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ORIGINAL ARTICLE

Improving health and energy efficiency through community-based housing interventions

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Abstract

Objectives Houses designed for one climate and cultural group may not be appropriate for other places and people. Our aim is to find cost-effective ways to improve the characteristics of older homes, ill-fitted for New Zealand's climate, in order to improve the occupants' health.

Method We have carried out two community randomised trials, in partnership with local communities, which have focused on retrofitted insulation and more effective heating and have two other studies under way, one which focuses on electricity vouchers and the other on housing hazard remediation.

Results The Housing, Insulation and Health Study showed that insulating 1,350 houses, built before insulation was required, improved the occupants' health and well being as well as household energy efficiency. In the Housing, Heating and Health Study we investigated the impact of installing more effective heating in insulated houses for 409 households, where there was a child with doctor-diagnosed asthma. Again, the study showed significant results in the intervention group; indoor temperatures increased and levels of NO_2 were halved. Children reported less poor health, lower levels of asthma symptoms and sleep disturbances by wheeze and dry cough. Children also had fewer days off school.

Conclusion Improving the energy efficiency of older housing leads to health improvements and energy efficiency improvements. Multidisciplinary studies of housing interventions can create compelling evidence to support policies for sustainable housing developments which improve health.

Keywords Community trials · Health · Home heating · Energy efficiency · Sustainability

Introduction

About a thousand years ago, the first wave of migrants to Aotearoa/New Zealand were Māori who, coming from Pacific islands closer to the equator, had to make major adaptations to the design of tropical housing, which had open sides for ventilation. Māori used local materials for their dwellings (*whare*), wood for the main structures and bull-rushes (*raupo*) and earth walls for insulation to protect themselves from lower temperatures, wind and rain which they found at latitudes between 35 and 45 south.

In the nineteenth century, most of the colonial settlers came from Scotland and Ireland, bringing very different cultural attitudes about most things including the Torrens system of individual land title. Despite the Treaty of Waitangi that was signed between the Crown and tribal leaders, which pledged to protect Māori sovereignty and natural resources and grant full rights of citizenship, land wars ensued. The wars resulted in huge confiscations of Māori communal land. Māori housing, which European settlers had originally admired for its solidity, grandeur and elaborate carvings, deteriorated markedly as the population was depleted by land confiscations and diseases.

This paper belongs to the special issue "Housing for health promotion".

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It is no coincidence then, that New Zealand, Scotland and Ireland hold the dubious record of having temperate climates conducive to human health, but more excess winter mortality than countries with colder climates, such as Sweden, Canada and Russia (Healy 2004; Davie et al. 2007). Nor is it a coincidence that within New Zealand, Māori are over represented in low-income households in areas with poorer quality housing.

New Zealand houses are considerably colder than the World Health Organization recommendation that houses should be maintained between 18 and 21°C, based on health impacts being evident below 16°C (World Health Organisation 1987). New Zealand houses are heated less than in any other country in the OECD (Schipper et al. 2001); usually only the living room is heated to above 18°C.

New Zealand housing, which is largely wooden and stand-alone, is of relatively poor quality. With rising fuel prices in a deregulated electricity market, the increasing cost of heating such housing falls unequally on low-income households, which are more likely to be renting (Howden-Chapman et al. 2007). Despite a lack of policy attention, there is a growing problem of fuel poverty (Lloyd 2006).

Housing and health research

The link between housing and health is well known, but as Lawrence has repeatedly pointed out, the *nature* of the complex relationship is less clear (Lawrence 1993, 1995, 2005). Relatively few intervention studies have rigorously examined the health effects of housing improvements (Thomson et al. 2001). Indeed, Krieger et al. (2002) have highlighted the difficulty of implementing community-based housing intervention trials. However, since several studies have indicated that this is a fruitful approach (Sommerville et al. 2002) and a major systematic review has recently highlighted that considerable progress has been made in the accrual of robust evidence (Thompson et al. 2009). This integrated policy planning for housing and energy policy has many advantages for low-income households, who are more vulnerable to social and economic deprivation (Herandez and Bird 2010).

To help establish robust causation about the nature of the relationship between housing and health, we have completed two community trials, the Housing, Insulation and Health Study and the Housing, Heating and Health Study. We are currently conducting two further community trials, the Warm Homes for Elderly New Zealanders and the Housing Injury Prevention Project. Several of these studies had concurrent qualitative studies to increase our understanding of the mechanisms. In this paper, we discuss the available results from the first two of four trials and the implications for policy.

Methods

For over a decade *He Kainga Oranga*/Housing and Health Research Programme, which draws on researchers from a variety of disciplines (social scientists, public health specialists, economists, engineers, physicists and mycologists) has carried out research in partnership with local communities. Strong community partnerships are an essential building-block for improving housing sustainability (Israel et al. 1998) and have led to participant retention rates of over 80% in our studies.

