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Home modifications to reduce injuries from falls in the Home Injury Prevention Intervention (HIPI) study: a cluster-randomised controlled trial

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Summary

Background Despite the considerable injury burden attributable to falls at home among the general population, few effective safety interventions have been identified. We tested the safety benefits of home modifications, including handrails for outside steps and internal stairs, grab rails for bathrooms, outside lighting, edging for outside steps, and slip-resistant surfacing for outside areas such as decks and porches.

Methods We did a single-blind, cluster-randomised controlled trial of households from the Taranaki region of New Zealand. To be eligible, participants had to live in an owner-occupied dwelling constructed before 1980 and at least one member of every household had to be in receipt of state benefits or subsidies. We randomly assigned households by electronic coin toss to either immediate home modifications (treatment group) or a 3-year wait before modifications (control group). Household members in the treatment group could not be masked to their assigned status because modifications were made to their homes. The primary outcome was the rate of falls at home per person per year that needed medical treatment, which we derived from administrative data for insurance claims. Coders who were unaware of the random allocation analysed text descriptions of injuries and coded injuries as all falls and injuries most likely to be affected by the home modifications tested. To account for clustering at the household level, we analysed all injuries from falls at home per person-year with a negative binomial generalised linear model with generalised estimating equations. Analysis was by intention to treat. This trial is registered with the Australian New Zealand Clinical Trials Registry, number ACTRN12609000779279.

Findings Of 842 households recruited, 436 (n=950 individual occupants) were randomly assigned to the treatment group and 406 (n=898 occupants) were allocated to the control group. After a median observation period of 1148 days (IQR 1085–1263), the crude rate of fall injuries per person per year was 0.061 in the treatment group and 0.072 in the control group (relative rate 0.86, 95% CI 0.66–1.12). The crude rate of injuries specific to the intervention per person per year was 0.018 in the treatment group and 0.028 in the control group (0.66, 0.43–1.00). A 26% reduction in the rate of injuries caused by falls at home per year exposed to the intervention was estimated in people allocated to the treatment group compared with those assigned to the control group, after adjustment for age, previous falls, sex, and ethnic origin (relative rate 0.74, 95% CI 0.58–0.94). Injuries specific to the home-modification intervention were cut by 39% per year exposed (0.61, 0.41–0.91).

Interpretation Our findings suggest that low-cost home modifications and repairs can be a means to reduce injury in the general population. Further research is needed to identify the effectiveness of particular modifications from the package tested.

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Introduction

Home injuries are an important contributor to the global burden of disease. Almost 110 000 people die every year in Europe as a result of an injury at home or leisure, and an estimated 32 million injuries require admission.[1]

In the USA, more injuries happen at home than in any other setting.[2] Falls are the main mechanism for home injuries. In 2012, more than 1 million medically treated injuries were recorded in home and community settings in New Zealand and almost half these injuries were attributable to falls.[3]

The home environment plays an important part in the occurrence of injuries, particularly falls. A relation seems to exist between the number of injury hazards in the home and the risk of home injury, although many factors could potentially confound this association.[4] A few randomised controlled trials have assessed the safety benefits of home modification, all of which focused on either children or older people. In these trials, an initial home-safety assessment was done with subsequent modification interventions, and these alterations were effective at reducing the rate of falls among older people living in the community (relative rate 0.81, 95% CI 0.68–0.97; six trials, 4208 participants) and the risk of falling for this group (relative risk 0.88, 0.80–0.96; seven trials, 4051 participants).[5] In a review of interventions to reduce falls among children, only three primary studies investigated prevention of falls or fall injuries and none included modifications to the home.[6] Typically, home modification is made available to people with disabilities in the community and is delivered by non-governmental organisations, public health nurses, or charities. However, evidence showing the safety benefits of home modifications to avoid environmental hazards is sparse.[7] In a

Cochrane review, Turner and colleagues[7] recommended that future studies should have large sample sizes and be undertaken as well-designed randomised controlled trials, with injury as the outcome measure.

We undertook the Home Injury Prevention Intervention (HIPI) study to investigate whether a package of home modifications could reduce the rate of injuries per person per year from falls at home needing medical treatment.

