

Effect of insulating existing houses on health inequality: cluster randomised study in the community

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ABSTRACT

Objective To determine whether insulating existing houses increases indoor temperatures and improves occupants' health and wellbeing.

Design Community based, cluster, single blinded randomised study.

Setting Seven low income communities in New Zealand.

Participants 1350 households containing 4407 participants.

Intervention Installation of a standard retrofit insulation package.

Main outcome measures Indoor temperature and relative humidity, energy consumption, self reported health, wheezing, days off school and work, visits to general practitioners, and admissions to hospital.

Results Insulation was associated with a small increase in bedroom temperatures during the winter (0.5°C) and decreased relative humidity (-2.3%), despite energy consumption in insulated houses being 81% of that in uninsulated houses. Bedroom temperatures were below 10°C for 1.7 fewer hours each day in insulated homes than in uninsulated ones. These changes were associated with reduced odds in the insulated homes of fair or poor self rated health (adjusted odds ratio 0.50, 95% confidence interval 0.38 to 0.68), self reports of wheezing in the past three months (0.57, 0.47 to 0.70), self reports of children taking a day off school (0.49, 0.31 to 0.80), and self reports of adults taking a day off work (0.62, 0.46 to 0.83). Visits to general practitioners were less often reported by occupants of insulated homes (0.73, 0.62 to 0.87). Hospital admissions for respiratory conditions were also reduced (0.53, 0.22 to 1.29), but this reduction was not statistically significant (P=0.16).

Conclusion Insulating existing houses led to a significantly warmer, drier indoor environment and resulted in improved self rated health, self reported wheezing, days off school and work, and visits to general practitioners as well as a trend for fewer hospital admissions for respiratory conditions.

Trial registration Clinical Trials NCT00437541.

INTRODUCTION

Improvements to housing could potentially prevent ill health, especially in sections of the population exposed to substandard housing. Several reviews have highlighted a dearth of studies in this area and the urgent need for studies from which causal inferences can be

drawn.¹⁻⁴ The housing, insulation and health study is a cluster randomised trial of insulating existing houses in low income communities. The study was designed as a practical intervention to improve the indoor environment at the community level.

METHODS

The study methods have been published previously, but a brief summary is given below.⁵

Setting

New Zealand has mean winter daytime temperatures ranging from 10°C in the south to 16°C in the north. Two thirds of the housing stock comprises three bedroom and four bedroom stand alone wooden houses on wood or concrete piles (Statistics New Zealand, www.stats.govt.nz/default.htm). Houses usually last about 90 years and about a third have no insulation. Most people only heat the living room and occasionally a bedroom.⁶

Recruitment

Our study was established in three urban and four rural areas. Each community selected 200 households. The selected households were in uninsulated dwellings; at least one household member had reported respiratory symptoms in the past year or had a history of asthma, pneumonia, or chest infections; and members were planning to remain in the dwelling for the next two winters.

Sample size calculations were based on the number of people whose health status could be expected to improve from "fair" or "poor" on the generalised health question in the SF-36 (short form 36) questionnaire.⁵

Participants

The study comprised 1350 houses. The tenure patterns showed some divergence from the 2001 New Zealand Census: 24% of houses in the study were rented compared with 32.2% nationally; 11% were rented from public landlords, compared with about 6% nationally. About a third of the houses were in the lowest tenth of socioeconomic areas, and two thirds were in the bottom three tenths, so participants were likely to be vulnerable to ill health. Twenty per cent rated their health as

poor or very poor, compared with 13% of the general population.

The initial, regionally stratified randomisation was carried out by an independent biostatistician. No evidence for systematic bias was seen between intervention and control groups (see bmj.com).

Intervention

Households randomly allocated to the intervention group had their houses insulated after the baseline measures were taken in the study's first winter (June to August 2001). The intervention consisted of installing ceiling insulation, draught stopping around windows and doors, and fitting sisalated paper beneath floor joists and a polythene moisture barrier on the ground beneath the house. (Households in the control group were insulated for equity at the end of the study after all data had been collected.)

