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A randomised trial of home energy efficiency improvement in the homes of elderly COPD patients

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ABSTRACT

Objective: To determine whether improving home energy efficiency in patients with Chronic Obstructive Pulmonary Disease improves health related quality of life.

Design Randomised trial.

Setting: Homes in Aberdeen, Scotland.

Participants: 178 patients with a previous hospital admission for Chronic Obstructive Pulmonary Disease.

Main outcome measures: Respiratory and general health status, home energy efficiency, hospital admissions.

Results: 118 patients were randomised: 60 agreed to monitoring only. Energy efficiency upgrading was carried out in 42% of homes randomised to intervention. Independent energy efficiency action was taken by 15% of control participants and 18% in monitoring group. Intention to treat analysis found no difference in outcomes between the two groups. In 45 patients who had energy efficiency action, independent of original randomisation, there were significant improvements in respiratory symptom scores (adjusted mean 9.0, 95%CIs 2.5 to 15.5), decreases in estimated annual fuel costs (-£65.3, 95%CIs -31.9 to -98.7) and improved home energy efficiency rating (1.1, 0.8 to 1.4).

Conclusions: Patients who have had a hospital admission for COPD are unlikely to take up home energy efficiency upgrading, if offered. Secondary 'pragmatic' analysis suggests that those who do take action may achieve clinically significant improvement in respiratory health which is not associated with an increase in indoor warmth.

Key words

COPD, Quality of life, housing, complex interventions.

INTRODUCTION

Poor housing standards in the UK may increase vulnerability to illness, particularly in winter[1, 2]. Perception of the home as cold is related to poor self reported health and increased respiratory symptoms[3,4]. Housing improvement studies show that upgrading insulation and central heating leads to dryer and warmer homes[5,6,7]. In New Zealand, participants in upgraded homes have reported better health[5].

Chronic Obstructive Pulmonary Disease (COPD) is the fifth largest cause of death worldwide[8], and respiratory exacerbations are a major contributor to winter illness[9]. Patients with COPD are likely to be particularly vulnerable to effects of poor housing. The current study, a combined project between Aberdeen City Council, Castlehill Housing Association, Aberdeen Royal Infirmary and the University of Aberdeen, aimed to evaluate through a randomised trial, whether home energy efficiency improvement was associated with improved health status and reduced readmission risk for patients who had had a hospital admission for COPD within the previous two years. We have previously reported that lower living room temperatures[10] and higher levels of indoor environmental tobacco smoke exposure[11] in this group of patients impacted independently and negatively on quality of life. The findings reported here consider the impact of a real-life intervention on quality of life in elderly patients who had had a hospital admission for COPD. The aim of this study was to assess the potential impact of home energy improvements, taking advantage of the Affordable Warmth scheme, on quality of life in moderate to severe COPD.

METHODS

Setting: Aberdeen is situated on the coast in the North East of Scotland. Outdoor weekly average temperatures between November and April during three successive years of the study ranged between a low of -3°C and a high of 10°C.

Recruitment: Was carried out between November and April 2004-5, 2005-6 and 2006-7. Hospital records were checked for patients who had been admitted to Aberdeen Royal Infirmary with an exacerbation of COPD between January 2003 and March 2006. Each patient was recruited during a 12 month period but not necessarily immediately after hospital admission.

Participants: Patients with clinician diagnosed COPD (confirmed by spirometry to GOLD guidelines[8]) and who lived in their own homes within the Aberdeen City Council boundaries were invited to participate by post. Patients living in nursing homes or sheltered accommodation were not invited. The majority of homes were close to the 5.4 Scottish average for energy efficiency[12] but below the 8.0 energy efficiency level (maximum score 10) required for new build houses in Scotland.

Demographic and environmental characteristics

Social deprivation was assessed by the Carstairs deprivation index[13]. This is a standardised score with zero as the national mean score and a standard deviation of 3.5. A positive score indicates greater disadvantage than average. Smoking status was assessed with cotinine analysis[14]. Indoor $PM_{2.5}$ levels (mass of particles < 2.5 μm in diameter: a marker of second-hand smoke exposure) were also assessed and have been reported previously[11].

Outdoor temperatures

The average minimum outdoor temperature over the study monitoring weeks was +2.9°C (IQR 1.1 to 5.0). Average maximum was 10.1°C (IQR 7.1 to 12.3°C).

