

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

2

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16 **Abstract**

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

18

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

22

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

28

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

35

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

38

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

40 **Background**

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

50

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

59

60 **Material and methods**

61

62 *Sample*

63 The British Regional Heart Study (BRHS) is a prospective, population-based cohort study
64 following up 7735 men (99% Caucasian) recruited from primary care practices in 24 British
65 towns in 1978–80. In 2014, 2820 surviving men aged 74–96 years were invited to complete a
66 comprehensive health status and life style questionnaire including self-reported measures
67 of cold homes [14]. 1655 men responded (99% between April and October) and 1402 had
68 complete data on all covariables of interest. Of the 1402, the number of observations
69 available varied from 1385 to 1402. The National Research Ethics Service (NRES) Committee
70 London provided ethical approval. Participants provided informed written consent to the
71 investigation, in accordance with the Declaration of Helsinki.

72

73 *Self-reported measures of cold homes*

74 Men were asked whether they were (i) having difficulties in meeting the heating/fuel costs;
75 (ii) staying in bed longer in order to stay warm during the previous winter; (iii) unable to
76 keep the living room comfortably warm during the cold winter weather, and (iv) turning the
77 heating off even when cold because of worries about the costs during the previous winter.
78 Having difficulties in meeting the heating/fuel costs was chosen as our main outcome, as an
79 overall proxy measure of cold housing.

80

81 *Individual factors*

82 Individual factors selected in this study were selected on the basis of previously reported
83 associations with cold homes in qualitative [8-10] and quantitative [1, 9, 11, 12] studies: for
84 example, manual social class, difficulties in making ends meet and being not married.
85 Factors investigated were categorised consistently with previous published work from the
86 BRHS [14-19], and represented five different domains: (i) socio-demographic (age, social
87 class, and region of residence), (ii) general health (number of chronic conditions, respiratory
88 health, mobility limitations outdoors, grip strength, depression, and feeling of social
89 isolation), (iii) behavioural factors (smoking and alcohol consumption), (iv) personal
90 circumstances (having increasing financial difficulties and house ownership), and (v) house
91 characteristics (types of home insulation, heating system). Also, a proxy measure of the
92 house energy efficiency (Energy Efficiency rating [20], aggregated from households within
93 participants' Lower Super Output Area [LSOA]) was linked to each of the BRHS men. Energy
94 Efficiency (EE) rating was investigated using descriptive statistics only; as a graded trend in
95 association with the main outcome of interest was not found, this variable was not included
96 in final models.

97

98 *Statistical analyses*

99 We examined the distribution of all variables of interest according to self-reported
100 measures of cold homes. As the Energy Efficiency rating did not show a graded linear
101 relationship with self-reported difficulties in keeping warm, we preferred to include house
102 characteristics collected at individual level (e.g. types of home insulation and heating) in
103 further analysis.

104

105 *Logistic regression models*

106 Logistic regression was used to estimate the associations of individual factors with each of
107 the cold home measures, firstly unadjusted, then mutually adjusted. The mutually adjusted
108 models were performed to demonstrate factors which were independently associated with
109 each of the four self-reported measures of cold homes collected in this study.

110

111

112 *Subsidiary analyses*

113 As older people are less active in winter [21], they are also likely to spend most time at
114 home during this period [7]; therefore, a subsidiary analysis was carried out to find out
115 which individual factors were associated with men both having difficulties in meeting the
116 heating/fuel costs and also being inactive or occasionally active. Physical activity levels were
117 derived from a self-reported questionnaire validated against objectively measured physical
118 activity in a previous study [15].

119

120 As it is unclear which measures of cold homes best predict those at risk of death [11], we
121 also investigated whether self-reported measures of cold homes, alone or in combination,
122 predicted mortality using Cox proportional hazard models; estimates (hazard ratios) were
123 adjusted for potential confounding factors such as age, social class, marital status, chronic
124 conditions, respiratory health, and region. We selected a combination of three measures of
125 cold homes:

- 126 1) Having difficulties in meeting the heating/fuel costs
- 127 2) Inability to keep the living room warm
- 128 3) Staying in bed longer in order to stay warm

129

130 Question 1 was regarded as an overall proxy measure of cold housing, question 2 was used
131 as the living room is likely to be used the most by older people in the daytime, question 3
132 included information about the bedroom, representing a distinct part of the house in which
133 older people will spend a large number of hours. We believe the 4th measure - "Turning the
134 heating off because of worries of the costs" was less informative than "having difficulties in
135 meeting the heating/fuel costs", as it did not give any specific information about the room

136 where the heating was turned on or.