Outcome measures

The study used interviewer administered questionnaires; participants' self reported experience; as well as independent measures of use of health services, house temperature, and other environmental characteristics of the houses (see bmj.com).

In spring 2001 and 2002, all household members 11 years and over completed a self administered questionnaire about their health, contact with the health system, smoking, and time lost from work or normal activities because of ill health. Care givers or parents completed a similar questionnaire for children under 11 years.

We checked use of primary care by contacting the specified general practitioners. The number, duration, and main ICD-10 (international classification of diseases, 10th revision) codes for hospital admissions were collected through a data matching process using the unique national patient identifier number.

Participants reported daily whether they felt warm, OK, or cold before their evening meal. The head of the household completed an interviewer administered questionnaire in the home about household demographics, dwelling characteristics, and space heating—including estimates of the use of solid fuel. Regional electricity and gas companies supplied data on the energy consumption of each household during the study period.

In 140 randomly selected houses, we recorded temperature and relative humidity in the main bedroom, every 15 minutes, during both winters. At two randomly selected houses in each of the seven communities, temperature and humidity were also continuously recorded outside.

Statistical methods

We compared the follow-up scores of the intervention and control groups and subtracted follow-up scores from baseline scores to derive change scores. The analysis of covariance (ANCOVA) is presented unless otherwise indicated. Analyses also controlled for the clustering of individuals within households and households within regions. We routinely added sex, ethnic origin, and age group to the adjusted model. In general, we adjusted

odds ratios for age, sex, region, and baseline values. The unadjusted odds ratios take account of clustering.

RESULTS

We recruited 1350 households; baseline household information was obtained from 1309 of these households and 4407 people. At follow-up, 1128 households and 3312 people remained—an 86% retention rate for households and a 75% rate for people. The proportion of indigenous Maori people (49%) and migrant Pacific people (22%) was higher in the sample than in the national population (15% and 6%, respectively).

Household factors

Self reporting showed that 18% of houses were in poor or very poor condition, 89% had condensation, and 75% had mould. Building inspectors reported worse conditions, with 53% of the houses in the subsample being in poor or very poor condition and 81% with some mould.

Outdoor and indoor environment

Mean winter daytime temperatures were 10.5°C and 11.3°C in 2001 and 2002. The odds of feeling cold always or most of the time when indoors decreased significantly in the insulated houses compared with uninsulated houses, as did the odds of reporting ineffective heating (table 1).

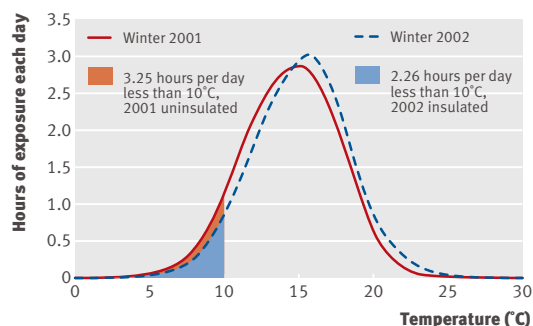
Mean bedroom temperature increased in the insulated houses from 13.6°C to 14.2°C and in the uninsulated ones from 13.2°C to 13.4°C. Mean relative humidity decreased in the insulated houses from 68.6% to 64.8% compared with 68.3% to 66.9% in the uninsulated houses (see bmj.com). Bedroom temperatures were below 10°C for an hour less in insulated houses and 45 minutes longer in the uninsulated houses (figure).

Reported damp and mould

At baseline, two thirds of households reported damp and three quarters reported mould, but after insulation the odds of insulated households reporting dampness or mould decreased significantly (table 1).