Methods

Participants

The HIPI study is a single-blind cluster-randomised trial undertaken over a 4-year period in the Taranaki region of New Zealand. We designed the study based on findings of an earlier cross-sectional study, in which we formulated a package of home modifications that might be effective in preventing common injuries.[8]

We recruited participants from a list of people living in the Taranaki region who had recently received government-subsidised home insulation that was retro- fitted to their homes. To qualify for this scheme, houses needed to have been constructed before 1980 and to have at least one occupant who was a holder of a community services card. These cards are held by people on a relatively low income, unemployed individuals, students, pensioners (age 65 years or older), and people in receipt of sickness benefits, and they indicate that the person is entitled to state subsidies. WISE-Better Homes, a local community trust, approached households that met these criteria and explained the aim of the HIPI study. Only individuals who said they intended to live at the house for at least the next 3 years were eligible to participate, because we sought to evaluate the safety benefits of home improvements over a 4-year period. Moreover, we only included owner-occupiers, because people renting houses are a very mobile population in New Zealand, which did not suit the aims of our study.

WISE-Better Homes obtained signed consent from at least one occupant of the house. The central regional ethics committee of the Ministry of Health gave ethics approval for the HIPI study (reference CEN/09/06/035).

Randomisation and masking

After consent had been obtained, a statistician in the research team generated a randomisation schedule with R version 2.10.0, using an electronic coin toss with equal probability to allocate households to either immediate home modification (treatment group) or a delay of 3 years before home modification (control group). We did randomisation in batches of around 100 households so that home modifications could be undertaken by a qualified builder in a timely manner without having to wait for all participants to be recruited. We did not stratify the randomisation process. We could not achieve masking of the random allocation for household members in the treatment group because modifications were made immediately to their homes.

We obtained records of home injuries from the Accident Compensation Corporation (ACC), a national no-fault personal injury insurer. Under the ACC insurance scheme, medical treatment is provided by family doctors, dentists, physiotherapists, osteopaths, and chiropractors. The ACC matched participants' names, dates of birth, and addresses to their claim files for unintentional home injuries but was unaware of the random allocation. Coders employed by the study team analysed text descriptions of injuries and were also unaware of the random allocation.

Procedures

Participants completed paper questionnaires that provided information on age, sex and ethnic origin. We obtained ACC claim data with the participants' written consent for the period from at least a year before recruitment to 4 years after. After recruitment, an initial audit of health and safety hazards was made for every house included in the study. This provided a baseline measure of fall hazards in all the houses studied.

After randomisation, qualified builders undertook an assessment of every house in the treatment group. They used a standard checklist to identify hazards in the home that were within the scope of the home-modification intervention. We approved all proposed modifications and costs quoted by the builder. Home modifications consisted of: handrails for outside steps and internal stairs; other minor repairs to outside steps; repairs to window catches; 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 bathmats; and slip-resistant surfacing for outside surfaces such as decks. Smoke alarms were installed, but we did not judge this modification relevant to the outcome measure. At the time the builder undertook the modifications, he gave householders a pamphlet on home safety. This pamphlet was not given to control households, who received no intervention during the study period.

We contacted by telephone a random sample of 10% of homes allocated to the treatment group to ascertain whether the house had been modified as specified. All householders we contacted confirmed the home modifications had been made.

Outcomes

Our primary outcome was the rate of unintentional falls at home per person per year that needed medical treatment. The home setting included indoor and outdoor areas of the property; streets and footpaths outside the property boundary were excluded. ACC provided text descriptions of injury circumstances, which usually consist of one sentence in response to a field on the ACC claim form to describe what happened. Coders categorised injuries according to our previous classification,[8] as either due to a fall (slips, trips, or falls), specific to the package of potential modifications used, or both of these. Slips, trips and falls were almost always identified clearly by the text description. If the text did not specify a disqualifying location or activity (eg, injuries arising from gardening, trips on toys, or children playing), the injury was coded as potentially specific to the intervention. Injuries in the treatment group were recorded from the date the home modification intervention began; injuries in the control group were counted from Aug 3, 2010, which was the median date at which home modifications began in the treatment group. Our secondary outcome was the rate of injuries caused by falls at home per year exposed to the intervention. We did secondary sensitivity analyses of injury outcomes excluding falls, most of which would not be thought to be affected by the home-modification intervention. As a further sensitivity analysis, we calculated rates of injury per person per year in control group households from timepoints dispersed throughout the period when treatment homes were modified (March 31, 2010, to May 13, 2011), corresponding roughly to the order of recruitment. This analysis was an attempt to mimic the period of observation for treatment homes that had been randomised in the same batch as the controls.