In order to establish robust causal conclusions we have conducted a series of community single-blinded trials, where the researchers have been blinded to the assignment of participants to intervention or control groups, but it has not been possible to blind the participants to whether they are in the treatment or control groups. Possible placebo effects have been controlled for in ANCOVA analyses.

With an aim of our work is to reduce inequalities in the environmental determinants of health inequalities (Signal et al. 2007), and ethnic inequalities in housing conditions. For this reason, the indigenous Māori, who form 15% of the general population, have been deliberately oversampled in our studies. Following the Treaty of Waitangi legislation, which enshrines Māori tribal rights in legislation and informs public health practice in New Zealand (Rada et al. 1999) we also took care to ensure participation of the Māori community organisations in the planning and design of our studies.

Results

The Housing, Insulation and Health Study

This study built on a pre-existing policy being implemented by a government energy efficiency agency designed to have a single outcome—reducing electricity consumption. We had previously identified that older people's health suffered from being in cold houses (Howden-Chapman et al. 1999) and worked with local communities and the energy agency to carry out a randomised community trial to look at the combined health and energy efficiency effect of retrofitted insulation to bring older houses up to the current Building Code (Howden-Chapman et al. 2005).

Study design and methods (Howden-Chapman et al. 2005) and results have been published previously (Howden-Chapman et al. 2007), but briefly presented here. In seven communities in New Zealand, community health organisations identified 1,350 households, in which there was at least one occupant with a chronic respiratory condition, who agreed to participate in the Housing, Insulation and Health Study. These households contained 4,407 people, who were monitored over two successive winters (June–September 2000 and 2001). The intervention group received the retrofitted insulation *before* the first winter and for equity reasons, the control group houses were insulated *after* the second winter, once the follow-up data collection was completed. Self-report measures as well as independent measures of outcome for the winter months were obtained wherever possible, including: general practitioner visits (collected via electronic linkage to general practice databases and hospitalisation records using the patient identifier number); and power bills obtained from the electricity and gas companies (using the customer reference number).

In houses that were in the intervention group, there was a small increase in bedroom temperatures during the winter (0.5°C) as well as decreased relative humidity (−2.3%), even though energy consumption in insulated houses was only 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 of participants in the insulated homes having *fair* or *poor* self-rated health (adjusted odds ratio 0.50, 95% confidence interval 0.38–0.68), self reports of wheezing in the past 3 months (0.57, 0.47–0.70), self reports of children taking a day off school (0.49, 0.31–0.80), and self reports of adults taking a day off work (0.62, 0.46–0.83). Visits to general practitioners were less often reported by occupants of insulated homes (0.73, 0.62–0.87). Hospital admissions for respiratory conditions were also reduced (0.53, 0.22–1.29), but this reduction was not statistically significant ($p = 0.16$) (Howden-Chapman et al. 2007).

This study showed that retrofitting insulation into existing houses, where there were occupants with chronic respiratory problems, improved health, increased well being, reduced hospitalisation and lowered energy consumption (Howden-Chapman et al. 2005, 2007, as well as reducing residential mobility Moreover, the economic benefits of retrofitting insulation in New Zealand houses are estimated to exceed the costs, with a benefit–cost ratio of almost 2:1 (Chapman et al. 2007).

Despite the positive results of the temperature increase and drop in relative humidity in the Housing, Insulation and Health Study, the retrofitted insulation still did not bring the indoor temperature up to the WHO recommended levels. In our next study, we decided to supplement this passive measure with the addition of effective heating and to concentrate on vulnerable children.

The Housing, Heating and Health Study

Our second community-based trial, the Housing, *Heating* and Health Study, was designed to address a particularly prevalent health problem in New Zealand, as well as addressing issues of energy efficiency and sustainability. For largely unknown reasons, a third of New Zealand children have asthma symptoms, still one of the highest recorded rates in the world (Asher et al. 2006). Asthma is the second most common cause for hospital admission and in 2005, 1053 children were hospitalised for asthma, with an average length of stay of 1.4 days (Asher and Byrnes 2006). Apart from the extreme events leading to hospitalisation, children with asthma are likely to have more days off school than other children, with adverse effects on their education (Taras and Potts-Datema 2005), even apart from their caregivers having to lose significant time off work (Laforest et al. 2004).

