Home modifications to prevent home fall injuries in houses with Māori occupants (MHIPI): a randomised controlled trial

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Summary

Background As with many Indigenous populations internationally, Māori in New Zealand suffer health inequity. We aimed to assess the rate of fall injuries at home with and without home modifications in houses with Māori occupants.

Methods We did a single-blind randomised controlled trial in the Wellington and Taranaki regions of New Zealand and enrolled owner-occupied households with at least one Māori occupant. Only households who stated they intended to live at that address for the subsequent 3 years were eligible for participation. We randomly assigned (1:1) households to either the intervention group, who received home modifications (handrails for outside steps and internal stairs, grab rails for bathrooms, outside lighting, repairs to window catches, high-visibility and slip-resistant edging for outside steps, fixing of lifted edges of carpets and mats, non-slip bath mats, and slip-resistant surfacing for outside areas such as decks) immediately, or the control group, who received the modifications 3 years later. Data on home injuries were obtained from the Accident Compensation Corporation and coded by study team members, who were masked to study group allocation. The primary outcome was the rate of medically treated fall injuries at home per household per year, analysed according to intention to treat. This Māori Home Injury Prevention Intervention (MHIPI) trial is now completed, and is registered with the Australian New Zealand Clinical Trials Registry, ACTRN12613000148774.

Findings Between Sept 3, 2013, and Oct 1, 2014, 824 households were assessed for eligibility and 254 were enrolled, of which 126 (50%) were assigned to the intervention group and 128 (50%) were assigned to the control group. After adjustment for previous falls and geographical region, there was an estimated 31% reduction in the rate of fall injuries at home per year exposed to the intervention compared with households in the control group (adjusted relative rate 0·69 [95% CI 0·47–1·00]).

Interpretation Low-cost home modifications and repairs can be an effective means to reduce injury disparities. The high prevalence of modifiable safety issues in Māori homes merits considerable policy and community effort.

Funding Health Research Council of New Zealand.

Lancet Public Health 2021; 6: e631–40

Published Online August 6, 2021 https://doi.org/10.1016/S2468-2667(21)00135-3

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Introduction

Fall injuries globally were responsible for 1·4% of disability-adjusted life-years (DALYs) due to disease and injury in 2017. In terms of age-standardised DALYs in 2017, falls as a cause of health loss were ranked as the 18th most common cause globally, higher than chronic kidney disease, Alzheimer's disease and other dementias, and asthma.[1] Compared with other injury types, falls were ranked third, following road injury and self-harm.[2] High-income countries, which commonly have growing proportions of older people (age >65 years), can expect corresponding increases in fall injuries, which already place considerable burden on hospitals and society generally.[3]

In Aotearoa (New Zealand), falls resulted in 567 deaths and accounted for 4·6% of total DALYs in 2017, and were by far the most important cause of injury-related health loss.[4] Between 2014 and 2016, there were an average of 544 unintentional deaths due to falls per year.[5] Over the period 2014–18, there were more than 24000 hospital discharges per year for unintentional fall injuries[5] and for the period 2011–18, there were an average of 658000 falls per year requiring some form of medical treatment, more than half of which occurred at home (if the setting was defined).[6]

Given the substantial health burden of falls and their preventability, it is surprising that more attention is not devoted to modifying the built environment as a means of preventing falls.[2] As the home is a common setting for falls, the home environment is a potential focus of prevention efforts, such as the installation of safety features or the removal of fall hazards. However, studies examining the safety benefits of home modification are rare. A 2012 meta-analysis of randomised controlled trials studying the effects of home safety assessments with subsequent modification showed a reduction in the rate of falls for older people living in the community compared with controls in unmodified homes (relative rate [RR] 0·81 [95% CI 0·68–0·97]; six trials; 4208 participants).[7] A subsequent meta-analysis in 2017 did not identify any

Research in context

Evidence before this study

We searched PubMed for publications from the past decade to April 3, 2021, in any language, using the search terms "randomised" AND "home" AND "injury" AND "modification" in any field. We also viewed all papers in Google Scholar that cited key systematic reviews and published randomised controlled trials regarding home modification to prevent injury.

A 2012 Cochrane review found that home safety assessment and modification interventions in the homes of older people (age >65 years) living in the community were effective in reducing the rate and risk of falls. There was greater benefit when the intervention was tailored to the individual. The people who had the most benefit from the interventions were older people with a history of falls. A subsequent review in 2017 found no further home-modification randomised controlled trials that focused on falls among older people. The New Zealand Home Injury Prevention Intervention (HIPI) randomised controlled trial evaluated the safety benefit of home modification for the general population and found a 26% reduction in the rate of fall injuries at home per year with home modification compared with a control group (relative rate 0·74 [95% CI 0·58–0·94]) and a 39% reduction in injuries specific to the home-modification intervention (0·61 [0·41–0·91]).