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

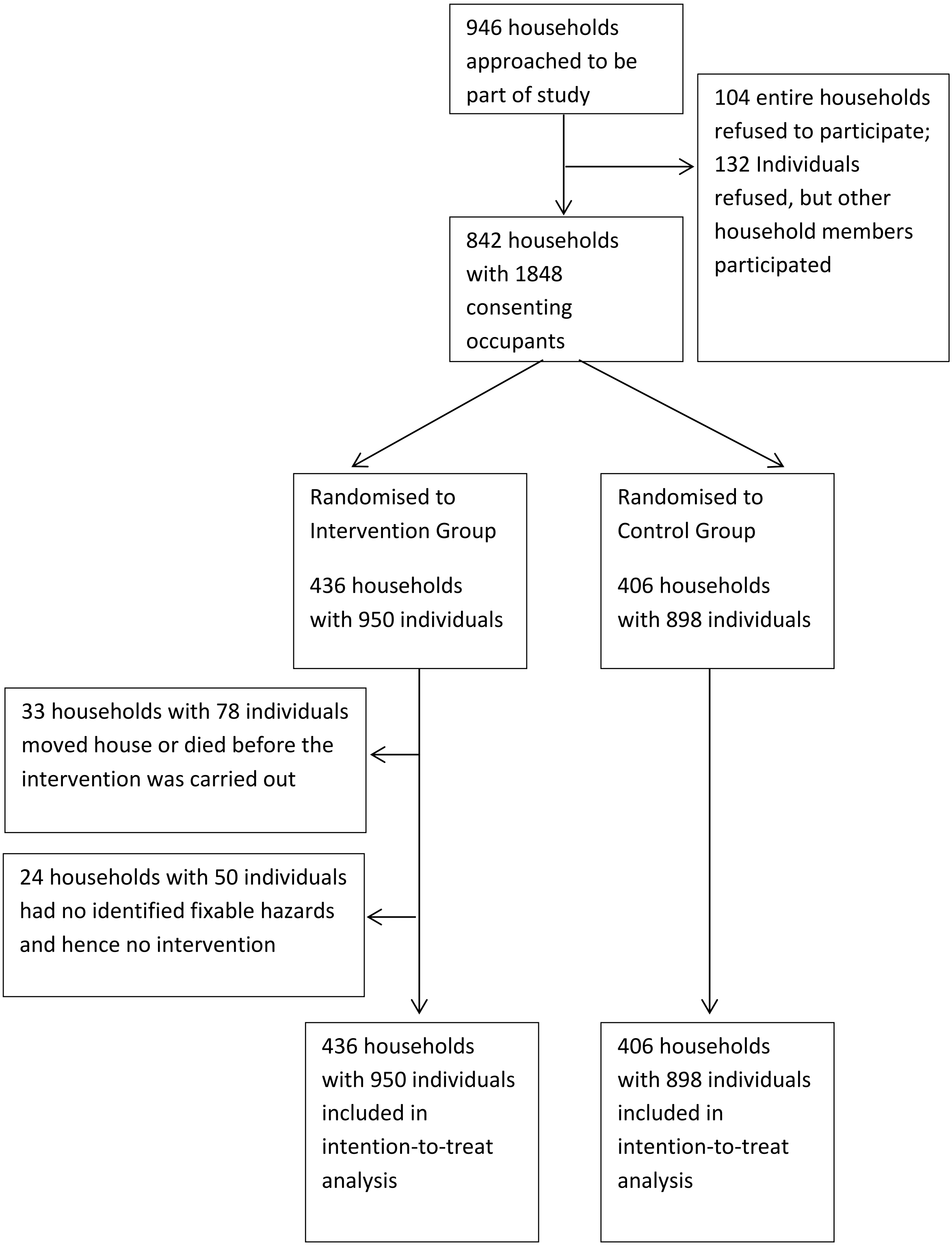

Figure 1: Trial profile

Statistical analysis

Our study was implemented over a 4-year period. To achieve 80% power to detect a change of 25% in the overall annual rate per person of injuries from falls (α of 0.05), we estimated that an unclustered sample size of 550 people each in the treatment and control groups would be sufficient. We aimed to recruit a total of 2000 people, a sample size we deemed probably sufficient after taking into account anticipated clustering effects at the household level, even if the intracluster correlation coefficient (ICC) was as high as 0.4 for a mean household size of three.