Intervention: An initial survey by a trained surveyor identified where energy efficiency improvements could be made. The work was carried out by Castlehill Housing Association (Care and Repair) after baseline indoor measures had been taken. Improvements included replacement and upgrades to central heating systems, installation of loft, underfloor, and cavity wall insulation, and benefit reassessment. Average time to achieve intervention was nine months, ranging from a minimum of one month to a maximum of 18 months.

Outcome measures

In Scotland energy efficiency is measured by the National Home Energy Rating (NHER)[12], calculated by estimating the energy costs for a property divided by the floor area, using a standard heating pattern of 9 hours heating per day during the week and 16 hours a day at weekends, with the living area calculated to 21°C and the rest of the house to 18°C. The index is adjusted to fit a 0 to 10 scale. In this study NHER was assessed for all homes by a trained surveyor. Respiratory and generic health status was measured by the St George's Respiratory Questionnaire[15] (SGRQ) and Euroqol Visual Analogue Scale[14] (EQ VAS) at recruitment and after intervention was achieved, or for the control group 12 months after recruitment.

The number of hospital admissions for COPD was recorded for all participants for 12 months prior to recruitment, and 12 months post recruitment.

Indoor living room and bedroom temperatures and humidity were measured at 30 minute intervals using electronic dataloggers over one week between the end of October and mid May in each of the three years of the study.

Power

Using NQuery Advisor V5 (Statistical Solutions Stonehill Corporate Center, MA, USA) a sample size of 140 was calculated as necessary for 80% power at alpha=0.05 to detect a four point difference in SGRQ means between groups in the randomised trial, a difference regarded as clinically significant..

Analysis

SPSS 15.0 was used for statistical analyses (SPSS V13, SPSS, Inc., Chicago ILL). Multiple regression analysis (or ANCOVA) was used for the main analyses. In this analysis the outcome measure at 12 months was the dependent variable and the corresponding measure at baseline was the independent variable together with the grouping variable. In multiple regression analysis the coefficient of the grouping variable indicates the average difference between the groups following intervention. The average difference can be corrected for potential confounders by including them in the multiple regression as additional independent variables. The multiple regression has the advantage of being unaffected by the baseline differences[17]. We first tested for differences between randomized arms of the study (intention to treat analysis) and then compared homes where action was carried out with homes where no action was implemented (pragmatic analysis). The average differences in health status scores were adjusted for demographic and clinical variables previously identified as significant covariates[11]. These were: age, levels of $PM_{2.5}$ in the home and % predicted

FEV_1 and FVC. As FEV_1 and FVC were highly correlated ($r=0.61$, $p<0.001$) only predicted FEV_1 was used.

RESULTS

617 patients were identified as eligible of whom 178 were recruited to and 146 (82%) completed the study. Figure 1 shows the flow of eligible participants through the study. Average time from entry to final assessment, for those who completed the study, was 19.9 months for the Intervention group and 19.8 months for the Control group. Average time from intervention to final assessment was 5 months, with a standard deviation of four months.

Non-participants did not differ in age or sex but had lower (better) deprivation scores ($p = 0.04$). Mean age of participants was 69.6 years (SD 8.5), 82 (46%) were male, mean % predicted FEV_1 was 41.6 (SD 17.4) and 37 (20%) were current smokers.

Of the 178 recruited, 118 were randomised. 59 were assigned to intervention and 59 to control arms. The remaining 60 agreed to monitoring but not to randomisation.

21 patients (12%) were classified as having mild COPD, 109 (61%) as having moderate COPD, and 48 (27%) as having severe COPD. 124 participants reported that they were not current smokers. 21 of these had salivary cotinine levels above 20 μg/l (27 μg/l to 420 μg/l)[14] and were reclassified as smokers.

Demographic and clinical characteristics of participants are shown in Table 1.

Demographic and housing characteristics of homes

Moderate energy efficiency is indicated by an NHER score between 3 and 6. 69% of homes in the study fell in this range compared to 71% in Scotland as a whole. 18% of homes had an NHER of 7 or above, compared to 21% in Scotland. 23 homes (13%) were rated as being below 3 in the NHER scale, regarded as 'unsatisfactory'[12]. This proportion of poor housing exactly matches that found in the National Scottish Homes Survey in 2002. The homes with unsatisfactory energy efficiency were larger (90 sq m vs 70 sq m, $p<0.02$) and 72% were privately owned, compared to 55% in homes with higher NHER.