Energy usage

Electricity and gas company data, and calculations from self reported wood and coal usage using standard



Bedroom temperatures in houses from intervention and control groups. The area under the frequency curves is proportional to the average number of hours each day below 10°C

Table 1 | Household results in a trial of insulating houses. Values are number/total number of households for self reported house condition and median/geometric mean (number of households) for energy use, unless stated otherwise

Outcome measure	Before intervention		After intervention		Odds ratio (95% CI)	
	Intervention group	Control group	Intervention group	Control group	Unadjusted	Adjusted
Self reported condition of house*						
Any mould	364/509	362/501	191/509	343/501	0.28 (0.21 to 0.36) P<0.0001	0.24 (0.18 to 0.32) P<0.0001
House cold most of the time or always	398/550	383/547	95/550	378/547	0.09 (0.07 to 0.12) P<0.0001	0.06 (0.04 to 0.09) P<0.0001
Condensation	487/538	486/535	318/538	480/535	0.17 (0.12 to 0.23) P<0.0001	0.16 (0.11 to 0.22) P<0.0001
Non-condensation dampness	334/519	324/516	156/519	339/516	0.23 (0.18 to 0.30) P<0.001	0.18 (0.13 to 0.24) P<0.0001
Heating ineffectivet	61/304	104/375	48/304	125/375	0.38 (0.26 to 0.55) P<0.0001	0.38 (0.25 to 0.57) P<0.0001
Energy use (kWh(e))						
Measured and self reported†	4722/5016 (195)	4583/5120 (193)	3678/3899 (195)	4866/4941 (193)	0.79 (0.64 to 0.97) P=0.02	0.81 (0.72 to 0.91) P=0.0006
Measured only§	2416/2451 (72)	2392/2317 (64)	2298/2200 (72)	2592/2328 (64)	0.95 (0.77 to 1.16) P=0.06	0.92 (0.83 to 1.02) P=0.097
Measured and self reported¶	—	—	3828/3847 (267)	4628/4262 (295)	0.90 (0.77 to 1.05) P=0.20	0.91 (0.79 to 1.04) P=0.17

*Question answered for both years and adjusted for baseline status, region, and amount of sunshine.

†Excludes those who reported using no heating in either year.

‡Estimated full fuel data for both years, including self reported wood, coal, and liquefied petroleum gas; adjusted for region and fuel use in year 1.

§Full fuel data for both years; households use only electricity and mains gas; adjusted for region and fuel use in year 1.

¶Households with full fuel data for year 2 only; adjusted for region only.

calorific values, showed that after adjusting for baseline usage, the insulated households consumed 81% of that consumed by control households (table 1). Taking a subsample of households (n=136), who used only electricity and mains gas in both years, the estimated value of fuel savings was around £25 (€37; \$49; excluding taxes) a year.

SF-36

Adults in insulated homes had half the odds of having fair or poor self rated health (adjusted odds ratio 0.50, 95% confidence interval 0.38 to 0.68). On the social functioning scale, role emotional scale, and role physical scale, participants in insulated houses reported improvement relative to the control group (table 2).

People in insulated houses had about half the odds of respiratory symptoms, such as recent wheezing (0.57, 0.47 to 0.70; P<0.0001) and self reported winter colds and flu (0.54, 0.43 to 0.66; P<0.0001) as those in the control group. In adults, the incidence of morning phlegm decreased significantly (0.64, 0.52 to 0.78; P<0.0001), and in children under 13 years the likelihood that the symptoms of wheezing would disturb sleep (0.57, 0.40 to 0.81; P=0.0019) or speech (0.51, 0.31 to 0.86; P=0.012) halved (see bmj.com).

Days off school and work

Children in insulated houses were reported to have half the odds of having a day off school compared with the control group (0.49, 0.31 to 0.80; P=0.004), and fewer adults reported having had a day off work (0.62, 0.46 to 0.83; P=0.0017).

General practitioner visits

We received records from general practitioners for 82% of the participants. Self reports of visits, but not general practitioner records of visits were significantly lower for insulated houses (table 3).

Hospital admissions

We accessed the hospital records of 80% of participants. We found little overall difference in the number of people who were admitted to hospital for all causes between the intervention group and control group (4.4% v 4.7%). People from insulated houses were less likely to be admitted to hospital for respiratory conditions (see bmj.com).

DISCUSSION

Our study used a community approach to investigate an important environmental determinant of health.

