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Retrofitting houses with insulation to reduce health inequalities: a community-based randomised trial

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Abstract

Housing is one of the key determinants of health, but it has been a relatively neglected area for interventions targeting health. There has been very little research that has shown housing interventions are effective in improving health as housing interventions are complex and resource intensive.

This study examined the health consequences of insulating New Zealand homes with a standard intervention package delivered by specially trained community retrofit teams in partnership with local organisations. The package was provided through a Government funded retrofit programme carried out by community groups throughout the country.

Nearly fourteen hundred households in seven communities participated. Baseline measures of temperature and fuel use, and health care utilisation were collected during the winter months of 2001. Households were then randomised and those in the

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intervention group had retrofitted insulation installed. During winter 2002 follow-up measures were collected and after the study was complete the control houses were insulated. Eighty four percent of households remained in the study throughout.

The results of this study show a consistent positive effect of the insulation over all the outcome measures: including health outcomes and measures of well-being, such as children's days off school, adults' days off work, self-rated general health and respiratory symptoms, objective measures of GP visits and hospitalizations as well as energy use.

The two-year multi-disciplinary, intersectoral study operated under the principle of partnership with both its funders and its participant communities. Although specific to New Zealand conditions, the study has international implications as it used a randomised controlled intervention research design to ensure rigorous results while balancing the practicalities of its implementation. Furthermore, it shows that improving existing housing is an effective, population-based intervention and provides an opportunity to reduce inequalities in the environmental determinants of health.

Introduction

The state of housing is a key environmental and economic factor in determining a population's health, therefore a sensible preventive strategy is to remedy any underlying housing issues (Rose 1992). This paper reports one of only a small number of randomised trials that have evaluated social interventions in general, and housing interventions in particular (Oakley 1998; Thomson, Petticrew et al. 2001; Thomson, Hoskins et al. 2004).

Despite the fact that we spend around 90 percent of our lives inside, we still know surprisingly little about the specific health effects of the indoor environment in our dwellings (Howden-Chapman 2004). It is clear that warm, dry housing is a fundamental human need. Poorly constructed or older houses are more difficult and expensive to heat, and fuel poverty can lead to little heating which can have health consequences for the occupants, particularly during winter. Colder houses place more physiological stress

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on older people, babies and the sick, all of whom spend more time inside and may help to explain excess winter mortality (Howden-Chapman, Signal et al. 1999; Wilkinson, Pattenden et al. 2004). Houses that are cold are also likely to be damp and this can lead to mould growth, which can cause respiratory symptoms(Tobin, Baranowski et al. 1987; Institute of Medicine of the National Academies 2004). The link between damp, cold, crowded housing conditions and poor health has been highlighted recently in a number of international reports (Acheson 1998; Department of Health 1998; Howden-Chapman and Tobias 2000; Bonnefoy, Braubach et al. 2003; Bonnefoy, Braubach et al. 2003; Institute of Medicine of the National Academies 2004).

Housing is a complex area in which to intervene and the skills of many disciplines and departments are needed (Lawrence 2004). Housing policy in New Zealand, as in many liberal welfare societies has under-emphasised the potential health benefits and public good benefits of housing to the detriment of the health of the occupants and the subsequent costs to society (Baker, McNicholas et al. 2000; Baker and Howden-Chapman 2003). Yet, institutions need robust evidence in order to formulate good policies. The focus on houses as the main unit of analysis in this study is thus intended to enhance the utility of the trial for the formulation of public policy, which depends on evidence of the cost-effectiveness of interventions. Intervening by retrofitting insulation in houses, rather than intervening at the level of the individual, for example by providing more clothes for individuals or a small heater, seems a potentially cost-effective and practical way of improving health through increasing the indoor temperature and lowering relative humidity.

Research Question

The key research question in this study was, does retrofitting houses with insulation increase the indoor temperature and lower the relative humidity, energy consumption and mould growth in the houses, as well as improve the health and well-being of the occupants and thereby lower their utilisation of health care?

Methods

There were 1,352 houses in the study, in which 4,415 people lived, half of whom (49 percent) were Maori, the indigenous people of New Zealand and 25 percent of whom were Pacific people, from Samoa, Tonga and other smaller island states, who include new migrants and their usually first and second generation descendents. The proportion of Maori and Pacific people in the sample was higher that in the national population. In the 2001 Census these fractions were 14.7% and 6.5% respectively.