Added value of this study

Our study shows the potential for home modification to address inequities in injury rates for Māori, New Zealand's Indigenous population, who are more likely than non-Māori to live in rented accommodation and in older homes. The 31% reduction in home fall injury rates and 40% reduction in injuries specific to the intervention were significant. The analysis suggests the home modification intervention is highly cost-effective for Māori homes as each fall injury was prevented at a relatively low cost (of around NZ$575, or approximately £300).

Implications of all the available evidence

WHO has highlighted housing conditions as an important mechanism whereby health and safety inequities arise from social and environmental inequality. Modification of housing is an effective means to reduce fall injury rates and could reduce inequities in injury rates for Indigenous populations, particularly when these inequities arise from poorer housing conditions.

further randomised controlled trials involving home modification to prevent falls in older people.[8] A New Zealand Home Injury Prevention Intervention (HIPI) randomised controlled trial[9] studied the safety benefits of home modification for all age groups, not just older people, and found a reduction in home fall injury rates of 26% (95% CI 6–42) for those in modified homes compared with those in unmodified homes, although the study was not powered to analyse specific groups. A subsequent economic analysis found a reduction in the costs (for medical treatment and loss of income) of home fall injuries of 33% (95% CI 5–49) due to the home modifications.[10] The social benefits of prevention of injuries were estimated to be at least six times the costs of the intervention.[10]

Indigenous populations experience poorer health and worse mortality than non-Indigenous people even in high-income countries, such as New Zealand.[11] There are consistent and wide-ranging health inequities between Māori, the Indigenous people of New Zealand, and non-Māori.[12] New Zealand has a constitutional obligation to address such inequities, as initially expressed in an 1840 agreement between the colonising English and Māori, Te Tiriti O Waitangi (The Treaty of Waitangi). Patterns of disparity are found in injury prevalence and severity.[13] In terms of DALYs, Māori experience twice the age-standardised rate of injury-related health loss compared with non-Māori, with elevated rates of all external causes of injury, including falls.[13] Two factors that are likely to contribute to greater injury burden for Māori are poorer home environments, leading to higher injury rates, and lower levels of access to health care following injury,[14] leading to worse long-term outcomes. Home ownership among Māori is half as common as among New Zealand Europeans;[15,16] and compared with owner-occupied housing, rental housing on average presents a substantially less safe environment in terms of injury hazards and safety features.[17] Māori whānau (families) are often large and numbers of inhabitants are higher in Māori homes than in non-Māori homes—about 20% of Māori houses are crowded compared with 4% of houses occupied by New Zealand Europeans according to the Canadian National Occupancy Standard.[18]

We aimed to assess whether a package of home modifications could reduce the rate of medically treated fall injuries at home per household per year in houses with Māori occupants. The protocol for applying the package of modifications was designed to be suited to a large-scale roll-out, similar to that of a successful scheme to retrofit insulation in New Zealand homes.[19,20]

Methods

Study design and participants

We did a single-blind randomised controlled trial and included households with Māori occupants in the Wellington and Taranaki regions of New Zealand. The Māori Home Injury Prevention Intervention (MHIPI) study design has been described in detail previously.[21] Because recruitment took longer than expected, we studied fall injuries over an average period of 2·3 years per household rather than the intended 3 years. The design of the trial was similar to the HIPI trial,[9] but with some refinements in implementation based on our experience with the previous trial.[22] Such refinements to the home modifications included using more durable solar lighting, edgings for steps that spanned the whole edge, and grab rails in bathrooms that were permanently fixed to walls (the HIPI trial used some grab rails that were attached via suction cups, which had a high failure rate).[22]

Participant households were recruited by two community trusts involved in home improvement schemes, WISE Better Homes in Taranaki, and the Sustainability Trust in Wellington. To be eligible for the study, houses needed to have at least one occupant who identified as Māori. Only households who stated they intended to live at that address for the subsequent 3 years were eligible, as the study evaluated safety benefits of home improvements over that period. Only owner-occupied households were eligible, as people renting houses tend to be a very mobile population in New Zealand, which would not suit the aims of the study. Various approaches were used to recruit participants. Some were from lists of people who had recently received government-subsidised home insulation retrofitted to their homes by the community trusts. Others were recruited from networks involving iwi (Māori tribal groups), direct advertising in community newspapers, presentations to community groups and events, as well as personal contacts of staff of the community trusts. Written informed consent to take part in the study was obtained from the households by the community trusts. Ethics approval was provided by the Massey University Human Ethics Committee (references Southern A Application 12/45 and MUHEC 4000022369). The trial protocol has been published previously.[21]