137

138 **Results**

139 We found (i) 288 (20.7%) men had difficulties in meeting the heating/fuel costs; (ii) 173
140 (12.4%) stayed in bed longer in order to stay warm; (iii) 47 (3.3%) could not keep
141 comfortably warm in the living room, and (iv) 130 (9.4%) turned heating off because of
142 worries about the costs. Manual social class, increasing financial difficulties, poor health in
143 general, and being not married were more common in men who were having difficulties in
144 meeting the heating/fuel costs (Table 1). Similar findings were found for other self-reported
145 measures of cold homes (results not shown).

146

147 *Logistic regression models*

148 In unadjusted models (Table 2, left column), many individual factors were associated with
149 having difficulties in meeting the heating/fuel costs. However, in fully adjusted models
150 (Table 2, right column), fewer associations were found. Having increasing financial
151 difficulties showed the strongest association (OR= 4.68, 95%CI 3.74-5.87, $p<0.001$). Also,
152 men who were of manual social class, not married, feeling socially isolated, having three or
153 more chronic conditions, persistent sputum production, and who were younger were more
154 likely to have difficulties in meeting the heating/fuel costs (all $p<0.05$).

155

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

167 factors such as smoking, region of residence, and heating system were not consistently
168 associated with cold home reports.

169

170 *Subsidiary analyses*

171 129 (9.5%) men had both difficulties in meeting the heating/fuel costs and were inactive or
172 occasionally active. Three individual factors showed statistically significant associations with
173 this outcome: having mobility limitations (OR=3.60, 95%CI 2.15-6.04), persistent sputum
174 production (OR=2.07, 95%CI 1.31-3.27), and having increasing financial difficulties (OR=
175 3.77, 95%CI 2.78-5.11). No associations were found between other individual factors and
176 this outcome (results not shown).

177

178 126 men died after completing the questionnaire (median follow-up period of 2.12 years,
179 interquartile range 2.15-2.25 years). Single self-reported measures of cold homes were not
180 associated with mortality in unadjusted cox proportional hazard models (Table 3). However,
181 assenting to having difficulties in meeting the heating/fuel costs, staying in bed longer in
182 order to stay warm, and inability to keep the living room comfortably warm vs not, n=21,
183 predicted all-cause mortality in unadjusted models (unadjusted Hazard Ratio [HR]=2.90,
184 95%CI 1.18-7.09, p=0.020; adjusted HR=2.85, 95%CI 1.11-7.30, p=0.029). Additional
185 adjustment for social isolation, financial difficulties, grip strength and other factors did not
186 alter the magnitude of this association (results not shown).

187

188 **Discussion**

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

192

193 *Overall findings*

194 Our findings showed that identifying older people who find it hard to keep warm in winter is
195 possible using a self-report questionnaire designed in the BRHS. First, we narrowed down
196 the list of factors which were independently associated with each of the four self-reported
197 measures of cold homes collected in this study; we thought it was important to assess
198 whether an individual factor remained significantly associated with reports of cold homes

199 after mutual adjustment for other individual factors. As expected these factors were
200 increasing financial difficulties, manual social class, and being not married (e.g. living alone)
201 which are known determinants of fuel poverty [1]. Nevertheless, men having more chronic
202 conditions (three or more vs none), who persistently produced sputum in winter (a marker
203 of chronic lung disease or respiratory infection), with lower grip strength (a marker of
204 physical frailty [22]), and who were feeling socially isolated (an indicator of reduced quality
205 of life [23]) were also more likely to live in cold homes. There was also a suggestion that
206 presence of mobility limitations particularly increased the odds of having difficulties in
207 meeting the heating/fuel costs if the men were also inactive (or occasionally active). As
208 most participants lived in a centrally heated home, absence of cavity or solid wall insulation
209 in the house appeared more relevant to cold housing. With these analyses we have gone
210 beyond findings reported in previous qualitative and quantitative studies which merely
211 listed factors linked with living in cold homes.