At baseline, the average annual cost for all homes in the study to achieve guideline warmth was £600. Mean Estimated Annual Fuel cost to achieve guideline warmth in privately owned homes was significantly greater than for social housing homes (£676 pa compared to £483 pa: diff £193 SE £44.8, $p<0.001$). 40% of privately owned homes would have needed to spend more that £600 for guideline warmth, compared to 12% of council/housing association homes.

Achieving energy efficiency action

60 participants were willing to be monitored but did not want energy efficiency improvements. Concerns over cost were expressed by some participants, despite being offered incentives of grants to cover the cost of the work, or low-cost loans set up to be repaid out of the savings made on fuel bills. Others considered that the work would be too disruptive, e.g. underfloor insulation would require the lifting of laminate flooring or carpeting, while loft insulation required the loft space to be cleared. Several were waiting for re-housing to sheltered accommodation by the council and did not want to jeopardise their chances of being allocated a new home. However 11 of the 60 initiated independent energy action during the study period.

In the intervention arm, after initial agreement to energy efficiency action and monitoring, 34 ultimately did not have improvements for reasons similar to those given above. Improvements carried out in 25 intervention homes were upgrading of central heating boilers, loft or underfloor insulation, or both.

In the control arm, after agreeing to being placed on the waiting list for 12 months, 9 participants had improvements carried out during the study. Some of these were due to homes being in the catchment area for council heating upgrade schemes while others were due to participants taking independent action. Ethical approval had been given for the study on condition that all participants were given information on how to access home improvement support.

Homes of patients where energy efficiency action was achieved differed from those who did not want action, or who initially agreed to action and then changed their minds. They had lower baseline NHER (4.8 vs 5.6, p=0.03) and fewer baseline hours of warmth above 21^{o}C in living rooms in the monitored week (48 hours vs 69 hours, p=0.03).

Health outcomes and energy efficiency action

Table 2 shows the multivariate model of the relationship of health status to randomisation group (intention to treat analysis), Table 3 shows baseline demography and Table 4 the outcomes model for groups defined by whether or not energy action was achieved (pragmatic analysis).

The only outcome variable significantly associated with the randomisation to action arm was hours of bedroom warmth, which in follow up was higher in homes assigned to the energy action arm. Symptom scores were lower (better) in those in the action arm, but the difference was not significant.

In a post hoc pragmatic analysis comparing the 45 patients who had action with the 101 who had not (at year two), independent of randomisation, a number of significant differences were observed (Table 4). Demographically, those who had an intervention differed significantly at baseline from those who did not being older (71.2 y vs 68.8 y), with lower energy efficiency and higher estimated fuel costs. However, they were no different from those in whom intervention was not achieved in terms of deprivation or quality of life scores. Those who undertook intervention had a lower number of COPD admissions in the previous year than those who did not (0.9 vs 1.23) but this did not quite achieve statistical significance (p=0.06). Homes where energy efficiency action had been taken had increased by 1.1 points on the 10 point NHER scale and estimated annual fuel cost had decreased by approximately 10%. The SGRQ symptom scores (adjusted for baseline score) had improved by 9.0 points in the intervention group. A change in score of 4 points is considered clinically significant[18]. There was no change in hours of indoor warmth in living room or bedroom, or indoor humidity levels, or in scores for illness impact, activity limitation or hospital re-admissions.

DISCUSSION

Using intention to treat analysis this study found no benefit in health outcomes or housing characteristics for homes randomised to have community-based energy efficiency action, compared to a waiting list control group. However, the comparison between intervention and control arms was blurred because less than half the homes randomised to intervention achieved energy efficiency action during the study. At the same time a sizeable minority of control and monitor only homes took independent energy efficiency action. Analysis comparing homes which had energy efficiency action with those which did not, independent of original randomisation status, found significant improvement in energy efficiency, estimated annual fuel cost and symptomatic health status but no effect on hospital re-admissions.