Randomisation and masking

Households were randomly assigned (1:1) to the intervention group or the control group in batches of around 20. This was done in batches to enable the modifications to be carried out while the recruitment process continued. Random numbers were assigned to each household address identification code using Excel and half of each batch (with the highest random numbers) were assigned to the intervention group, who received the home modifications immediately, and the remainder were assigned to the control group, who received the modifications 3 years later. The randomisation process was stratified by region (Taranaki or Wellington) but not by other household characteristics. We could not mask participants to allocation to the intervention group because modifications were made immediately to participants' homes.

We obtained records of home injuries from the Accident Compensation Corporation (ACC), a national no-fault personal injury insurer. The ACC matched participants' addresses to claim files for unintentional home injuries but was unaware of the random study group allocation. As each claim made included the address of the claimant at the time of the claim, there would have been some of the original participants who moved house and were not included in subsequent counts of home injury, and other claimants who were not part of the original study whose injury counts were analysed as within the scope of the study because they became occupants of addresses that were part of the study. Coders employed by the study team coded text descriptions of injuries and were also unaware of study group allocation.

Procedures

Qualified builders (one team in each of the two regions) assessed every house in the intervention group, excluding households that could not be contacted, using a checklist (available from authors) to identify all features of the home that were within the scope of the intervention, based on common injury hazards identified by New Zealand surveys involving inspection of housing conditions.[23] We reviewed all proposed modifications and costs quoted by the builders to ensure that modifications were clearly within the scope of the study and the costs of the modifications were reasonable. On rare occasions, the scale of proposed modifications was reduced to avoid exceeding our budget. Home modifications consisted of: handrails for outside steps and internal stairs, other minor repairs to outside steps, repairs to window catches (to avert falls from windows), grab rails for bathrooms and toilets, adequate outside lighting, high-visibility and slip-resistant edging for outside steps, fixing of lifted edges of carpets and mats, non-slip bath mats, and slip-resistant surfacing for outside surfaces such as decks. Smoke alarms were installed because it was relatively cheap and convenient to do so, but we did not consider this modification relevant to the outcome measure. Households in the control group received no intervention initially, but the majority received modifications 3 years after the intervention group did. A sample of 10% of households in the intervention group were contacted by telephone following the intervention to check that the modifications had been made as expected.

Data on injury claims were supplied by the ACC matching the addresses we supplied with addresses of claimants. Information that could identify the claimants, such as the address, was stripped from the data before the analysis. For these deidentified addresses, ACC provided claims data for unintentional home injuries that occurred in the year preceding the intervention date and for the 2·3 years after that date.

For each of the home injury claims, there was a single line of free text to describe the injury circumstances. Using these text descriptions in conjunction with other fields in the ACC claims data, study coders classified injuries as either falls or injuries specific to the package of modifications.[9] Other fields used for this classification