212

213 *Measures of cold homes and mortality*

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

219

220 *Comparison with previous studies*

221 Consistent with our main findings, previous studies identified highest levels of fuel poverty
222 in households occupied by a single person over 60 years old (vs couples over 60) with low
223 income [12]. The English Longitudinal Study of Ageing (ELSA) also found that age in older
224 adults was inversely associated with living in cold homes; the authors reported that ELSA
225 participants under 80 years who were living in cold homes had a worse cardiovascular risk
226 profile including higher blood pressure, and were less likely to have blood pressure checked
227 [5]. Interestingly, we also found that men who were drinking alcohol daily (vs occasionally)
228 were less likely to stay in bed longer in order to stay warm, and less likely to turn the
229 heating off because of worries of the costs. To our knowledge these findings were not
230 previously reported and may indicate reduced sensitivity of alcohol consumers to cold [24]

231 or an indicator of greater financial resources. It is also plausible that daily drinkers spent
232 more time outside and thus required less home heating.

233

234 *Strengths and limitations*

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

251

252 The study lacked an objective measure of cold homes, such as indoor temperature (a better
253 marker of thermal efficiency of the dwellings). Also, we observed that a higher EE rating of
254 the house measured at LSOA level did not correspond to less difficulties in meeting the fuel
255 costs in the BRHS; suggesting that this broad measure of EE is less suitable than the
256 individual level data available in the BRHS. However, we acknowledge its relevance in other
257 studies on cold homes at household or macro-area level.

258

259 A further minor limitation is the inclusion of only male participants; in the UK and in
260 comparison to men, a higher proportion of the female population are aged 75 and over (9%,
261 compared with 7% of males in 2013 [26]), so we would expect a higher absolute number of
262 women exposed to cold weather, and so cold housing, than men. We would expect that a

263 cold homes-mortality relationship could be found in the female population; previous reports
264 found that women were more likely to suffer fatal events in a cold period than men [1, 4].
265 Lastly, although our measure of grip strength was self-reported, our finding was consistent
266 with one from a previous study [5].

267

268 We also acknowledge the potential importance of factors which were not measured nor
269 reported in our study, such as biological markers of inflammation and influenza rates. This is
270 a limitation of our study; to measure those factors could have helped in understanding the
271 biological pathways linking cold homes with mortality [5]. Larger studies may explore this
272 important scientific questions in the future. However, our work still makes an important
273 contribution to the literature and enhance the understanding of which profiles of older men
274 live in cold homes, and the implications for their future mortality.

275

276 *Implications*

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

285

286 Our findings also suggest that a few simple questions, such as the ones on grip strength and
287 persistent sputum production, may be a useful tool in identifying those who find it hard to
288 keep warm in winter in primary care. Present studies are already evaluating the feasibility of
289 implementing grip strength measurement into routine clinical practice, because it is
290 inexpensive and simple to measure [22]. Other factors related to cold homes in our study
291 are already collected in primary care (e.g. chronic conditions, marital status, and alcohol
292 consumption), while others can be potentially routinely collected in the future (e.g.
293 spirometry to measure lung function [28], or a single item question rather than a complex
294 score to measure social isolation [29]), as part of an admission procedure during winter. This

295 would help primary care teams in identifying, or improving the assessment of heating needs
296 of, older people who find it hard to keep warm without visit them at home, as the National
297 Institute for Health and Care Excellence (NICE) have recommended in England [2, 13].

298

299 **Conclusions**

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

306

307

308 **AUTHORS CONTRIBUTIONS**

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

315

316 **Acknowledgements**

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

327

328 **Conflict of interest statement**

329 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
<i>Socio-demographic characteristics</i>				
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)	
<i>General health</i>				
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

<i>Behavioural factors</i>				
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)	
<i>Personal circumstances</i>				
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)	
<i>House characteristics</i>				
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
<i>Socio-demographic characteristics</i>				
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
<i>General health</i>				
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
<i>Behavioural factors</i>				
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
<i>Personal circumstances</i>				
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
<i>House characteristics</i>				
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)
<i>Self-reported measures of cold homes during previous winter</i>		
(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
<i>Combination of measures</i>		
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

Supplementary table 1 - PART A- Cross-sectional associations from logistic regression models between individual characteristics and self-reported measures of cold homes measured in BRHS men (aged 74-95) who completed a questionnaire in 2014. Per each of the individual characteristics the associations are reported as Odds Ratio (OR) in comparison to the reference category. The statistically significant results are reported in bold.