We do know that asthma symptoms can be triggered by aspects of the indoor environment, such as cold, damp, mould and pollutants, as well as combustion by-products from heating (Strachan 2000). Many aspects of New Zealand housing and the indoor environment are poorly regulated. For example, a third of New Zealand households own unflued gas heaters (Statistics New Zealand 2007) that are legal in New Zealand, unlike many jurisdictions. This is despite such heaters emitting nitrogen dioxide (NO_2) among other gases and particulates that inflame the lining of the lungs and can increase the severity of respiratory viral infections (Chauhan et al. 2003).

In the Housing, Heating and Health Study, we built on what we had learnt from our earlier study to overcome the undoubted difficulties of carrying out environmentally based community trials (Matheson et al. 2005). We wanted to find out whether, in addition to retrofitting insulation, installing non-polluting, more effective home heating reduced children's asthma symptoms over the winter period. We also wanted to know whether we could increase households' energy efficiency and thereby lower fuel poverty.

To answer these questions we carried out a randomised community trial of 409 households in five communities. The inclusion criteria were: a 6- to 12-year-old child, with doctor-diagnosed asthma, living in a household where the main form of heating was a plug-in electric heater or an unflued gas heater. The study design and methods have also been previously published (Howden-Chapman et al. 2008), but summarised here.

Building on the results of our Insulation Study, where necessary, houses in both the intervention and control groups were all insulated to the NZ Building Code standard before baseline measurements were taken (Howden-Chapman et al. 2005). Again, with the help of our community partners in four cities, we carried out community meetings to discuss the pros and cons of the three replacement heater types available for installation (heat pumps, wood pellet burners or flued gas heaters). We placed a full report on heater types on our website (www.healthyhousing.org.nz).

We asked all homeowners to choose from a range of heaters that produced no indoor or outdoor emissions, to replace their existing 2 kW electric heaters or portable unflued gas heaters. We encouraged landlords to consider their tenants' heater preferences. After a public tender to select the heater models, low emission heaters capable of generating at least 6 kW thermal output were installed by contractors in the intervention group before the beginning of the follow-up winter period 2006. All control households received the heater of their choice once the follow-up measurements were completed.

We selected community partners in five local area-based, primary health organisations (three with close ties to Māori) and asthma societies. These partners employed community coordinators, who approached suitable families to ask them to participate. We also publicised the study in radio interviews and invited families in these areas to take part. We asked households to collect a broad range of data, which were again supplemented by independent hourly measures of temperature and relative humidity, as well as measures of NO_2. The children kept daily diaries with twice-daily recordings of their lung function (PEFR and FEV_1) records as well as their respiratory symptoms and any medication they took. Again, independent measures of outcome for the winter months were obtained and this time also included records of school attendance measured in half-days.

Results from the Heating Study showed that indoor temperatures increased by 1.1°C in the living room ($t = 5.63$; $p < 0.001$) and 0.53°C in the bedroom of the child with asthma ($t = 2.87$; $p = 0.002$). Exposure to low temperatures (hours per day, weighted by number of degrees <10°C) was about 50% less in the intervention compared to the control group in both the living room ($t = 4.67$; $p < 0.001$) and the child's bedroom ($t = 4.94$; $p < 0.001$). The levels of NO_2 indoors reduced by half. Parents of the children with asthma in the intervention group reported less poor health (adjusted O.R. 0.44; CI 0.28–0.70, $p < 0.001$) and subsequently lower levels of asthma symptoms than children in the control group. Sleep disturbance by wheeze (aO.R. O.51; CI 0.32–0.81, $p = 0.005$) and dry cough (aO.R. 0.50; CI 0.31–0.82, $p = 0.01$) were also reduced. Daily diaries kept by the parents of their children's asthma showed reduced lower respiratory symptoms ($p = 0.01$), less coughing at night ($p = 0.003$) and reliever use in the morning ($p = 0.05$). Independent school records showed the children in the intervention group had 1.8 days less of school during the 50 days of the winter term (CI 0.11–3.13; $p = 0.04$) (Free et al. 2009); fewer visits to general practitioners (0.13, CI 0.05–0.20, $p = 0.005$); and to pharmacists (0.06, CI 0.03–0.07, $p = 0.007$). There was no difference in lung function between the intervention and control group, although the difference in FEV_1 was significant after controlling for NO_2 levels in the home.

The results of the Housing, Heating and Health Study reinforced earlier research indicating that higher indoor temperatures caused by improved heating reduces asthma symptoms (Sommerville et al. 2002) and builds on our own work showing that retrofitting insulation in homes improves health status and respiratory symptoms (Howden-Chapman et al. 2007). After controlling for a wide range of confounding factors our results show a clear, significant impact of less polluting, more effective heating on children's self-reported asthma symptom severity.