The insulation of houses by trained community retrofit teams was the randomly allocated intervention. The insulation package was the standard New Zealand Energy Efficiency and Conservation Authority package – insulation in the ceiling, draught-stopping around the windows and doors, sissilated paper strapped under the floor joists and a polyethylene covering over the ground. See (Howden-Chapman, Crane et al. 2004) for a fuller description.

Households allocated to the intervention group had their houses insulated after the baseline measures were taken, those in the control group were insulated *after* the study had finished. The intervention was free to householders, because additional funds were raised to cover the costs of labour and materials.

The study was set-up in seven geographical areas, three urban and four rural areas, in partnership with diverse organisations, all of whom had an interest in housing and health and supporting people in their local area. We signed memoranda of understanding with organisations that were community-based in each area, to make explicit not only the partnership models where there were mutual obligations on both sides, but to highlight the need for everyone to benefit from the research. Multi-site approval was obtained.

The study was a clustered randomised community trial, where houses rather than individuals were randomly assigned to the study groups. As the intervention was insulating uninsulated houses, clustering by houses and thus households (rather than individuals) was the only feasible way of carrying out the trial. The trial was single-blinded; that is the households knew whether their house had been insulated, but the baseline interviews and subsequent analyses were carried out with the interviewers and the researchers not knowing which households had been assigned to each group.

Each organisation established a team of local health workers to select 200 households in their community, in line with the research protocol criteria. The inclusion criteria were: the house had to be uninsulated; at least one person in each household had to suffer from some respiratory disease symptoms (e.g. asthma, pneumonia, chronic bronchitis); and households had to be planning to stay in their house for the next two winters. The study design was explicitly described to community leaders and individual participants, by face-to-face meetings and written material.

The research was advertised in local papers, on radio and by word of mouth. Enrolment continued until nearly two hundred households in each community, who met the research criteria for inclusion were selected. After the selected householders agreed to participate, their houses were audited by builders and the retrofit teams to check that they were indeed uninsulated before they were finally included in the study. Members of the households signed informed consent forms that confirmed their house would be insulated eventually, but that it would be chance whether it was during or at the completion of the study. Like the researchers, the organisations, who recruited the households into the study, were unaware of the subsequent allocation of the household until *after* the baseline measures were collected.

The houses in the study were largely single story, stand-alone houses. The tenure patterns showed some divergence from the 2001 New Zealand Census: 24 percent of houses in the study were rented as against 32.2% nationally; 12% were rented from public landlords, as against approximately 6 percent nationally; and 76% of the houses were owned, as against 68% for NZ as a whole. Overall, about one-third of the houses were in the lowest socio-economic decile of small areas, and two-thirds were in the bottom three deciles. That is, the sample population selected was more vulnerable to ill-health due to the social and economic pattern of the area in which they lived. As they were also living in houses with inadequate insulation, the participants represented a high risk sub-group of the New Zealand population.

Table 1: Sample characteristics

	Control group	**Intervention Group**
Household factors at baseline		
Number recruited	672	680

Number returned questionnaire		652		658	
Dwelling reported in "poor" or "very poor" condition (%)		116/644	(18)	118/653	(18)
Condensation reported (%)		566/633	(89)	577/640	(90)
Non-condensation dampness reported (%)		413/613	(66)	437/641	(68)
Mould reported (%)			(75)	490/651	(75)
		481/643			
Dwelling cold "always" or "most of the time" (%)		452/647	(70)	473/651	(73)
Individual factors at baseline					
Number		2152		2261	
Female(%)		1115/2152	(52)	1187/2261	(53)
Ethnicity	NZE(%)	794/2121	(37)	835/2231	(37)
	Maori(%)	1005/2121	(47)	1109/2231	(50)
	Pacific(%)	578/2121	(27)	501/2231	(22)
Age	0-4(%)	249/2152	(12)	294/2261	(13)
	5-14(%)	524/2152	(24)	566/2261	(25)
	15-24(%)	237/2152	(11)	229/2261	(10)
	25-44(%)	592/2152	(28)	594/2261	(26)
	45-64(%)	362/2152	(17)	391/2261	(17)
	65+(%)	188/2152	(9)	187/2261	(8)
Health rated "fair" or "poor"(%)		438/2138	(20)	445/2242	(20)

As we could find no previous published trials that had attempted to improve health by retrofitting insulation in houses, proxy sample size calculations were based on the number of individuals whose health status could be expected to improve on a generalised health question. To increase the power of the study, a population with pre-existing respiratory conditions, who were expected to have a larger effect size, was selected.