	Staying in bed longer in order to stay warm during the previous winter n=1393				Inability to keep the living room comfortably warm during the cold winter weather n=1385				Turning the heating off even when cold because of worries about the costs during the previous winter n= 1402			
	Unadjusted Model		Adjusted Model		Unadjusted Model		Adjusted Model		Unadjusted Model		Adjusted Model	
	OR (95%CI)	p-value	OR (95%CI)	p-value	OR (95%CI)	p-value	OR (95%CI)	p-value	OR (95%CI)	p-value	OR (95%CI)	p-value
<i>Socio-demographic characteristics</i>												
Age (years)	0.99 (0.95,1.03)	0.611	0.95 (0.91,0.99)	0.023	0.99 (0.93,1.06)	0.813	0.99 (0.91,1.07)	0.738	0.95 (0.91,1.00)	0.033	0.92 (0.88,0.97)	0.003
Social class: Non-manual (ref.)	1		1		1		1		1		1	
Manual	2.52 (1.79,3.53)	<0.001	1.61 (1.11,2.35)	0.013	4.20 (2.06,8.54)	<0.001	2.71 (1.25,5.88)	0.012	2.63 (1.78,3.89)	<0.001	1.55 (1.00,2.40)	0.049
HMF	1.97 (0.74,5.27)	0.178	1.60 (0.56,4.62)	0.382	4.38 (0.92,20.81)	0.063	4.54 (0.87,23.63)	0.072	2.16 (0.73,6.42)	0.165	1.95 (0.61,6.22)	0.257
Region: South (ref.)	1		1		1		1		1		1	
Midlands	0.87 (0.49,1.53)	0.622	0.78 (0.43,1.45)	0.439	0.94 (0.36,2.43)	0.891	1.00 (0.36,2.79)	0.993	0.89 (0.47,1.67)	0.710	0.84 (0.42,1.66)	0.614
North	1.33 (0.91,1.94)	0.141	1.31 (0.87,1.98)	0.196	1.00 (0.50,1.98)	0.995	1.02 (0.49,2.12)	0.967	1.39 (0.91,2.13)	0.126	1.27 (0.80,2.03)	0.306
Scotland	2.07 (1.27,3.39)	0.004	1.81 (1.05,3.11)	0.032	1.42 (0.57,3.51)	0.452	1.10 (0.41,2.98)	0.853	1.57 (0.87,2.83)	0.136	1.19 (0.62,2.30)	0.595
<i>General health</i>												
Chronic conditions ¹ : None (ref.)	1		1		1		1		1		1	
One/Two	1.15 (0.82,1.62)	0.416	0.88 (0.60,1.29)	0.509	1.46 (0.75,2.85)	0.267	1.17 (0.57,2.41)	0.670	1.26 (0.86,1.86)	0.236	1.20 (0.77,1.85)	0.419
Three or more	1.95 (1.14,3.36)	0.015	0.91 (0.48,1.72)	0.768	3.72 (1.57,8.83)	0.003	1.92 (0.71,5.24)	0.200	1.75 (0.93,3.30)	0.085	1.09 (0.51,2.34)	0.825
COPD ² : No (ref.)	1		1		1		1		1		1	
Yes	2.03 (1.19,3.47)	0.009	0.97 (0.51,1.84)	0.923	4.32 (2.07,9.00)	<0.001	2.13 (0.86,5.29)	0.102	1.96 (1.07,3.58)	0.029	1.08 (0.52,2.26)	0.840

Supplementary table 1 - PART B - Cross-sectional associations from logistic regression models between individual characteristics and self-reported measures of cold homes measured in BRHS men (aged 74-95) who completed a questionnaire in 2014.