We gathered data on several individual-level variables, to increase the power of the study by adjusting for possible differences between groups. We derived the main estimate of the treatment effect from models fitted to data at the individual level, which included all available individual-level covariates according to our prespecified analysis plan: age (0–9, 10–19, 20–29, 30–39, 40–49, 50–59, 60–69, and ≥70 years); sex; ethnic origin (Indigenous Māori or non-Māori); and injuries in the year before the study. We did sensitivity analyses that were unadjusted for covariates.

		Control group	Treatment group
Persons		898	950
Households		406	436
Female		501 (56%)	541 (57%)
Māori		86 (10%)	88 (9%)
Age group	**0-9**	187 (21%)	175 (18%)
	10-19	82 (9%)	89 (9%)
	20-29	37 (4%)	34 (4%)
	30-39	112 (12%)	116 (12%)
	40-49	96 (11%)	90 (9%)
	50-59	51 (6%)	65 (7%)
	60-69	105 (12%)	132 (14%)
	70 plus	228 (25%)	249 (26%)
Mean age (age std deviation)		43 (28.1)	45 (28.0)
Age range		0-92	0-94
Home injuries excluding falls in past year		103 (0.1147)	122 (0.1284)
Home falls in past year		61 (0.0679)	87 (0.0916)
Specific injuries in past year		24 (0.0267)	23 (0.0242)

Data are: Number, number (% of group), mean age as at 3 August 2010, number of all injuries in home occurring in 365 days before intervention date (rate per person), number of slips/trips/fall injuries in home occurring in 365 days before intervention date (rate per person), number of injuries most specific to intervention occurring in 365 days before intervention date (rate per person).

Table 1: Participant characteristics at baseline

Because individuals were clustered at the household level, we used negative binomial generalised linear models with generalised estimating equations, which accounted for clustered data. We assumed an exchange- able correlation structure, whereby a correlation is taken to be constant between any two cluster members. As a sensitivity analysis, we tested the independent correlation structure. We did not judge other correlation structures appropriate for clustered data with varied numbers of observations per cluster and no particular order or sequence within clusters. We used person-years as an offset to the models to account for different amounts of time participants were resident at the house.

Some participants moved house over the study period and others died. Mortality data and information about residential mobility were more complete for the treatment group than for controls because we had a greater intensity of engagement with the treatment group. For this reason, and to provide the most policy-relevant estimate of effectiveness, we did an intention-to-treat analysis, ignoring data for residential mobility and mortality. However, our analysis will probably result in conservative estimates of safety improvements associated with home modifications. We used SAS version 9.3 and R version 3.0.2 for all analyses.

This trial is registered with the Australian New Zealand Clinical Trials Registry, number ACTRN12609000779279.

Role of the funding source

The funder had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

The HIPI study was initiated on Sept 1, 2009, when the first participants were recruited, and it ended in October, 2013, which allowed an average observation period of 3 years. Home modifications were undertaken between Jan 15, 2010, and May 5, 2011. The trial period was extended by a year because home modifications took longer than expected to be completed. The median observation period was 1148 days (IQR 1085–1263).

842 households comprising 1848 occupants were recruited for the study (figure); 309 (37%) houses had just one occupant, 293 (35%) had two participants, 78 (9%) had three people in the study, 110 (13%) had four residents, 39 (5%) had five people taking part, and 13 (2%) had six or more occupants participating. 436 households with 950 occupants were randomly allocated immediate home modification (treatment group) and 406 households with 898 occupants were randomly allocated no treatment until the end of the trial (control group). The initial assessment of fall hazards in all 842 houses identified a slightly higher number of hazards in homes allocated to the treatment group than those assigned to the control group (1.98 vs 1.91). Table 1 shows baseline characteristics of individual occupants. After randomisation, 78 people assigned to the treatment group either moved house or died before home modifications were done, affecting 33 households (figure).

The average cost of modifications per house was NZ$560 (UK£290). 24 houses (50 individual participants) needed no modifications apart from smoke alarms (figure). The maximum amount spent on modifications to a home was $3000 (£1523). Table 2 presents the average costs and settings of home modifications.