Outcome measures

This study used a number of subjective and objective tools to measure the environmental characteristics of houses and occupants (see Table Two). Measures were recorded over the three coldest winter months, June, July and August.

Table 2 Outcome measures

Level	Outcome	Measure
Individual	Self-reported health	SF36 scales
		Respiratory symptoms
		Days off work and school
		Variety of health care utilisation questions
	Objective health care utilisation	Number of GP visits
		Hospital visits – number and length
Household	Energy measures	Self-reported fuel usage
		Electric and gas company bills
	Warmth/dampness	Objective temperature and relative humidity
		Comfort charts
		Self reported dampness
	Subjective fungal activity	Musty smell
		Observed mould
	Objective fungal activity	Mould speciation
		Mould mass
		Endotoxins
		Beta-glucans

During the three winter months of 2001, households recorded their subjective feelings of warmth (by placing a pink, green or blue sticker on a chart located on the refrigerator to denote being ‘warm’, ‘OK’ or ‘cold’ respectively that day) before their evening meal. In September, all members of the house-holds, filled in a questionnaire about their health, their smoking patterns and their absences from their normal activities over the preceding winter due to sickness; adults in the households filled the health forms in for babies and children under eleven. In addition, the person designated as the head of the household was interviewed by a local community interviewer, about the demographics of the household occupants, the type of heating used in the house, their economic preferences for heating as against disposable income, and their perception of the surrounding neighbourhood.

In addition to these subjective measures of warmth, in a randomly selected 140 (10%) houses, objective measures of temperature and relative humidity were recorded by 'data-loggers', that were located by interviewers in the main bedroom. Further, in each of the seven communities, two houses had data loggers installed externally to measure the outside temperature. Independent building inspectors visited this sub-sample of 140 houses and appraised the physical condition of these houses and the degree of damp and mould in the houses. In addition, in 150 houses randomly selected across three communities, samples of dust were systematically taken from the main bedrooms and analysed for allergens, endotoxins and beta glucans. Mould populations actively associated with dust particles were also extracted from dust samples by standard microbiological isolation methods to provide both an estimate of total culturable biomass as well as to enumerate species diversity present (Samson, Hoekstra et al. 2000) .

During the winter of 2002, all the objective and subjective energy measures were repeated and, as in 2001, immediately following winter the health questionnaires were repeated and further dust samples collected. Once the formal part of the study data collection was completed, the houses in the 'control' group were insulated.

Electricity and gas companies supplied data on the energy consumption of each household. We also collected self-reports of coal, wood and for unflued gas heaters, LPG consumption.

General practitioners visited by the study participants were contacted to obtain the number of visits each person made to the doctor during the three winter months. The diagnoses could not be obtained, because in most cases medical records are not computerised and thus this would have required the employment of medical staff to check medical records. The number, duration and diagnostic codes for inpatient hospital visits were collected through a data matching process using the unique national patient identifier number.