	Staying in bed longer in order to stay warm during the previous winter n=1393				Inability to keep the living room comfortably warm during the cold winter weather n=1385				Turning the heating off even when cold because of worries about the costs during the previous winter n= 1402			
	Unadjusted Model		Adjusted Model		Unadjusted Model		Adjusted Model		Unadjusted Model		Adjusted Model	
<i>General health</i>	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Persistent sputum production: No (ref.)	1		1		1		1		1		1	
Yes	1.79 (1.28,2.52)	0.001	1.34 (0.91,1.98)	0.141	2.51 (1.39,4.52)	0.002	1.62 (0.82,3.21)	0.166	2.13 (1.46,3.10)	<0.001	1.83 (1.18,2.84)	0.007
Difficulties in getting outdoor: None (ref.)	1		1		1		1		1		1	
Yes	3.00 (2.16,4.17)	<0.001	2.02 (1.35,3.02)	0.001	2.93 (1.60,5.36)	0.001	1.44 (0.68,3.05)	0.340	1.75 (1.22,2.52)	0.002	0.86 (0.54,1.37)	0.529
Grip Strength ³ : Good/Very good (ref.)	1		1		1		1		1		1	
Fair/Poor	2.99 (2.11,4.23)	<0.001	2.09 (1.41,3.10)	<0.001	1.76 (0.91,3.38)	0.091	0.88 (0.42,1.87)	0.744	2.29 (1.54,3.41)	<0.001	1.59 (1.00,2.53)	0.050
Depression (van Marwijk score): No (ref.)	1		1		1		1		1		1	
Yes	2.13 (1.38,3.28)	0.001	1.01 (0.61,1.69)	0.964	3.16 (1.60,6.24)	0.001	1.69 (0.76,3.76)	0.202	2.06 (1.26,3.36)	0.004	1.02 (0.57,1.84)	0.943
Feeling isolated from others: No/rarely (ref.)	1		1		1		1		1		1	
Sometimes/often	2.97 (2.13,4.15)	<0.001	1.78 (1.19,2.66)	0.005	2.45 (1.35,4.44)	0.003	1.24 (0.60,2.58)	0.565	3.40 (2.35,4.94)	<0.001	2.44 (1.55,3.83)	<0.001
<i>Behavioural factors</i>												
Smoking: No (ref.)	1		1		1		1		1		1	
Yes	2.24 (1.12,4.49)	0.023	1.15 (0.52,2.57)	0.725	2.85 (0.98,8.29)	0.055	1.29 (0.37,4.48)	0.691	1.47 (0.61,3.55)	0.386	0.70 (0.25,1.94)	0.498
Alcohol consumption: Occasionally (ref.)	1		1		1		1		1		1	
None	1.06 (0.69,1.62)	0.785	0.86 (0.54,1.38)	0.545	0.91 (0.41,2.01)	0.811	0.69 (0.30,1.62)	0.400	1.13 (0.69,1.85)	0.618	0.94 (0.55,1.62)	0.820
Daily	0.41 (0.27,0.63)	<0.001	0.46 (0.29,0.71)	0.001	0.45 (0.21,0.95)	0.036	0.54 (0.24,1.21)	0.135	0.63 (0.41,0.97)	0.038	0.72 (0.45,1.16)	0.180

Supplementary table 1 - PART C - Cross-sectional associations from logistic regression models between individual characteristics and self-reported measures of cold homes measured in BRHS men (aged 74-95) who completed a questionnaire in 2014. Per each of the individual characteristics the associations are reported as Odds Ratio (OR) in comparison to the reference category. The statistically significant results are reported in bold.

	Staying in bed longer in order to stay warm during the previous winter n=1393				Inability to keep the living room comfortably warm during the cold winter weather n=1385				Turning the heating off even when cold because of worries about the costs during the previous winter n= 1402			
	Unadjusted Model		Adjusted Model		Unadjusted Model		Adjusted Model		Unadjusted Model		Adjusted Model	
	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
<i>Personal circumstances</i>												
Finance managing ⁴ (score 1-3): Well/Quite well/alright or not well	2.20 (1.78,2.71)	<0.001	1.59 (1.25,2.01)	<0.001	3.02 (2.05,4.44)	<0.001	2.24 (1.46,3.43)	<0.001	3.07 (2.41,3.93)	<0.001	2.62 (2.00,3.44)	<0.001
House ownership: Owner (ref.)	1		1		1		1		1		1	
Renting/Other ⁵	2.11 (1.36,3.25)	0.001	0.98 (0.59,1.63)	0.942	2.13 (1.01,4.50)	0.048	0.66 (0.27,1.60)	0.356	1.66 (1.00,2.77)	0.051	0.71 (0.39,1.30)	0.264
Present circumstances: Married (ref.)	1		1		1		1		1		1	
Single/Alone/Divorced/Separated	2.67 (1.59,4.48)	<0.001	2.60 (1.44,4.70)	0.002	4.31 (2.01,9.23)	<0.001	3.88 (1.60,9.45)	0.003	2.17 (1.19,3.93)	0.011	2.24 (1.13,4.43)	0.021
Widowed	1.93 (1.34,2.79)	<0.001	1.73 (1.12,2.67)	0.013	1.47 (0.72,3.01)	0.292	1.08 (0.47,2.47)	0.864	1.66 (1.09,2.52)	0.018	1.73 (1.04,2.87)	0.034
<i>House characteristics</i>												
House centrally heated, Yes (ref.)	1		1		1		1		1		1	
No	1.27 (0.78,2.06)	0.334	1.02 (0.59,1.77)	0.938	2.73 (1.36,5.48)	0.005	1.70 (0.76,3.79)	0.195	1.04 (0.58,1.86)	0.897	0.81 (0.42,1.57)	0.536
Cavity/solid wall insulation, Yes (ref.)	1		1		1		1		1		1	
No	1.09 (0.78,1.52)	0.630	1.04 (0.72,1.52)	0.818	1.83 (1.02,3.27)	0.043	1.87 (0.98,3.55)	0.057	1.35 (0.93,1.95)	0.116	1.47 (0.97,2.22)	0.072