Data for the primary outcome were obtained from the ACC by matching participants by name, date of birth, and address. 96 (7%) text descriptions were flagged as ambiguous by the coders and were referred to a committee (comprising two of us) for classification. Coders and the committee were unaware of the group status of the individuals whose injury text descriptions were being assessed. Of the remaining injury descriptions, 84% agreement was noted in the classification of injuries considered to be affected by the intervention (referred to as specific injuries—ie, the injury might have happened in a setting and in a manner relevant to the home-modification intervention) and 92% agreement was recorded in the classification of falls.

Table 3 presents the number of injuries recorded during the 3-year study period, and the crude injury rate per person per year. The crude rate of medically treated falls per person per year was 0.061 in the treatment group and 0.072 in the control group (relative rate 0.86, 95% CI 0.66–1.12). The crude rate of injuries specific to the intervention per person per year was 0.018 in the treatment group and 0.028 in the control group (0.66, 0.43–1.00). We compared injury rates per person per year between groups, controlling for individual-level differences (table 4). Compared with the control group, a significant reduction of 26% was estimated in the rate of injuries caused by falls at home per year exposed to the intervention (relative rate 0.74, 95% CI 0.58–0.94). For all injuries considered to be most relevant to the intervention (specific injuries), a significant reduction of 39% was estimated per year exposed (0.61, 0.41–0.91).

Setting modified	Number of Homes	Average cost ($NZ 2012)
Intervention (overall)	436	$564
Steps only (handrails; slip-resistant edging; minor repairs)	62	$317
Bathroom only (grab rails; non-slip bathmats)	1	$66
Other only (fixes to carpets; provision of lighting; surfacing of decks and porches; minor repairs to window catches etc.)	18	$287
Steps + Bathroom	25	$246
Steps + Other	113	$714
Bathroom + Other	8	$319
Steps + Bathroom+ Other	152	$731
No intervention needed	24	$80
Intervention not carried out	33	$0

Data are by setting of intervention: number of homes; costs in NZ dollars adjusted for inflation to 2012 dollars. Costs include travel costs (time, fuel, vehicle). Labour costs accounted for 37% of costs overall.

Table 2: Home setting of modifications in treatment homes, with costs

		Control group		Treatment group	
		injuries	**rate (std error)**	**injuries**	**rate (std error)**
Home injuries excluding falls overall		259	0.097 (0.0076)	327	0.109 (0.0077)
Falls overall		192	0.072 (0.0068)	182	0.061 (0.0063)
Falls by age group	0-9	36	0.063 (0.0131)	18	0.032 (0.008)
	10-19	7	0.028 (0.0099)	2	0.007 (0.0047)
	20-29	4	0.037 (0.0171)	4	0.035 (0.0199)
	30-39	13	0.039 (0.0115)	12	0.032 (0.0084)
	40-49	8	0.029 (0.0109)	5	0.019 (0.0082)
	50-59	12	0.078 (0.02)	5	0.026 (0.0115)
	60-69	30	0.094 (0.0192)	40	0.092 (0.0214)
	70 plus	82	0.124 (0.0197)	96	0.125 (0.0178)
Falls by falls history					
	No fall in previous year	163	0.065 (0.0062)	135	0.048 (0.0053)
	Fall in previous year	29	0.166 (0.0554)	47	0.195 (0.0425)
Specific injuries overall		73	0.028 (0.0039)	53	0.018 (0.0031)
Specific injuries by age group	0-9	3	0.005 (0.0029)	0	0 (0)
	10-19	1	0.004 (0.0039)	0	0 (0)
	20-29	2	0.017 (0.0119)	0	0 (0)
	30-39	2	0.006 (0.004)	4	0.01 (0.0051)
	40-49	6	0.022 (0.0098)	2	0.007 (0.0051)
	50-59	7	0.046 (0.0165)	3	0.016 (0.0094)
	60-69	14	0.044 (0.0114)	14	0.033 (0.0089)
	70 plus	38	0.059 (0.0118)	30	0.041 (0.0097)
Specific injuries by history					
	No injury in previous year	64	0.025 (0.0037)	47	0.016 (0.0028)
	Injury in previous year	9	0.127 (0.0582)	6	0.096 (0.0573)

Data are: Number of non-fall injuries in home occurring between intervention date and follow-up, mean rate per person per year (standard error of mean), number of slips/trips/fall injuries in home occurring between intervention date and follow-up, mean rate per person per year (standard error of mean), number of injuries most specifically affected by intervention occurring between intervention date and follow-up , mean rate per person per year (standard error of mean). The standard error estimates provided here account for clustering at the household level using Taylor series linearisation.