Indoor hours of warmth in the homes studied were below levels recommended by housing guidelines. Homes where participants chose to have energy efficiency action independent of randomisation had significantly lower hours of warmth at the beginning of the study than homes which did not have action. These lower temperatures were associated with poorer respiratory quality of life[10] at baseline. Although these homes then achieved significantly higher NHERs, and estimated fuel costs were significantly reduced, no change was observed in hours of warmth within the home. This parallels the results of studies in New Zealand[5] and in Devon[6]. In the New Zealand study installation of insulation was associated with improved health status, but less than a $1^{o}C$ change in average indoor temperature. In the Devon study, after initial temperature and humidity benefit, temperatures and humidity returned to original levels.

Post hoc analysis of the data which compared actual take up of energy intervention to no take up found that those participants who had energy intervention had significant symptomatic improvement. Their respiratory symptom scores improved by 9 points, double the size of change regarded as clinically important. Change in COPD impact and activity limitation scores were also in the same direction. Those who accepted energy intervention were older and had higher estimated fuel costs on entry to the study, but they were not different at baseline from the non intervention group in respiratory symptoms, activity limitations or distress. Severity of COPD therefore was not an obvious influence on the decision to proceed with energy action. Future studies will need to assess health related quality of life with other measures of disease control such as medication use or hospital admissions. Benefits from improving housing were not mediated through absolute changes in indoor warmth and humidity[19] but may be due to a more even distribution of warmth within the home[4]. Alternatively, there may be broad psychosocial benefits from reduced fuel costs following home improvement, which impact on health.

This study highlights the difficulties of carrying out real life pragmatic trials of this kind of social policy intervention, notably in terms of recruitment, retention within the randomisation groups and timing of intervention by the engineers/builders. Although more than 1200 patients with COPD are admitted to Aberdeen Royal Infirmary each year, only 600 were eligible for entry to the study because almost half of those admitted were not living in independent housing. Among those who did agree to take part ultimately less than half of the intervention arm had energy action Their age (mean 69.9 years) and illness made them less likely to be willing to take part in the study and more likely to withdraw during the course of the study. For a small number there were also logistic delays which meant intervention was not achieved within the study time limits. This is similar to the New Zealand[5] study where only 30% of targeted homes received the full improvement package. A further difficulty in studies of this type is the time necessary to achieve the intervention, shortening the time available for assessment.

As well as withdrawals from the action group, some randomised to the control group decided to go ahead with improvements from their own resources rather than wait until the end of the study follow up period   Ethical approval for the study was granted only on condition that all participants be told, and given written information, that they could independently apply to the Affordable Warmth scheme for grants to have energy efficiency action carried out. Several participants applied to the Scottish Government's Central Heating Programme as a consequence. The blurring of randomisation by all of these factors weakened the power of the study. This is an important issue in "real-life studies" where researchers do not have complete control over all aspects of the study.

Does it matter that more vulnerable groups are difficult to access for a controlled trial of this kind? Can it be argued that benefits from home improvement observed in younger, healthier populations e.g. the New Zealand[5] and the Devon studies[6] must translate to benefits for older, more ill populations? The activity involved in home improvement is stressful and disruptive. It may be the case that in homes with moderate energy efficiency, as in the present study, health benefits are not great enough to make a cost effective policy for this group. On the other hand, those participants who actively sought energy efficiency action in the present study had a large and significant point gain in respiratory health status, more than twice the minimum required for clinical significance.

Conclusion

The results of this study indicate that the majority of elderly patients with COPD are unlikely to take up energy efficiency upgrading if this is offered to them. However, the minority who do respond to encouragement to seek home energy efficiency action may achieve clinically significant improvement in respiratory health status . This may have implications for current housing policy for the elderly with COPD.