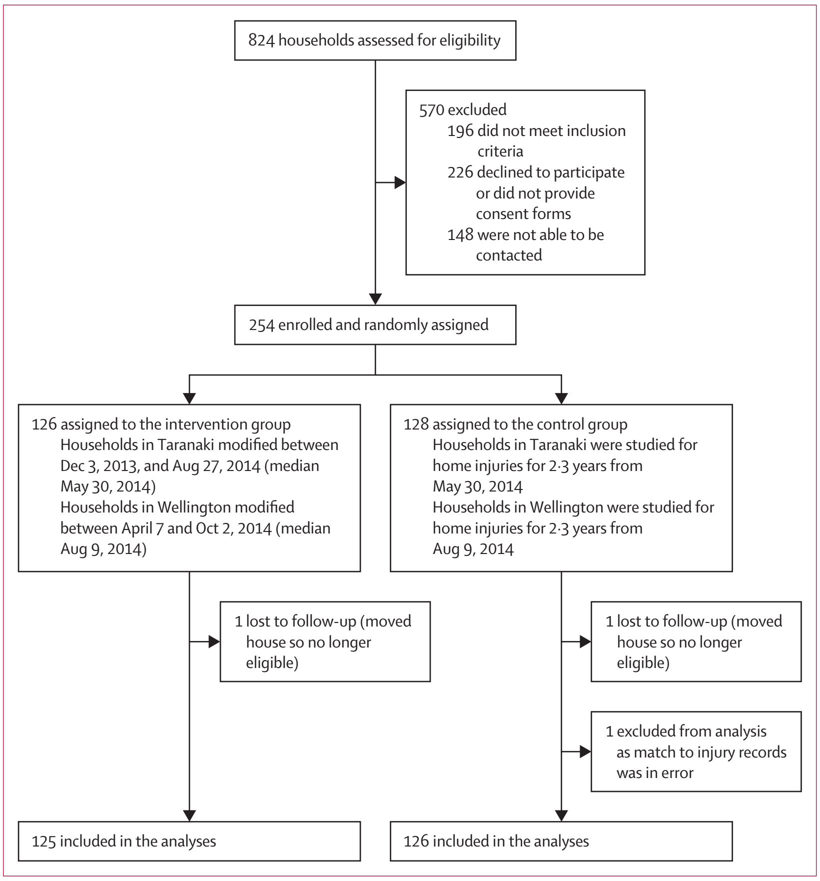

Figure: **Trial profile**

were the activity immediately preceding the injury (eg, running or walking); the so-called cause of injury (eg, tripping or stumbling); any contact with objects, people, or animals (eg, contact with ground or floor); any so-called external agency (eg, stairs or steps); and a general injury diagnosis (eg, contusion). Injuries specific to the intervention were those that occurred in the locations where modifications had been made (mainly steps, stairs, and bathrooms) and excluded those arising from gardening, trips on toys, and children playing, where these details were provided. An example of text describing a specific injury was: "fell out of shower hurting wrist". For a subset of 1200 injuries independently classified by two coders, there was 85% agreement in the classification of injuries as specific and 92% agreement in the classification of falls.

Costs incurred per house for the package of modifications varied according to the configuration and level of maintenance of each house. We recorded actual costs for every modification made, including travel costs, labour, and materials used.

There is a well established and efficient protocol for treatment providers to cover most costs for these treatments via the ACC system. Fault and the activity being undertaken at the time of the injury are not criteria for accepting claims, and around 97% of claims are approved.[24] To assign medically treated home injuries from these claims data to the participating addresses, a match was made by ACC between the claimant's address (as provided on the ACC claim form) and the addresses of participants (as provided by the community trusts recruiting households). It was common for a given participant household address to be matched to two differently specified ACC claim addresses, particularly when the city field of the address can be defined in more than one way (as an administrative district or as a region). One participating household's address was matched to 24 differently specified addresses in the ACC claims database, which was clearly an error, and the household was excluded from the analysis.

Outcomes

The primary outcome was the rate of unintentional falls at home per household per year for which treatment was provided by family doctors, dentists, physiotherapists, osteopaths, or chiropractors according to accepted claims made to ACC. For studies of self-reported falls, the Prevention of Falls Network Europe[25] proposed that falls should be defined as "an unexpected event in which the participants come to rest on the ground, floor, or lower level", involving loss of balance. We used this recommendation to ensure injuries from the ACC claims data were related to a fall event. The home setting was defined to include indoor and outdoor areas of the property. Injuries occurring on streets and footpaths outside the property boundary or in garages for vehicles (which in New Zealand are commonly separate buildings, often with direct access from the street) were excluded.

The secondary outcome was the rate of medically treated specific injuries (injuries that could potentially be prevented by the intervention applied) per household per year. All analyses were done according to intention to treat.

Statistical analysis

We evaluated the safety effect of the intervention using the SAS version 9.4 procedure GENMOD,[26] fitting a Poisson model to injury counts at the household level, with time observed as an offset. In addition to an indicator variable to distinguish households in the intervention groups from the controls, covariates included a count of fall injuries in the 365 days before the start of the trial for the given household, along with a variable to discriminate between participants in Taranaki and those in Wellington.

In the analysis of the HIPI study data done previously, the treatment and control groups were distributed differently according to age, which attenuated unadjusted estimates of the treatment effect. Therefore, we also did a sensitivity analysis of the odds of a home fall injury, where the intervention effect was estimated by comparing odds of home fall injuries with odds of other non-fall home injuries in the intervention group and in the control group, controlling for age group, sex, study area, and injury history. To calculate crude and adjusted odds ratios (ORs), the SAS procedure GENMOD[26] was used with a statement with the repeat function, which fits a generalised estimating equations (GEE) model to adjust SEs for the effects of clustering of injuries within households. Estimates were adjusted according to prespecified levels of covariates.[21]

As households (rather than individuals) were recruited and randomly assigned to treatment and control groups, our power calculation was done at the household level. Using a simplified version of the proposed analysis, we powered the study to detect a reduction of 26% in the proportion of households experiencing at least one injurious fall from a baseline rate of 67% (estimated from the control households in the previous HIPI study). The 26% was the estimated effect of the HIPI study on injury rates per person.[9] To achieve 80% power to detect this change (α=0·05), we estimated that 125 households in each of the intervention and control groups would be sufficient.