Analyses

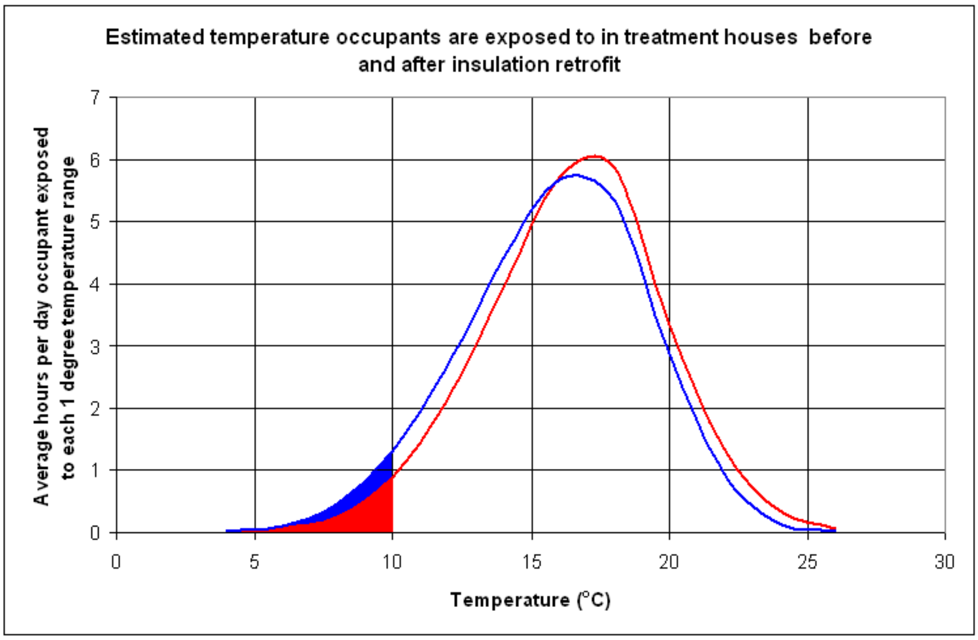
We analysed the trial in several ways. Having established that the randomisation process had not led to any discernible systematic biases, we compared the follow-up post-intervention scores in the intervention and control groups – the difference scores. In analysis comparing follow-up scores of intervention and control groups, covariate adjustment of baseline scores was also made. We also subtracted the follow-up scores from the baseline score – the change scores. Both scores are presented here on the basis of intention to treat. For a fuller description of the exposure measure used see (Cunningham, Viggers et al. 2004).

Results

Results in all outcome areas were in the desired direction, and were with the exception of health care utilisation statistically significant.

In terms of exposure to cold temperatures and damp, the intervention group showed a small, but significant increase in average bedroom temperature from the baseline winter to the following winter (0.6^{o}C compared to 0.2^{o}C for the control group, p=0.04). Average relative humidity for the treatment group fell by 3.8 percent versus 1.5 percent for the control group (p=0.007).

Time below 10^{o}C for the intervention group fell by 0.65 hour per day, while it increased by 0.11 hour per day for the control group. Time above 75 percent relative humidity for the treatment group fell by 1.55 hours but decreased by 0.74 hours for the control group.



On the basis of meter readings, the intervention group used 23% less power than the control group. There was a fourfold increase in the risk of being cold and a two-fold risk of feeling that the house was damp in the uninsulated control group compared to the insulated group ($p<0.0001$).

Controlling for age group, ethnicity, gender and having time-off during the baseline winter and clustering, there was a significant decrease in the risk of having time off school in the second winter for the children aged 6 to 17 years old, O.R. 2.3 ($p=0.001$) and the risk of having time off work for working adults, 18 to 64 years O.R. 1.7 ($p=0.003$).

For the winter of 2002, there was a sevenfold increase in self-reported health in the intervention group as measured on the SF36 general health question, after controlling for sex, age group and personal smoking status ($p<0.0001$). There was also a decrease in self-reported winter colds and flu (O.R. 1.8, $p<0.0001$) as well as respiratory symptoms such as recent wheezing and usual morning phlegm (O.R 1.6, $p<0.0001$).

There was a significant difference in the number of visits to hospitals made by adults between the intervention and control group, but not for the population as a whole, although the trend for the other age groups was in the same direction. For respiratory conditions, specified independently by two doctors as being the medical condition most likely to relate to cold and damp housing, the O.R. was 3.7 ($p=0.047$). For cardiac–related conditions the OR was 0.65 ($p=0.52$) and for cancer-related admissions, the control condition, selected because there was no plausible causal link to the quality of housing, the O.R. was 0.85 ($p=0.51$).

For the sample as a whole, there was also a significant difference between the intervention and control group in terms of the numbers of days of hospitalisation for respiratory conditions when counted by admission, not by persons. In the intervention group there were 3 day-admissions, 6 inpatient admissions for a total of 35 hospital nights. In the control group, there were no day admissions, but 14 inpatient admissions for a total of 81 hospital nights.