Table 3: Unadjusted outcomes at 36-month follow up

	falls	specific injuries
Intervention	0.74 (0.58, 0.94)	0.61 (0.41, 0.91)
Age group		
0-9	2.02 (1.06, 3.82)	0.20 (0.05, 0.79)
10-19	0.78 (0.32, 1.87)	0.15 (0.02, 1.28)
20-29	1.70 (0.67, 4.31)	0.70 (0.14, 3.54)
30-39	1.60 (0.79, 3.24)	0.62 (0.20, 1.89)
50-59	2.14 (0.99, 4.62)	1.94 (0.70, 5.35)
60-69	4.13 (2.19, 7.78)	2.59 (1.10, 6.11)
70 plus	4.85 (2.67, 8.81)	3.14 (1.42, 6.94)
Injuries in year prior to intervention	2.44 (1.82, 3.28)	3.36 (1.62, 6.97)
Māori	0.76 (0.47, 1.25)	0.55 (0.19, 1.59)
Female	0.94 (0.73, 1.20)	1.19 (0.78, 1.80)

Data are estimates of relative injury rate adjusted for covariates: age relative to age group 40-49; treatment group relative to control group; rate for one additional injury in year prior to intervention; Māori compared to non- Māori; female compared to male

Table 4: Adjusted estimates from negative binomial GEE models fitted to data at 36-month follow up

Age and previous injuries had a strong effect on subsequent injury rates (table 4). Previous injuries—matched by the ACC to the year before home modification began—were of a similar type to subsequent injuries. The home-modification intervention would not be expected to have affected injuries not caused by falls. In our sensitivity analysis, we used the same model to assess the treatment effect on non-fall injuries, with all injuries in the home as the dependent variable (data not shown). No effect of the home-modification intervention was recorded. We also fitted more complex models to identify potential treatment effects for various subgroups. An interaction term added to the model, between treatment group and previous falls, was not significant (p=0.50), showing no differential effect of the intervention according to history of previous falls. Similarly, no interaction was noted between age group and assigned treatment (p=0.38), indicating no differential effect across age groups, despite some apparent variation in unadjusted treatment effects by age (table 3).

The robustness of the estimated treatment effect was assessed with respect to different assumptions and explanatory variables. When an independent correlation structure was specified for the generalised estimating equations, estimated treatment effects changed very little (data not shown). When the number of falls in the previous 3 years was included as a term in the models, instead of the number in the previous year, estimated safety effects were unchanged (data not shown). Excluding individuals allocated to the treatment group whose homes were not modified (ie, who had moved or died after recruitment and before the modifications were done) also made little difference (data not shown). Similarly, scant difference was noted when injury rates in the control group were assessed from points in time dispersed over the 14 months when the modifications were done, in roughly the order of recruitment (data not shown). Moderate ICCs were estimated for injuries specific to the intervention (0.19), for fall injuries generally (0.21), and for all home injuries (0.24).

Discussion

Home modifications focusing on fairly common hazards in the home can reduce injuries caused by falls. As we expected, the home-modification intervention had a strong benefit in reducing injuries most closely related to the modifications made (specific injuries). A smaller benefit was noted for all injuries caused by falls at home, but home modifications had no effect on injuries not resulting from a fall. In view of the large injury burden posed by falls at home globally, these results have important implications for design of effective preventive programmes focused on the home environment.

Most modifications were structural and designed to be long-lasting, for occupants of different households from New Zealand's fairly mobile population. For this reason, home modifications were not tailored to the individual occupants but were designed to provide a safer home environment for all age groups. Because modifications to the home affect everyone exposed to that environment, but particularly long-term residents, a cluster-randomised controlled trial was a logical design to test potential safety benefits of home modifications, as has been used for studies of the health benefits of insulation and heating.[9,10]

A strength of our study was having access to independent administrative records on medically treated home injuries, ranging in severity from minor injuries to those needing admission or resulting in death; records were made available by the national no-faults accident insurer ACC. Coverage of medically treated injuries by this scheme is very high, providing us with a fairly large number of records of injury events without any degree of self-report by participants. When trials rely on self-report, participants' awareness of their treatment status can compromise estimates of treatment effect.[11] Nevertheless, some individual differences in willingness to access medical treatment will be present, which arise from the type and availability of treatment and individual factors.[12] A limitation of use of ACC data is that the scheme matched participants by name, date of birth, and address to primary outcome data, but we do not know how complete the matching of data was because not all participants would have made a claim to the ACC. A reasonable assumption is that matching could not have been affected by treatment status of participants. A further limitation is the dependence on text-field reporting of the circumstances of the injury, with unknown validity—particularly, whether or not a fall might have been the cause.