We aimed to increase the power of the study by adjusting for possible differences between groups in terms of history of fall injuries (injuries in the past year for the household). As different providers made the modifications in each of the study regions (Wellington and Taranaki), we included a stratum variable in the analysis with the aim of capturing differences in implementation of the intervention. We did not assess the safety of the homes in the control group at baseline, nor did we follow up with these households regarding any safety improvements made over the study period.

The intervention would be expected to have little effect on home injuries not caused by falls. As a prespecified sensitivity analysis, we used the same model with rates of non-fall injuries as the outcome.

To predict the benefits of an intervention on a population of households, our analysis was by intention to treat. However, we also did a post-hoc sensitivity analysis that excluded 22 households in the intervention group where no modifications were made. The same number of control households were also excluded, matched as closely as possible according to geographical region and injuries that occurred in the year before the intervention (total home injuries, falls, and specific injuries).

This trial is registered with the Australian New Zealand Clinical Trials Registry, ACTRN12613000148774.

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Between Sept 3, 2013, and Oct 1, 2014, 824 households were assessed for eligibility: 570 households were excluded (196 did not meet the inclusion criteria, 226 did not provide consent forms, and 148 were not able to be contacted) and 254 were enrolled (figure). 126 (50%) households were randomly assigned to the intervention group and 128 (50%) were randomly assigned to the control group. After randomisation, one household assigned to the treatment group and one in the control group moved house and were excluded from the analysis, as well as one household in the control group that was clearly matched in error to injury claims data. Home modifications were done for the Taranaki intervention group between Dec 3, 2013, and Aug 27, 2014, and for the Wellington intervention group between April 7 and Oct 2, 2014.

	Control group (n=126)	Intervention group (n=125)
Home injuries excluding falls in past year	54 (0·429)	48 (0·384)
Home fall injuries in past year	21 (0·167)	23 (0·184)
Specific injuries in past year	16 (0·127)	16 (0·128)

Data are n (rate per household per year). Past year refers to the 365 days before the intervention date; the intervention date was the date the modifications were made for the intervention group, and the median date interventions were made in intervention group households in that region for the control group. Specific injuries are injuries that could potentially be prevented by the intervention applied.

Table 1: **Baseline characteristics**

Injuries in the intervention group were counted from the actual day the modifications were made. Injuries in control group households in the Taranaki stratum were counted from May 30, 2014, which was the median date of intervention in the intervention group; for the control group households in Wellington, injuries were counted from the corresponding date of Aug 9, 2014. Injuries were then counted for the control group households until the actual date that modifications were made or until the median date of control group modifications for the households where modifications were not made; for households in the intervention group, injuries were counted until the median date that modifications were made in the control group within each region (Feb 9, 2017, for the Taranaki stratum and Aug 22, 2016, for the Wellington stratum). The mean period of observation overall was 851 days (IQR 246).

35 (14%) of 251 households had no matching ACC claims. Of these households, 13 (37%) were in the intervention group. In the analyses, these households were assumed to have made no claims for injuries.

The rates of injuries before the intervention were similar in both groups (table 1). The mean cost of the intervention per house was $460 (NZ$, 2017; about £240). In the intervention group, 13 houses required no modifications except for the installation of smoke alarms; nine houses were not assessed for modification as the participants could not be contacted, or family circumstances (such as sickness or death in the

	Households, n	Mean cost, NZ$ (2017)
Overall	125	464·80
Steps only (handrails, slip-resistant edging, or minor repairs)	11	281·09
Bathroom only (grab rails or non-slip bath mats)	2	150·48
Other setting only (fixes to carpets, provision of lighting, surfacing of decks and porches, or minor repairs to window catches)	16	270·83
Steps and bathroom	3	416·93
Steps and other setting	27	820·61
Bathroom and other setting	3	354·20
Steps, bathroom, and other setting	21	690·57
No modifications needed	13	57·79
Unspecified modifications (data lost by contractor)	20	323·38
Home not assessed for modifications or modifications not done	9	0

Costs are in NZ$ adjusted for inflation to 2017 values, and include travel expenses (ie, time, fuel, and vehicle costs).