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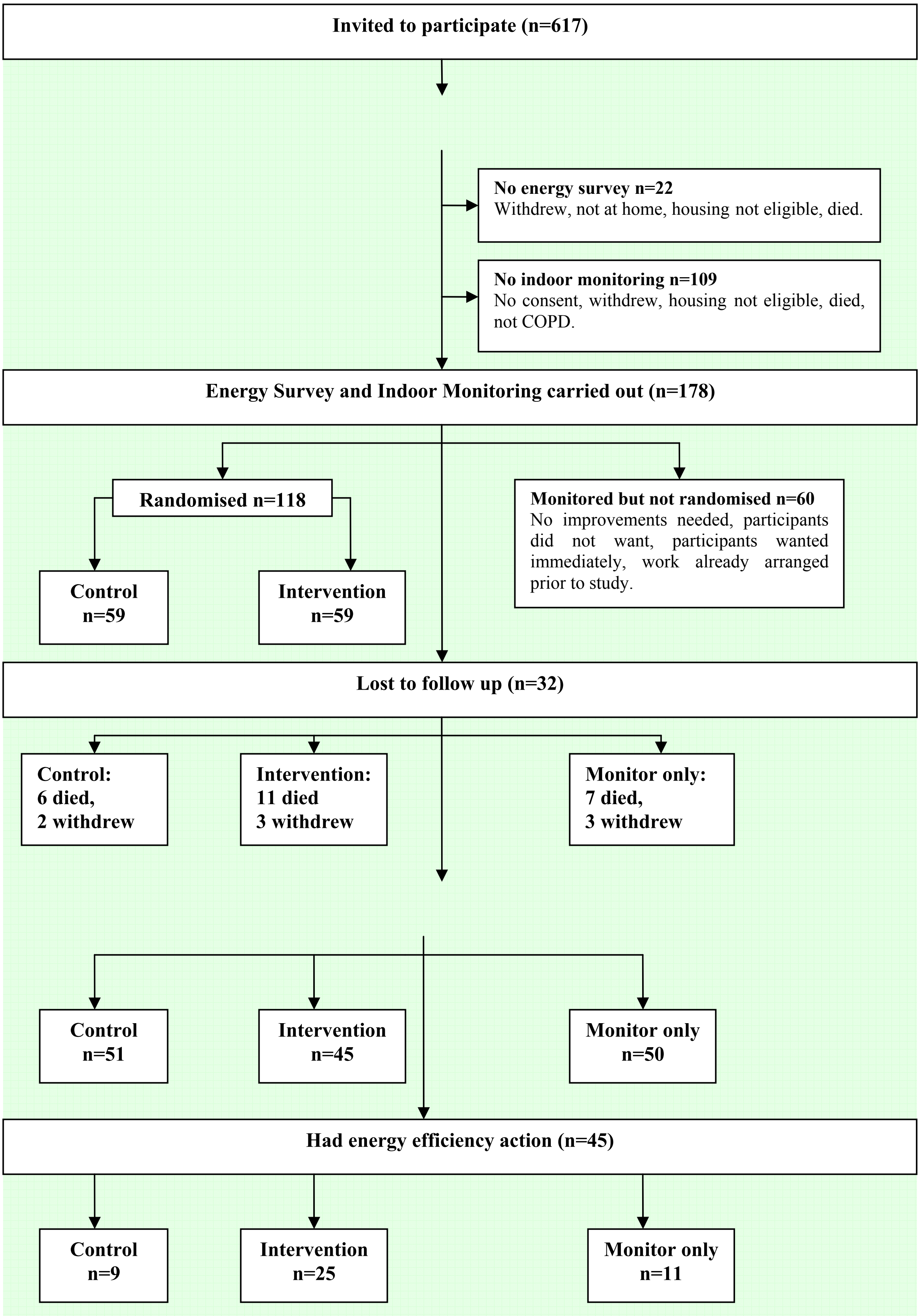
3000 words

Figure 1: Flow of participants through study



Osman et al 2009 Figure 1

Consented (n=309)

Table 1: Participant baseline social, clinical and housing characteristics by study group

