityinenglandandwales/2014-11-28>.

27. Iparraguirre J. Have winter fuel payments reduced excess winter mortality in England and Wales? J Public Health (Oxf). 2015;37(1):26-33.

28. Rothnie KJ, Mullerova H, Goss H, Chandan J, Quint JK. Validity and Interpretation of Spirometry for Patients in Primary Care. Thorax. 2015;70(Suppl 3):A188-A90.

29. Steptoe A, Shankar A, Demakakos P, Wardle J. Social isolation, loneliness, and all-cause mortality in older men and women. Proc Natl Acad Sci. 2013;110(15):5797-801.