Table 2: **Home modification settings and costs in the intervention group**

	Control group		Intervention group	
	n	Rate (SE)	n	Rate (SE)
All injuries excluding falls	189	0·650 (0·047)	158	0·537 (0·043)
Fall injuries overall	65	0·223 (0·028)	47	0·160 (0·023)
Fall injuries by falls history				
No fall injury in past year	41	0·165 (0·026)	32	0·129 (0·023)
Fall injury in past year	24	0·560 (0·114)	15	0·328 (0·085)
Specific injuries overall	42	0·144 (0·017)	25	0·085 (0·017)
Specific injuries by specific injury history				
No specific injury in past year	32	0·124 (0·022)	18	0·069 (0·016)
Specific injury in past year	10	0·313 (0·099)	7	0·202 (0·077)

Shown are the number of injuries occurring in the home between the intervention date and end of follow-up; the intervention date was the date the modifications were made for the intervention group, and the median date interventions were made in intervention group households in that region for the control group. Rates are mean rate per household per year. Specific injuries are injuries that could potentially be prevented by the intervention applied. Falls history was determined at the household level.

Table 3: **Unadjusted outcomes**

household) prevented the assessment and modifications being done; and 20 houses were modified but the contractor lost documentation regarding what in particular was modified, although total costs per modified house are known (table 2).

Of the households who were contacted to check the modifications were done as expected, one person per household was contacted from 11 of 13 households sampled (85% response rate). All 11 households confirmed that the modifications had been made to the home in accordance with the information provided to us by the community trusts, who employed the builders.

The crude rate of medically treated fall injuries per household per year was 0·160 in the intervention group and 0·223 in the control group (RR 0·71 [95% CI 0·49–1·04]; table 3). The crude rate of injuries specific to the intervention per household per year was 0·085 in the intervention group and 0·144 in the control group (0·59 [0·36–0·97]).

After adjustment for household-level differences in injury history as well as for strata (geographical region), a reduction of 31% was estimated in the rate of injuries caused by falls at home per year exposed to the intervention compared with households in the control group (RR 0·69 [95% CI 0·47–1·00]; table 4). For injuries considered to be specific to the intervention, a significant reduction of 40% was estimated per year exposed to the intervention (0·60 [0·36–0·98]).

In the sensitivity analysis where non-fall injuries were used as the outcome, there was no significant effect of the home modification intervention on rate of non-fall injuries compared with the control group (RR 0·88 [95% CI 0·71–1·09]). In the sensitivity analysis that excluded households where no modifications were made, the intervention was associated with a larger estimated reduction in fall injuries of 36% (RR 0·64 [95% CI 0·43–0·96]) and a larger reduction in specific injuries of 43% (0·57 [0·34–0·96]) than in the primary analysis.

See Online for appendix

The adjusted ORs of falls and specific injuries compared with non-fall injuries, controlling for additional characteristics that might affect fall rates, were consistent with the estimated RRs (appendix). Participant age group (p=0·055) and sex (p=0·041) were important in this model, but the inclusion of these factors in the model only marginally changed the estimated intervention effect compared with a simpler model without these factors. When interaction terms were fitted in this model, there was no evidence of a differential treatment effect across age groups in terms of fall injuries. Similarly, other interaction terms between the available factors (appendix) and the intervention indicator term were not significant.

Discussion

For households with Māori occupants, modifying some common fall hazards in the home reduced home fall injuries generally. There was a larger safety effect for more specific injuries that the modifications were more likely to prevent. The home modifications tested appear to be a promising approach to reduce some of the current large inequities in injuries for Māori.[13]

Randomised controlled trials of the safety benefit of home modification to reduce fall injuries are scarce.[7,8] The previous HIPI study, which used the same protocol as this study, was the largest such trial, to our knowledge.

Apart from highlighting a new approach to addressing health inequities, the MHIPI study is important for other reasons. It adds to the small pool of randomised controlled trials addressing this outcome and exposure, and shows that the intervention still has strong safety benefits when implemented by different providers in a different population. However, the safety benefits of the modifications tested can be expected to be smaller in houses that pose fewer fall hazards.

It was not possible to investigate the effectiveness of specific components of the package of modifications, such as stair and step modifications. There are non-random elements of the home environment, which could not be randomised in this trial, that limit such analyses. People select the homes they live in to an extent, and can consider the type and degree of injury hazard the home might pose to them. For example, a person with mobility limitations is unlikely to choose to live in a house with many steps to negotiate. Another randomised controlled trial (the Safety on Steps trial) is currently ongoing, specifically studying the safety of access ways to homes and the effectiveness of handrails and step edgings in preventing injurious falls.