Similar to other Indigenous populations, access to health-care services is generally reduced for Māori,[13] meaning that the prevalence of injury in this population might be underestimated according to the outcome measure used in this study. Reporting bias can be minimised if only injuries of high severity are considered (eg, fractures),[14] but our study would have been under- powered to detect safety benefits for such injuries.

Stratification of participants would have been preferable during the random allocation procedure. In at least one other study of falls,[15] the strongest predictor of a fall injury at 1-year follow-up was a count of falls in the year before recruitment. Randomisation was done at the household level, rather than at the individual level, meaning that previous falls by individuals could not be used easily as a stratification factor during randomisation. Because we did not stratify by important individual predisposing factors for falls, most notably history of previous falls and age, we risked the treatment and control groups being unmatched despite the random allocation. By chance, participants in the treatment group were older and had a higher rate of previous falls compared with controls (table 1). However, models fitted to data were adjusted statistically for individual-level covariates, including previous falls, age group, sex, and ethnic origin, effectively correcting for baseline differences between groups in terms of these characteristics. As a result, the adjusted point estimate for the reduction in all fall injuries was larger than the crude estimate, even though the crude and adjusted point estimates of the reduction of injuries most specific to the intervention were very similar. The discrepancy between the crude and adjusted treatment effect on falls can be attributed to adjustment by the model for the treatment group's higher baseline rate of all fall injuries, and a slightly older average age. Older people had a significantly higher risk of injury from falls, adjusting for other factors (table 4). If models had not been adjusted for previous specific injuries or previous falls (because of non-availability of data), models adjusting only for age, sex, and ethnic origin would have estimated a reduction in injury of 40% for specific injuries (p=0.013) and of 21% for fall injuries (p=0.058).

Another limitation of our study relates to respondents moving house, despite stating at enrolment that they intended to be resident at the surveyed house for at least 3 years. Although the unit of randomisation was the house, home injuries continued to be counted for consenting occupants of the homes even when the occupant moved to another dwelling. Generally, we would expect this factor to attenuate the estimated treatment effect, unless a systematic tendency existed for occupants of modified homes to move to safer dwellings, or for occupants of control homes to move to hazardous dwellings. To envisage a feasible mechanism leading to such behaviours is difficult. When we excluded from the analysis people who were known to have either moved house or died before home modifications were done, little change was noted to the estimated safety effect.

Although our study had sufficient power to detect the anticipated safety effect, a larger sample size (eg, the 2000 participants we initially aimed to recruit) might have provided some added explanatory power to do secondary subanalyses of the data gathered.

Generalisability of results depends on the nature of the housing stock considered. The houses included in our study were owner-occupied and included at least one resident who received government financial assistance. Such houses can undergo scant maintenance[16] because of the restricted incomes of the occupants. New Zealand housing consists mainly of stand-alone dwellings, with an outside area and an access path that typically includes steps. Many of the home modifications we made addressed the outdoor areas of the home—ie, steps, pathways, decks, and lighting. Substantial proportions of housing stock in Australia and the USA will share many features addressed by this study. Blocks of apartments contain the types of stair, step, and lighting hazards that were within the scope of this study, even though these access ways are shared. Minor aspects of the modification package will be applicable to most dwellings globally, including installation of grab rails in bathrooms and toilets, provision of non-slip bathmats, and fixing of carpet edges to the floor.

The HIPI study is currently being extended to investigate injury hazards and safety benefits specifically in homes of the Indigenous Māori population, who constituted 10% of participants and represent 14% of the population generally.[17] This extension is aimed at identifying potentially important factors behind current inferior health outcomes generally for Māori.[18] In the future, power will be augmented for investigation of the effectiveness of particular components of the package of home modifications applied, such as internal stair and outside step modifications, by assessment of changes in injury rates to the control group of houses, which at the time of writing are having the home modifications.