Although only half the houses in each group initially had unflued gas heaters, the halving of mean NO_2 in the intervention group suggests a dual beneficial effect of the new heaters: raising the indoor temperature in more rooms and reducing NO_2 levels. Analyses indicate that, when controlling for NO_2 levels, installation of new heaters led to significant increases in FEV_1 measures of lung function in the children with asthma (Gillespie-Bennett et al. 2011).

The capital cost of the study intervention was again not borne by the participants and was relatively high for a population-based intervention (NZ $3,000, about €1,800) compared to the cost of the portable heater at NZ $100 (€60). Moreover, two-thirds of the houses in the study were initially uninsulated (insulation cost NZ $2,500, about €1,500). Nonetheless, the results suggest that improving both the type and extent of heating in the homes of children with asthma has a number of cost beneficial effects (Preval et al. 2010). Houses in this study included all forms of tenure, so apportioning the relative benefits to the participants and to the public good is an important policy issue. Scotland has made the policy decision that installing central heating in all social and pensioner housing, regardless of tenure, is largely a public good and will pay more health dividends than focusing on clinical waiting lists, as in England (Walker et al. 2006). All the replacement heaters used in the present study were non-polluting and more environmentally sustainable than the less effective heaters they replaced, an important benefit in terms of climate change (Wilkinson et al. 2007).

Discussion

Community trials carried out in partnership with local communities are complex, time-consuming and expensive, but they are very rewarding and can have major impacts on shaping healthy public policy. Our multidisciplinary housing interventions had a significant impact on a range of government policies designed to address both health and the broader sustainability issues of environmental and economic, as well as social well being.

For feasibility reasons and to increase the impact of our studies, we successfully sought both public and private sector funding. In both the Housing, Insulation and Health Study and the Housing, Heating and Health Study, we employed a partnership model that entailed working with 18 different community agencies and private organisations and we were able to maintain a high level of support throughout. These studies also demonstrated the success of a partnership research design in facilitating the participation of Māori community organisations and Māori respondents (Matheson et al. 2005).

Our two current community trials have also been set up in partnership with local organisations and directly address the nexus between housing, energy and health. The Warm Housing for Elderly New Zealanders Study is enrolling around 500 people over 55 years of age with chronic obstructive pulmonary disease. After making sure their houses are insulated, participants are randomised, with half receiving NZ $500 (about €300) electricity vouchers. The aim of the study is to encourage people with chronic respiratory diseases to keep their homes warm during winter, to reduce the risk of further exacerbations.

The Housing Injury Prevention Intervention has enrolled 900 households in a community trial of the health impacts of remediating common hazards at a cost of between NZ $500 and $1000 (about €300 to €600) per household. We have previously shown that housing hazards increase the risk of injuries (Keall et al. 2008). A preliminary cost benefit study of the pilot of this intervention study showed the benefits of home remediation exceeded the costs by nine to one (Keall et al. 2011).

Our community trials have been designed to address the upstream social determinants of health and reduce inequalities in health. There are structural solutions to being cold and three of the four trials directly address the energy inefficiency of the housing stock, one of the main contributors to fuel poverty (Howden-Chapman et al. 2009). Overall, structural solutions are more effective than individual action and are likely to reduce socio-economic inequalities in the determinants of health (Graham 2007). Our research has shown that it is not just premature deaths that are related to housing problems, but also health problems and, moreover it is possible to address these problems at a population level through housing programmes, which have demonstrated co-benefits in reducing energy insecurity and carbon emissions.

In conclusion, our multidisciplinary housing studies have shown that working in partnership with communities and government agencies to retrofit insulation and install more effective heating has led to significant improvements in health and well being. Such interventions are not only cost-effective, but also can have an important impact on housing, health and energy policy, nationally and internationally.

The positive results of our two completed community trials have been widely reported in the local media. We also filmed both studies and produced short DVDs (available on our website www.healthyhousing.org.nz). The favourable benefit–cost ratios, particularly for insulation, made a major contribution to national policy initiatives. The combined benefits, including the emission of less carbon, which yields a fiscal benefit under the Kyoto Protocol, were influential in the negotiations between the Green Party and the Labour Government to allocate NZ $1 billion (about €600 million) to a national housing retrofit scheme. After the 2008 election, the incoming National Government, which took power during the current economic recession, allocated NZ $323 million (about €194 million) to a similar scheme on the basis that it would create employment for builders as well as improving health outcomes.

At a national level, our studies have been referred to in housing (Housing New Zealand Corporation 2006), energy (Ministry of Economic Development 2007) and health policy strategic documents as providing the necessary evidence for cross-departmental investments in the housing area. Internationally, they have been cited as examples of best practice for the way in which they are carried out and the rigour of the studies (Thomson et al. 2009). The studies have being included in the World Health Organization's report on Health in the Green Economy (WHO 2011) and the development of the World Health Organization global guidelines on Housing and Health.

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