Table 2 | Self reported SF-36 results in a trial of insulating houses. Results are mean score in adults who had data for both years, unless stated otherwise

Scale	Before intervention		After intervention		Difference (95% CI)	
	Intervention group	Control group	Intervention group	Control group	Intervention group	Control group
Social functioning	69.2	69.3	78.4	72.3	6.1 (3.9 to 8.4) P<0.0001	6.2 (3.8 to 8.6) P<0.0001*
Role emotional	63.1	62.4	77.5	66.7	10.8 (7.2 to 14.5) P<0.0001	10.9 (7.1 to 14.6) P<0.0001*
Role physical	52.5	52.2	70.0	58.8	11.2 (7.4 to 15) P<0.0001	11.8 (8.0 to 15.5) P<0.0001*

*Adjusted for score in baseline, age group, sex, ethnic origin, household, and region.

Table 3 | Use of health care in a trial of insulating houses. Values are number of people (total number of people with available data) unless stated otherwise

Outcome measure	Before intervention		After intervention		Odds ratio (95% CI)	
	Intervention group	Control group	Intervention group	Control group	Unadjusted	Adjusted
Primary care						
Self reported visit to general practitioner	813 (1448)	769 (1396)	664 (1448)	715 (1396)	0.81 (0.70 to 0.94) P=0.0043	0.73 (0.62 to 0.87) P=0.0002†
General practitioner reported visit	814 (1390)	765 (1346)	769 (1390)	743 (1346)	1.01 (0.86 to 1.17) P=0.9484	0.95 (0.81 to 1.13) P=0.58†
Secondary care*						
Admitted to hospital; main code a respiratory condition	7 (1379)	10 (1340)	8 (1386)	14 (1345)	0.552 (0.23 to 1.32) P=0.18	0.53 (0.22 to 1.29) P=0.16 χ^2 /df=0.89‡
Admitted to hospital; main code a control condition	48 (1379)	56 (1340)	43 (1386)	48 (1345)	0.865 (0.569 to 1.312; P=0.50)	0.90 (0.59 to 1.37) P=0.61

Outcomes were measured on people with attendance records for both years in primary care and by using a unique identifier in the second year in secondary care. All adjusted odds ratios were adjusted for age, sex, and ethnic origin.

*Twelve babies were born in the year between the first and second winter: 7 in the intervention group and 5 in the control group.

†Also adjusted for baseline value and region.

‡Also adjusted for region.

All outcome measures improved with insulation, and except for the use of healthcare facilities, results were statistically significant. The effect size was greater for the self reported data, although independent housing inspectors judged the houses to be in worse condition than did the occupants.

Limitations and strengths of the study

Our study was of necessity only single blinded. Possible bias was minimised by the collection of external data gathered from independent sources such as power companies, general practitioners, and hospitals.

By targeting uninsulated households where at least one member had current respiratory symptoms we identified a group of people whose homes were more likely to be older, colder, and damper than in the general population, and where increased warmth and decreased humidity and damp might be expected to have a greater effect. The population contained a disproportionately high proportion of Maori and Pacific people, who have higher morbidity and premature mortality than Europeans.⁷

Some economists have argued that low household income rather than substandard housing is the fundamental problem underlying health inequality.⁸ Such confounding makes a randomised controlled trial like ours important for determining cause and effect. Income and housing are obviously inter-related, but it is easier to upgrade low income housing than to redistribute income.

Benefits of insulation

Fitting older homes with insulation led to a statistically significant increase in the indoor temperature and a decrease in relative humidity. This may be the main reason occupants reported a significantly higher level of comfort. Alternatively, insulation may have reduced heat transfer between the occupants and the outside or the occupants may have had an increased sense of control over their fuel bills. People in insulated houses also reported that their houses felt significantly less damp and mouldy, but our study does not identify the key environmental factors involved.

Householders spent significantly less on heating their houses after the intervention, and these savings may have increased their effective disposable income. The finding that householders took advantage of the efficiency gains to lower energy consumption is consistent with the relatively small change in mean temperature and other empirical studies in this area.⁹⁻¹¹ It also suggests that the improvement seen in health was not due to average temperature and humidity changes, which were relatively small, but to larger changes in exposure to very low temperatures and high humidity.