Home modification has rarely shown safety benefits;[7] therefore, how does our trial differ from previous studies (panel)? In a Cochrane review, several limitations of past studies of the safety effects of home modification were noted.[7] First, most homes included in the studies were already fairly safe, potentially leaving the effects of only modest changes in the home environment to be recorded.[7] Our study dealt with a fairly hazardous home environment, with many identifiable injury hazards.[8] Second, few studies were large enough to provide sufficient statistical power to test the effectiveness of the interventions.[7] Our study was comparatively large, and we could monitor injuries over the course of 3 years (on average) after the intervention, which provided further power. Third, most studies had a very low uptake rate,[7] which also limits power and reduces generalisability. In our study, only 33 (8%) households randomly allocated to immediate home modification did not undergo intervention (because occupants died or moved house). Finally, in the Cochrane review, no previous studies were identified that investigated the safety effect of home modification for the general population and in which falls or injuries due to falls was the outcome measure.[7]

The injury burden attributable to aspects of the home environment is difficult to estimate because information on housing quality (exposure to hazards) and studies estimating increases in risk of injury according to hazards in housing are scarce.[19] The HIPI study fills an important gap, which can serve to motivate remedial measures that will reduce risk of injury. Developed countries that have growing populations of older people can expect corresponding increases in injuries from falls, which already place considerable burden on hospitals and society in general.[20]

Even if an intervention has been shown to prevent injuries, do the benefits (in terms of injuries prevented) justify the costs of the intervention? In our study, per injury prevented, the package of home modifications cost on average $830 (2012 costs): fall injuries can be assumed to happen at the baseline rate (table 1), and home modifications can be expected to last for 20 years, during which time 26% of fall injuries are prevented, discounted at 3% per year. WHO has defined interventions that prevent every additional disability- adjusted life-year (DALY) at a cost less than the gross domestic product (GDP) per person for a given country as very cost effective, and defined interventions that prevent a DALY at a cost one to three times the GDP per person as cost effective.[21,22] New Zealand fall injuries were estimated to account for 29 481.9 DALYs in 2010.[23] Of these, probably around 60% happened in the home.[24] If we assume that the programme of modifications used in this study could be rolled out nationally, and injuries prevented were representative of all fall injuries at home, then the one-off cost would be almost $980 million ($564 per home on average; 1 734 500 dwellings),[25] preventing an estimated 15 800 DALYs over 20 years. The cost of the intervention per discounted DALY prevented is $14 300, considerably less than the New Zealand GDP per person, which was $45 769 in 2012,[26] classifying the intervention as very cost effective according to WHO.[21,22] Even if the lower bound of the 95% CI for fall injuries prevented in this study (6%) were used to estimate DALYs prevented, the cost of the intervention per discounted DALY prevented would be $62 000, which still would classify the intervention as cost effective according to WHO.

We think the package of home modifications that constituted the treatment in this study is feasible for national rollout, 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, which was designed to address aspects of poor thermal performance (insulation and heating) of New Zealand housing generally. A basis for the high level of government investment in this scheme was provided by the noted health benefits shown in two randomised community trials[9,10] and by estimates of cost-effectiveness in terms of health benefits (morbidity and mortality prevented) compared with the costs of the remediations.[27] The probable cost-effectiveness of the intervention described here and the size of the potential injury burden reduction clearly merits a similar effort.

Panel – research in context

Systematic review

A recent Cochrane review looking at the effectiveness of various interventions in the prevention of falls amongst older people living in the community found that home safety assessment and modification interventions were effective in reducing rate and risk of falls[5]. Home modification was more effective for people at higher risk of falls and when the intervention was delivered by occupational therapists, who could tailor the intervention to the individual[5]. Interventions to prevent child falls at home have rarely been evaluated in terms of preventing falls or fall injuries, and no home modification interventions have been evaluated in this way[6, 7].

Interpretation

The current study is the first randomised controlled trial assessing the effectiveness of home modification in preventing medically-treated falls for the general population. The 26% reduction in injuries due to home falls was statistically significant and important in a public health context, constituting around 10% of all unintentional medically-treated home injuries amongst the participants.

Contributors

MDK designed the trial with input from NP, MGB and PH-C. All authors contributed to the conduct of the trial, interpretation of results, and revision and correction of the report, which was drafted by MDK. The analyses were led by MDK and NP. All authors read and approved the final version of this report.

Declaration of interests

We declare that we have no competing interests.

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