Demographic	Intervention n=59 N (%)	Control n=59 N (%)	Monitor Only n=60 N (%)
Age - Mean (SD)	71 (10)	68 (7.2)	69 (7.9)
Male – No (%)	27 (46%)	27 (46%)	28 (47%)
Marital status: Never married	3 (5%)	4 (7%)	4 (7%)
Married	36 (61%)	36 (61%)	35 (58%)
Widowed/divorced	20 (34%)	19 (32%)	21 (35%)
Lives alone	20 (34%)	20 (34%)	21 (35%)
•Smoker	20 (34%)	26 (46%)	18 (33%)
Deprivation score Mean (SD)	-0.55 (2.8)	0.22 (2.9)	-0.53 (3.2)
Clinical and health status	**Mean (SD)**		
FEV_1*(litres)	0.98 (0.44)	1.1 (0.46)	1.0 (0.49)
%PredFEV_1[*]	40.4 (16.5)	45.0 (18.5)	39.4 (16.9)
FVC (litres)[*]	2.2 (0.80)	2.2 (0.71)	2.1 (0.78)
%PredFVC[*]	59.9 (19.3)	60.6 (16.2)	56.5 (19.6)
All Admissions Mean (SD) [++]	1.9 (1.6)	1.7 (1.5)	1.9 (1.5)
COPD Admissions Mean (SD) [++]	1.1 (1.1	1.1 (1.1)	1.2 (1.0)
SGRQ[+]-Symptoms	73.8 (17.4)	76.5 (18.3)	77.1 (16.3)
SGRQ[+]-Activities	85.5 (17.1)	83.0 (16.0)	81.7 (19.8)
SGRQ[+]-Impact	56.7 (21.2)	57.1 (19.5)	54.6 (24.6)
SGRQ Total	68 (17.1)	68 (16.5)	68.3 (19.9)
Followed up (n=146)			
Social housing[**]	23 (39%)	30 (51%)	22 (37%)
Central heating	48 (81%)	54 (92%)	48 (80%)
Energy efficiency (NHER)	5.1 (1.9)	5.5 (1.7)	5.5 (1.7)
EAFC[+++]	£695 (£434)	£533 (£187)	£553 (£224)

•11 participants had no saliva for cotinine analyses.
[*]Missing for 1 participant. [**] Three homes were privately rented; these are included in the social housing category
[+]St George's Respiratory Questionnaire.
[++]Admissions in 12 months before study entry.
[+++]Estimated Annual Fuel Costs to heat according to housing guidelines.

Table 2: Difference in outcome measures at 12 month follow up – intention to treat analysis: control vs intervention

	At study entry		12 months after intervention		Difference (95% CI)	
Outcome	Intervention Group	Control Group	Intervention Group	Control Group	Unadjusted	Adjusted for baseline score
National Home Energy Rating	5.1	5.5	5.5	5.7	0.2 (-0.5, 0.9)	0.2 (-0.1, 0.6)
Estimated Annual Fuel Costs (£)	696	533	647	580	-66.9 (-250.2, 116.4)	-12.1 (-52.4, 28.7)
LR hours at 21^{o}C	55.9	73.1	59.4	64.0	4.6 (-19.2, 28.3)	7.4 (-11.0, 25.8)
BR hours at 18^{o}C	100.2	109.5	111.9	102.2	-9.7 (-36.4, 17.0)	22.4 (1.6, 43.4)
LR average humidity	46.4	60.0	43.8	43.0	-0.9 (-4.8, 3.0)	-1.7 (-4.9, 1.6)
BR average humidity	50.0	65.4	49.5	48.7	-0.8 (-4.3, 2.7)	-0.8 (-3.5, 1.9)
COPD admissions	1.1	1.1	1.5	1.1	-0.4 (-1.2, 0.4)	0.4 (-0.4, 1.1)
Symptom score*	73.8	76.5	73.2	77.1	-3.8 (-12.4, 4.8)	-3.5 (-11.3, 4.3)†
Impact score*	56.7	57.1	61.0	58.8	2.1 (-6.8, 11.0)	3.0 (-4.3, 10.2,) †
Activities score*	85.5	83.0	83.5	82.6	0.9 (-6.9, 8.7)	-1.4 (-7.7, 4.8) †
SGRQ Total	68	68	69.8	68.9	-0.9 (-8.5, 6.6)	-0.9, (-6.7, 4.9)
VAS score††	50.3	47.1	48.5	48.5	0.0 (-1.0, 1.0)	-0.3 (-1.2, 0.6) †

*St George's Respiratory Questionnaire; LR = living room. BR = bedroom ††Visual Analogue Scale; †Adjusted for baseline score, age, %predFEV_1 and $PM_{2.5}$.