Mycotoxic and allergenic moulds were isolated in all household dust samples. While the number of colonies was not affected by the intervention, the occupants of the insulated houses reported a significantly reduced mouldly smell. While endotoxin counts were high, they also were not affected by intervention.

Discussion

This study of the impact of retrofitting older houses has taken a population approach to improving the environmental determinants of health. The intervention of retrofitting older homes with insulation led to a significant increase in the indoor temperature and a significant decrease in relative humidity. The occupants' exposure to particularly low temperatures below 10oC showed marked differences. As a result, the amount householders spent on heating their houses was significantly reduced and contributed to increasing their disposable income.

The results of this study have shown that a relatively modest investment in insulation per house of around Euro 950 has led to significant improvements in the population's health: a trend of fewer hospitalisations for respiratory conditions and a lower risk of children having time off school and adults in the workforce having sick days off work. People in the intervention group reported significant improvements in their general health, their respiratory symptoms and their sense of comfort and well-being. However, the intervention had no impact on the level of mould or endotoxins in the households (results not reported here).

The study was an experimental study, but was of necessity only single-blinded. The initial randomisation was carried out by an independent biostatistician, and the researchers were blinded to the allocation of households during the data analysis. The independent building inspectors and the interviewers were not told which households were in the intervention group, but as it was not practical to install the insulation without the knowledge of the householders, and in rental properties the landlord, it is likely that during the follow-up interviews some householders may have given some unprompted feedback about the intervention to the interviewers, who were instructed not to inquire what group the households were in. However, the possible bias introduced by the study being only single-blinded was minimised by the collection of external data gathered from independent sources such as power companies, general practitioners and the National Health Information System.

Does this study provide evidence for an effective environmental intervention to reduce the inequalities in the determinants of health(Graham 2001)? By targeting older houses and households containing people with chronic respiratory conditions, we identified a group of people who were more likely to be living in areas that are socio-economically deprived and whose homes were insulated and therefore more likely to be colder and damper than newer homes. The population was disproportionately Maori and Pacific people who suffer from higher morbidity and premature mortality than the European population (Howden-Chapman and Tobias 2000; Ajwani, Blakely et al. 2003). However, some economists have argued that it is the occupants' low household incomes rather than the sub-standard housing they live in that is the fundamental underlying problem(Le Grand, Propper et al. 1984). Nonetheless, there is likely to be more public support for policy makers to upgrade low-income housing than there is to redistribute income, so that housing improvements such as retrofitting older houses are more likely to be implemented. Moreover, when regulatory standards have been historically low, for example the Building Code has not requiring insulation, there is unlikely to be an adequate supply of insulated housing so that a third of houses are uninsulated in New Zealand. Many occupants, particularly older people vulnerable to cold, do not or cannot get up into their attics, or under their house, to see whether their house is insulated, so they have imperfect information when making their housing choices, which for most home-owners is infrequent.

Evidence from a major British cohort study has shown that the effects of poor housing conditions are cumulative over the life course (Marsh, Gordon et al. 1999). Beyond the direct connection between poor health in childhood and health in adulthood, poor health in childhood could affect adult well-being through its impact on educational attainment. This possibility was tested in a Canadian cohort of children where respiratory conditions, and in particular asthma, where the most common chronic health problem (Currie and Stabile 2002). Thus, housing interventions can have significant health multiplier effects.

A cost-benefit analysis of this intervention trial (not reported in detail here), indicates the tangible health and energy benefits outweighed the costs by a factor approaching two, when calculated in present value terms at a five percent real discount value over 30 years.

This is a conservative estimate, as the potential avoidable mortality from cold homes, which has been calculated in a British study to be a two percent increase for every degree below 18oC, has not been taken into account (Wilkinson et al, 2003), nor have the inevitable rises in fuel prices. Nonetheless, the cost benefit analysis and provisional results from this study lead to an increased budget allocation for retrofit insulations from several ministries and has led to a number of primary health organisations and district health boards working with local councils to retrofit older houses.

Conclusion

Housing is an important determinant of health and well-being. Retrofitting older houses with insulation is a cost-effective population intervention for improving health and well-being and reducing fuel poverty and has the added advantage of having a high degree of community, policy and political acceptance.

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