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)

Supplementary table 2 – Descriptive statistics of individual factors in BRHS men aged 74-96 who died before the end of the follow up time (left column) vs men who were still alive (right column).

	BRHS participants at the end of follow up n=1385 (complete case analysis used in survival models)		
	Dead (n=126, 9.1%)	Alive (n=1259, 89.9%)	p-value
<i>Socio-demographic characteristics</i>			
Age at baseline (years), mean (SD)	80.7 (4.1)	83.9 (5.2)	<0.001
Social class:			
Manual, n (%)	65 (51.6)	559 (44.4)	0.234
Non-Manual, n (%)	57 (45.2)	669 (53.1)	
HMF, n (%)	4 (3.2)	31 (2.5)	
Region, n (%)			
South	40 (31.8)	446 (35.4)	
Midlands	179 (13.5)	178 (14.1)	
North	49 (38.9)	500 (39.7)	
Scotland	20 (15.9)	135 (10.7)	
<i>General health</i>			
Chronic conditions ¹ , n (%)			
None	40 (31.8)	544 (43.2)	0.012
One/Two	70 (55.6)	624 (49.6)	
Three or more	16 (12.7)	91 (7.2)	
Chronic obstructive pulmonary disease (COPD) ² : Yes, n (%)	21 (16.7)	68 (5.4)	0.001

Persistent sputum production: Yes, n (%)	49 (38.9)	292 (23.2)	<0.001
Mobility limitations in getting about outdoor: Yes, n (%)	69 (54.8)	461 (36.6)	<0.001
Grip strength ³ : fair/poor vs good/very good, n (%)	26 (20.7)	227 (18.1)	0.481
Depression: Yes vs no, n (%)	20 (15.9)	125 (9.9)	0.038
Feeling isolated from others: Sometimes/often vs rarely/not, n (%)	31 (24.6)	273 (21.7)	0.299
<i>Behavioural factors</i>			
Smoking: Yes vs no, n (%)	6 (4.8)	41 (3.3)	0.374
Alcohol consumption, n (%)			0.636
Occasionally	67 (53.2)	645 (51.2)	
None	21 (16.7)	185 (14.7)	
Daily	38 (30.2)	429 (34.1)	
<i>Personal circumstances</i>			
Finance managing ⁴ , n (%)			0.211
Very well	60 (47.3)	683 (54.3)	
Quite well	43 (34.1)	409 (32.5)	
Alright or not well	23 (18.3)	167 (13.3)	
House ownership ⁵ : Renting/Other vs owner, n (%)	23 (18.25)	121 (9.6)	0.002
Present circumstances, n (%)			0.070
Married	86 (68.3)	914 (72.6)	
Single/Alone/Divorced/Separated	15 (11.9)	81 (6.4)	
Widowed	25 (19.8)	264 (21.0)	
<i>House characteristics</i>			

House centrally heated: No vs Yes, n (%)	14 (11.1)	131 (10.4)	0.805
Cavity/solid wall insulation: No vs Yes, n (%)	40 (31.7)	418 (33.2)	0.741

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, living in sheltered accommodation, or unspecified accommodation

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