An important consideration in choosing competing measures to reduce health inequities is the benefit of each measure compared with its costs. The costs and benefits of a programme involving home modification will vary according to the nature of the housing modified as well as the number of occupants and their propensity to be injured, which will vary by age and other factors. The previous HIPI intervention was found to be highly cost-beneficial when the benefits included social costs of injuries avoided: a conservative benefit–cost ratio of at least six.[10] Per injury prevented, the HIPI intervention was estimated to cost $830 (NZ$, 2012),[9] which is about $870 (around £450) adjusted for inflation to 2017 values. The same value calculated for the MHIPI study was $575 (around £300), derived by assuming fall injuries occur at the baseline rate as shown in table 1; costs are as in table 2; and 31% of fall injuries are prevented over the 20 years the modifications are expected to last, discounted at 3% per year. There are several factors to explain why the MHIPI intervention's cost per fall injury prevented is only around two-thirds of that for the HIPI intervention. One factor is the larger size of Māori households on average (mean 3·4 residents per dwelling compared with 2·7 for all ethnic groups in New Zealand).[27] This difference means that a given home modification would benefit more occupants on average in Māori households than in non-Māori households, preventing more injuries for a given cost. Another factor is the lower costs of the intervention on average. The same package of modifications was being tested in both studies but the approach had been refined[22] for the MHIPI study to exclude some ineffective safety products. The households in the MHIPI study were mainly based in urban areas and so the modifications involved less travel (and consequent less travel costs) than the HIPI study, which spanned the entire Taranaki region. Lastly, the point estimate of the safety effect of the intervention compared with the control group was slightly larger for the MHIPI study than for the HIPI study, although the 95% CIs overlapped each other.

	Home fall injuries	Specific injuries
Intervention group *vs* control group	0·69 (0·47–1·00)	0·60 (0·36–0·98)
Taranaki region *vs* Wellington region	1·03 (0·71–1·50)	1·05 (0·65–1·70)
Households with one additional injury in the year before intervention	2·24 (1·73–2·91)	2·22 (1·45–3·39)

Data are adjusted relative rate per year exposed to the intervention (95% CI).

Table 4: **Adjusted estimates from models fitted to data after intervention**

Previous modelling[28] of health benefits from home modifications to prevent falls, although focused on a population of older people (aged 65 years or older), was consistent with higher (although not significantly higher) health benefits for older Māori from the perspective of a so-called equity analysis,[29] in which it was assumed that non-Māori morbidity and mortality rates applied to Māori. Targeting the home modification programme to older people with a history of injurious falls was particularly cost-effective.[28] Higher rates of fall injuries among those with previous injurious falls were found in the earlier HIPI study,[9] and found again in the MHIPI study (table 4). The same proportional reduction in fall injuries for a group with a higher baseline rate, such as those with an injurious fall history, will prevent a larger number of injuries.

Although New Zealand is a relatively wealthy, high-income nation, deficiencies in its housing stock have been identified in terms of thermal protection and safety.[30,31] In this context, the economic analysis of the HIPI intervention concluded that there was a compelling economic rationale for a general roll-out of structural home modifications, such as trialled in the MHIPI study, to improve population safety by making the home environment safer for occupants generally, whatever their age or ethnicity.[10] However, older people are more prone to fall injuries (appendix p 1) and interventions tailored to their mobility and balance limitations, such as home modifications delivered by occupational therapists, have been shown to be particularly effective.[7]

An intended secondary outcome for this study was counts of self-reported falls. Although these were also outcomes collected for the HIPI trial, when we matched self-reports to administrative data on claims for medically treated injuries, self-reported falls were problematic for two reasons. First, there were various recall-related issues, such as telescoping of time intervals (eg, where an incident that preceded the timeframe of the study is recalled as occurring more recently), as also found in other studies.[25] Second, some respondents reported minor injuries and others only reported more major injuries. As the ACC data were clearly superior in both respects (with a well defined date and a defined severity threshold, whether or not the injury was sufficiently severe to require medical treatment), we did not ask participants to report details of their injuries.

It was both a strength and a limitation of the study that our outcome measures were derived from matches made to administrative records for medically treated injuries of all severities, as held by the ACC. Because of the well established protocols regarding claims for health-care costs under this scheme, its coverage of medically treated injuries will be virtually complete and uncompromised by degrees of self-reporting by the participants, particularly when they are not masked to intervention status.[32] The accessibility of this scheme is reflected by the high prevalence of injury claims for medical treatment in New Zealand. In 2018, there were 0·43 medically treated injury claims per head of population, of which 39% were fall injuries,[33,34] although part-charges required for some medical treatments can act as a barrier to seeking treatment.[35] However, the claims matching process can be expected to have some errors. Some injured occupants of homes in the study (whether in the intervention or control groups) might not have their home address matched to the lists we provided to ACC, despite considerable care taken to specify addresses correctly. Of 252 households, 35 (14%) had no match to ACC claims over the period studied. Some of these 35 households will have had no medically treated injury over the period; for others, a claim might have been made but the address of the claimant was mis-specified. So the 14% will be an upper limit of the degree of such non-matching that occurred. Of these 35 addresses, 13 (37%) were in the intervention group. Some of the non-matched addresses will have no matching injuries as no occupant had an injury resulting in an ACC claim while at that address. It is difficult to imagine a mechanism whereby the success or otherwise of the matching process could be affected by the randomisation inducing some sort of bias.

