IP Online First, published on May 24, 2016 as 10.1136/injuryprev-2016-041999

Home safety assessment and modification to reduce injurious falls in community-dwelling older adults: cost-utility and equity analysis

Frank Pega, Giorgi Kvizhinadze, Tony Blakely, June Atkinson, Nick Wilson

▸ Additional material is published online only. To view please visit the journal online (http://dx.doi.org/10.1136/injuryprev-2016-041999).

Burden of Disease Epidemiology, Equity and Cost-Effectiveness Programme (BODE[3]), Department of Public Health, University of Otago, Wellington, New Zealand

Correspondence to
Dr Frank Pega, Department of Public Health, University of Otago, 23a Mein Street, Newtown, Wellington 6242, New Zealand; frank.pega@otago.ac.nz

Received 22 February 2016
Accepted 2 April 2016

ABSTRACT

Background This study aimed to improve on previous modelling work to determine the health gain, cost-utility and health equity impacts from home safety assessment and modification (HSAM) for reducing injurious falls in older people.

Methods The model was a Markov macrosimulation one that estimated quality-adjusted life-years (QALYs) gained. The setting was a country with detailed epidemiological and cost data (New Zealand (NZ)) for 2011. A health system perspective was taken and a discount rate of 3% was used (for both health gain and costs). Intervention effectiveness estimates came from a Cochrane systematic review and NZ-specific intervention costs were from a randomised controlled trial.

Results In the 65 years and above age group, the HSAM programme cost a total of US$98 million (95% uncertainty interval (UI) US$65 to US$139 million) to implement nationally and the accrued net health system costs were US$74 million (95% UI: cost saving to US $132 million). Health gains were 34 000 QALYs (95% UI: 5000 to 65 000). The incremental cost-effectiveness ratio (ICER) was US$6000 (95% UI: cost saving to US $13 000), suggesting that HSAM is highly cost-effective. Targeting HSAM only to older people with previous injurious falls and to older people aged 75 years and above were also cost-effective (ICERs=US$1000 and US $11 000, respectively). There was no evidence for differential cost-effectiveness by gender or by ethnicity (Indigenous New Zealanders: Māori vs non-Māori).

Conclusions As per other studies, this modelling study indicates that the provision of an HSAM intervention produces considerable health gain and is highly cost-effective among older people. Targeting this intervention to older people with previous injurious falls is a promising initial approach before any scale up.

Trial registration number ACTRN12609000779279.

INTRODUCTION

The WHO has recently called for further studies investigating the cost-effectiveness of interventions addressing the social determinants of health.[1] One potential intervention area is around structural housing interventions,[2] but recent systematic reviews of economic analyses of housing interventions demonstrated the relative scarcity of such studies.[1 3 4]

Home safety assessment and modification (HSAM) is one such structural housing intervention to reduce injurious falls among community-dwelling older people.[5] It involves a two-stage intervention consisting of a personalised assessment of injury hazards in the home (generally by an occupational therapist), followed by a systematic removal of these hazards.[6] Injury hazards removal includes actions such as reducing tripping hazards, adding grab bars inside and outside the tub or shower and next to the toilet, adding hand rails on both sides of stairways and improving home lighting.[6] A recent systematic review of effectiveness and meta-analysis of randomised controlled trials of HSAM interventions concluded that they reduced the rate of falls by 19% (95% CI 3% to 32%).[7] Accordingly, HSAM is recommended by the WHO for preventing injurious falls.[8] An overview of other interventions for falls prevention is provided elsewhere.[7]

From our systematic review of health economic analyses of structural housing interventions,[4] we are aware of eight such previous economic analyses of HSAM interventions, four studies for the USA,[9–12] three for Australia[13–15] and one for New Zealand (NZ).[16] All but one of these studies[14] concluded that HSAM was cost-effective in reducing injurious falls in the home among older people. However, these previous analyses had two primary methodological limitations. First, those economic analyses that used decision analytic modelling often relied largely on expert judgement rather than actual data. Second, most analyses did not explore differential cost-effectiveness by key population characteristics, thereby potentially masking differential impacts for different population groups, including those with relatively poorer health status such as Indigenous people and men. Previous analyses also did not answer two key questions for intervention design and implementation. First, they did not investigate the relative cost-effectiveness of HSAM targeted to older people with a high risk of injurious falling (ie, people with previous injurious falls) versus universal HSAM for all older people. Second, they also did not investigate the relative cost-effectiveness of providing the intervention to older people aged 75 years and above.

This study aimed to investigate the cost-effectiveness of HSAM for reducing injurious falls in the home in community-dwelling older people (65 years and above) in NZ, using Markov macrosimulation modelling. More specifically, we aimed to answer the four research questions presented in the online supplementary appendix text box A1.

METHODS

Perspectives and general approach

We followed the Burden of Disease Epidemiology, Equity and Cost-Effectiveness Programme (BODE[3])

To cite: Pega F, Kvizhinadze G, Blakely T, *et al*. *Inj Prev* Published Online First: [*please include* Day Month Year] doi:10.1136/injuryprev-2016-041999

Protocol.[17] Accordingly, this study took a health system perspective, evaluating health system costs for the rest of the life of the cohort, using quality-adjusted life-years (QALYs) gained, health sector costs and incremental cost-effectiveness ratios (ICERs) as our outcome measures. The target population for the HSAM intervention was community-dwelling older people aged 65 years and above in 2011. The studied HSAM interventions, both provided universal and targeted, are described in more detail in the online supplementary appendix text box A2.