Table 3: Demographics at baseline for all participants, and for those who had action/had no action

Demographic	All n=178		Had Action n=45		No Action n=133		Sig
Age - mean (SD)	69.6	(8.5)	71.2	(7.2)	68.8	(8.8)	p=0.03
Male – No (%)	82	(46%)	20	(44%)	62	(47%)	NS
Marital status: Never married	11	(6%)	4	(9%)	7	(5%)	
Married	107	(60%)	26	(58%)	81	(61%)	NS
Widowed/divorced	60	(34%)	15	(33%)	45	(34%)	
Lives alone	61	(34%)	18	(40%)	43	(32%)	NS
Smoker*	64	(38%)	14	(32%)	50	(41%)	NS
Carstairs deprivation score	-0.29	(2.9)	-0.32	(3.0)	-0.49	(2.7)	p=0.10
Clinical and health status				**Mean (SD)**			
FEV1 (mean, litres)	1.03	(0.46)	1.05	(0.49)	1.02	(0.46)	NS
%pred FEV1	41.6	(17.4)	43.5	(18.0)	41.0	(17.2)	NS
FVC (mean, litres)	2.17	(0.77)	2.15	(0.77)	2.17	(0.76)	NS
%pred FVC	59.0	(18.4)	59.0	(18.8)	59.0	(18.3)	NS
COPD prior admissions††	1.15	(1.1)	0.9	(0.9)	1.23	(1.1)	p=0.06
SGRQ† Symptoms	75.8	(17.3)	72.4	(16.8)	77	(17.4)	p=0.13
SGRQ† Activity limitation	83.4	(17.7)	86.3	(12.5)	82.4	(19.0)	p=0.12
SGRQ† Impact	56.1	(21.8)	58.3	(20.7)	55.4	(22.2)	NS
SGRQ† Total score	67.5	(17.8)	68.9	(15.2)	67	(18.6)	NS
VAS	4.8	(1.8)	4.6	(1.7)	4.9	(1.8)	NS
EQ-5D	53	(24.8)	53.3	(22.4)	52.9	(25.6)	NS
Housing				**N (%)**			
Social housing	75	(42%)	18	(40%)	57	(43%)	NS
Central heating	150	(84%)	10	(22%)	18	(14%)	NS
Energy efficiency (NHER)	5.3	(1.8)	4.8	(2.1)	5.5	(1.7)	p=0.03
EAFC†††	£594	(£309)	£705	(£417)	£557	(£253)	p=0.03

*11 participants had no saliva for cotinine analyses.
†St George's Respiratory Questionnaire;
††Admissions in 12 months prior to entry to study;
†††Estimated Annual Fuel Costs to heat according to housing guidelines.

Table 4: Difference in outcome measures at 12 month follow up – action versus no action

Outcome	Before action		12 months after action		Difference (95% CI)	
	Action Group	No action Group	Action Group	No action Group	Unadjusted	Adjusted for baseline score
National Home Energy Rating	4.8	5.6	6.0	5.7	0.3 (-0.3, 0.9)	1.1 (0.8, 1.4)
Estimated Annual Fuel Costs (£)	£705	£557	£612	£576	-36.5 (-105.7, 81.8)	-65.3 (-31.9,- 98.7)
LR hours at 21^{o}C	47.9	69.0	54.1	69.2	15.2 (-6.1, 36.4)	1.9 (-15.0, 18.8)
BR hours at 18^{o}C	104.5	114.8	110.5	112.0	1.5 (-21.1, 24.0)	0.8 (-22.8, 21.3)
LR average humidity	46.6	51.8	44.7	43.6	-1.1 (-4.4, 2.2)	0.4 (-2.4, 3.2)
BR average humidity	49.5	56.2	49.7	48.2	-1.4 (-4.5, 1.6)	-0.6 (-2.9, 1.7)
COPD admissions	0.9	1.2	0.8	1.4	0.5 (-0.2, 1.2)	-0.3 (-0.9, 0.4)
Symptom score*	72.4	77.0	66.0	77.7	-11.7 (-19.2, -4.1,)	-9.0 (-2.5, -15.5)†
Impact score*	58.3	55.4	58.8	59.6	0.9 (-7.2, 8.9)	-5.7 (-12.3, 0.8)†
Activities score*	86.3	82.4	83.2	83.8	0.6 (-6.8, 8.0)	-3.9 (-9.3, 1.5)†
SGRQ total	68.8	67	67.4	69.9	-2.5 (-9.2, 4.2,)	-5.7 (-0.7, -10.7)
VAS score††	46.1	49.2	46.9	47.8	0.08 (-0.76, 0.92)	0.1 (-0.8, 0.9)†

*St George's Respiratory Questionnaire; LR = living room. BR = bedroom ††Visual Analogue Scale; †Adjusted for baseline score, age, %predFEV_1 and $PM_{2.5}$

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