The sensitivity analyses to check the consistency of the results when analysed differently highlighted no issues. The adjusted ORs of falls and specific injuries compared with all non-fall injuries, controlling for additional characteristics that might affect fall rates, were consistent with the estimated RRs. There was no evidence that particular groups might benefit disproportionately more than others from the intervention. When a model was fitted with counts of non-fall injuries as the outcome, which should be generally unaffected by the intervention, there was no significant reduction in injury rates per household for the intervention group. The free text provided in the ACC claims data often provides little detail about the mechanism or setting of an injury, which means our coding of specific injuries particularly was open to a degree of interpretation. Although it is unlikely that the coding of injuries by masked coders could affect the RRs of the outcomes of interest, we looked at counts of coded injuries for the intervention group divided by that for the control group according to the different coders. For the subset of 1200 injuries that were independently classified, the discrepancies were small: these RRs differed by 0% for specific injuries and by 2% for falls.

We consider that the package of modifications that constituted the intervention in this study could feasibly be rolled out nationally, subsidised to some degree by central government. An example of such a programme to address deficiencies in housing quality is the Warm Up New Zealand: Heat Smart Programme.[19] This programme was designed to address aspects of the poor thermal performance (insulation and heating) of housing in New Zealand generally. A basis for the high level of government investment in this scheme was provided by the demonstrated health benefits provided by two randomised community trials[36,37] and estimates of cost-effectiveness in terms of health benefits (morbidity and mortality prevented) compared with the costs of the remediations.[38] The cost-effectiveness of the intervention described in our study and the size of the potential injury burden reduction clearly merit a similar effort.

Because households were recruited and randomly assigned, and the house was the environment that was modified (presumably benefiting all occupants), we recruited households with at least one occupant who identified as Māori. As ACC claim forms include a field where claimants self-nominate a single ethnicity category, we could check for differences between this classification among the claims in the intervention and control groups. Of all the injury claims made during the study period, including the year before the intervention started, 48% of claims in the control group and 50% in the treatment group were for Māori.

WHO has highlighted housing conditions as part of an important mechanism whereby health and safety inequities arise from social and environmental inequality.[39] Our study confirms that houses occupied by Māori can be made significantly safer by applying a package of safety modifications. This intervention is therefore well suited to addressing health inequity arising from poorer safety of Māori homes. Our analysis of the intervention tested has shown the relatively low cost of preventing each fall injury and has shown sustained safety benefits across various providers of the intervention. The intervention tested would be likely to produce even greater safety benefits if applied to rental housing in New Zealand, which is on average a less safe environment than owner-occupied housing as included in this study.[17] We focused on owner-occupied housing for two main reasons. First, occupants of rental housing are more mobile,[40] so injury rates might be more variable across time within a given rental house just because the occupants change more frequently, reducing the power of the study to detect a safety benefit. Second, the owner of the house needed to consent for the modifications made. Consent for modifications is much easier to obtain when the owner is the occupier than when the owner is the landlord, as was found in a scheme retrofitting insulation to homes in New Zealand.[19]

Contributors

MDK, CC, NP, MGB, and PH-C contributed to the study conceptualisation and methods. MDK did the formal analysis. MDK wrote and prepared the first draft of the manuscript. NP, PH-C, MW, HT, and CC reviewed and revised the manuscript. CC, PH-C, and MDK acquired the funding. MDK and NP accessed and verified the data. All authors read and approved the final version of the manuscript. All authors had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Declaration of interests

We declare no competing interests.

Data sharing

Individual participant data for this study will not be made available as these data belong to a third party (ACC).

Acknowledgments

We thank the trial participants, and Anaru Marshall (WISE Better Homes, Taranaki) and Philip Squire (Sustainability Trust, Wellington) for managing the recruitment of participants and the assessment and modification of homes. Thanks also to Zhang Wei, Angela Coffey, Caroline Fyfe, and Brodie Fraser (Wellington, New Zealand) for data entry, data management, and coding. We also acknowledge the support of the ACC, who provided matched anonymised data. The MHIPI study was funded by the Health Research Council of New Zealand (HRCNZ). The views expressed in this report are those of the authors and do not necessarily represent those of the HRCNZ or ACC.

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