Spending around £700 excluding taxes per house led to significant improvements in self reported health and a lower risk of having time off school or work. We saw no reduction in visits to general practitioners according to official reports; however, the absence of a unique patient identifier in primary care means that patients' recall of visiting several general practitioners, which is common in New Zealand, may be more accurate than the records from their main practitioner. In secondary care, we saw a trend towards fewer admissions to hospital and fewer days in hospital for respiratory conditions.

A cohort study has shown that the effects of poor housing conditions are cumulative over the life course.¹² A conservative cost-benefit analysis of this intervention trial indicated that the tangible health and energy benefits outweighed the costs by a factor approaching 2, when calculated in present value terms at a 5% real discount rate over 30 years, and that the energy savings component covered around half the cost of the insulation.¹³

CONCLUSION

Fitting insulation is a cost effective intervention for improving health and wellbeing. It has a high degree of acceptance by the community, policy makers, and politicians.

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WHAT IS ALREADY KNOWN ON THIS TOPIC

Damp, cold, and mouldy houses are associated with poor health

WHAT THIS STUDY ADDS

Insulating existing houses makes the indoor environment significantly warmer and drier, while lowering energy use

Fitting insulation significantly improves occupants' self rated health, self reported wheezing, days off school or work, and visits to general practitioners, and results in fewer hospital admissions for respiratory conditions

teams; and all the householders who took part in our study. We are grateful to our community coordinators the late Ruth Nepia, Pounamu Skelton, and Jo-Ani Robinson. We also thank the general practitioners, the National Health Information Service, the energy companies who supplied us with utilisation data, and June Atkinson, who carried out the randomisation.

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Competing interests: None declared.

Ethical approval: This multicentre study was approved by the central region ethics committee.

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Folic acid supplements and risk of facial clefts: national population based case-control study

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ABSTRACT

Objective To explore the role of folic acid supplements, dietary folates, and multivitamins in the prevention of facial clefts.

Design National population based case-control study.

Setting Infants born 1996-2001 in Norway.

Participants 377 infants with cleft lip with or without cleft palate; 196 infants with cleft palate alone; 763 controls.

Main outcome measures Association of facial clefts with maternal intake of folic acid supplements, multivitamins, and folates in diet.

Results Folic acid supplementation during early pregnancy (≥ 400 $\mu\text{g/day}$) was associated with a reduced risk of isolated cleft lip with or without cleft palate after adjustment for multivitamins, smoking, and other potential confounding factors (adjusted odds ratio 0.61, 95% confidence interval 0.39 to 0.96). Independent of supplements, diets rich in fruits, vegetables, and other high folate containing foods reduced the risk somewhat (adjusted odds ratio 0.75, 0.50 to 1.11). The lowest risk of cleft lip was among women with folate rich diets who also took folic acid supplements and multivitamins (0.36, 0.17 to 0.77). Folic acid provided no protection against cleft palate alone (1.07, 0.56 to 2.03).

Conclusions Folic acid supplements during early pregnancy seem to reduce the risk of isolated cleft lip (with or without cleft palate) by about a third. Other vitamins and dietary factors may provide additional benefit.

INTRODUCTION

Folic acid deficiency is known to produce facial clefts in rodents.¹ However, studies of an association with facial clefts in humans have provided inconsistent results,²⁻⁷ and the question remains unresolved.⁸ This question is especially relevant in countries where fortification of foods with folic acid has not been allowed. One of these is Norway, which has one of the highest rates of facial clefts in Europe.⁹ We assessed possible effects of folic acid on facial clefts in Norway through a population based case-control study.

METHODS

Study design

Infants born in Norway with orofacial clefts are treated in one of two surgical centres (Oslo and Bergen). We contacted the families of all newborn infants born from 1996 to 2001 who had been referred for surgical treatment of a cleft (either cleft lip with or without cleft