We assessed the effect of HSAM on injurious falls in the home leading to any health service use, but not on outcomes with less tangible impacts on QALYs (eg, fear from injurious falling). In the base analysis, we compared targeted HSAM with no intervention, which can be regarded as current 'business as usual' in NZ. This can be considered to be a reasonable assumption given that only a small proportion of existing homes in NZ may have ad hoc fall-reducing modifications and these are unlikely to be at the state-of-the-art levels achieved by a programme-level HSAM intervention. In scenario analyses, we expanded our analysis to studying HSAM targeted to just those aged 75 years and above. Similarly we also expanded our analysis to studying the provision of HSAM at one point in time as a once-off intervention. In the base case analysis, we applied the standard discount rate of 3% on both QALYs gained and costs. In scenario analyses, we used discount rates of 0% and 6%.

Core model structure

As per most previous studies on this topic,[9–11 13 15] we used a Markov macrosimulation model with annual cycles (see online supplementary appendix figure A1). The model commenced with the target cohort of community-dwelling older people starting in a non-injured state in 2011 and followed this simulated cohort up until death or age 110 years old. The model estimates the effect of HSAM on QALYs gained, net costs and cost-effectiveness in the target population by modelling the reduction of injurious falls in the home (and the associated burden of disease and costs, respectively).

Previous studies[9–11 15] generally modelled the effect of HSAM on injurious falls via *three* risk groups (low, medium and high based on falls and injurious falls histories) and *indirectly* through the intervention affecting any (injurious and non-injurious) falls (for model structure see, eg, figure 2 in Church *et al*[15]). In contrast, we assumed *two* risk groups, 'low risk' for persons with no previous injurious fall and 'high risk' for persons with any previous injurious fall, and modelled the effect of HSAM *directly* on injurious falls (for model structure, see online supplementary appendix figure A1). We believe that our approach is justified, considering that sensitivity analyses of previous models[15] demonstrate no influence of the probabilities of falling by risk group or of injurious falls from falling on cost-effectiveness estimates. In addition, we also did not have access to data on falls without injury, so that we were unable to replicate the previous model structure. We modelled heterogeneity in the incidence rates of injurious falls by age, gender and ethnicity. Persons could either have or not have an injurious fall event, with fallers being either injured requiring hospitalisation, injured requiring non-hospital healthcare or have no injurious fall. At each annual cycle, a person could move into residential aged care where they could no longer potentially benefit from the community-based HSAM intervention (and adopted the background morbidity and mortality rates as per their age/gender/ethnic group).

To account for considerable social mobility in the NZ population, we modelled inflows and outflows from houses with and without HSAM over time. We identified the older population (65 years and above) who resided in private dwellings and calculated the number of years they had spent in the same dwelling from the 2013 Census of Population and Dwellings. For each age group, we calculated the proportion of persons who had moved houses at or after age 65, and projected transitions into and out of modified and unmodified private dwellings for the study cohort. This long-term approach smoothed the effect of events that may have disproportionately affected inflows and outflows from private dwellings, such as the 2008 global economic recession.

To evaluate heterogeneous impacts of the HSAM intervention, we stratified the target population by age (65–69, 70–74, 75–79, 80–84, 85 and above), gender (men, women) and ethnicity (Indigenous New Zealanders: Maori and non-Māori), giving 20 discrete cohort subpopulations.

Health gain measure

The QALY metric is a composite measure capturing both years of life lost from premature mortality and quality of life lost from morbidity. We valued the morbidity state in our model (ie, an injurious fall), using health status valuations extracted from the Global Burden of Disease Study (pairwise comparison methodology),[18] adjusted for NZ.[17] More information on the specific type of QALY measure used in BODE[3] analyses is provided in the Programme's protocol.[17] The model was parameterised with the underlying population mortality and morbidity using life tables, with average prevalent years of life lived in disability for each of the cohort subpopulations extracted from the New Zealand Burden of Disease Study.[19] QALYs were cumulatively tallied for the life span of the modelled cohort.

Health system costs

We determined costs of hospitalisation after falling, costs of attendance of non-hospital healthcare after falling and cohort-specific average population healthcare costs from the Ministry of Health's New Zealand Health Tracker[20] and an official injury compensation claims register (the Government's Accident Compensation Corporation's injury compensation claims register). Both of these administrative health data collections cover all public health system costs, including costs of publicly funded pharmaceuticals. Again, we determined heterogeneity of these health system costs by cohort determined by age, gender and ethnicity (for values, see online supplementary appendix table 1) and modelled uncertainty, using a range of 0.5–1.5 times the point estimate. We used NZ$ values and adjusted all values to year 2011 values. However, we converted some of the NZ$ values to US$ for comparative purposes, using the Organisation for Economic Co-operation and Development 2011 benchmark purchasing power parity of 1.486.

Utility values

The key utility value was a disability weight of 0.10 with a 95% uncertainty interval (UI) of 0.06 to 0.15, which was estimated based on Salomon *et al*,[18] assuming that each injurious fall accrued the disability weight for fracture of 0.30 applied for a 4-month period over the 1 year cycle.

Intervention effectiveness

The measure of effectiveness was a synthesis-based estimate extracted from a Cochrane systematic review of interventions for preventing falls in older people.[7] This effect size was of a 19% reduction in the rate of injurious falling (95% CI 3% to 32%).[7] We assumed the parameter to have a log-normal distribution. Since evidence on the effectiveness of HSAM on injurious falls is inconclusive,[21] we assumed that HSAM reduces the rate of falling[7] to the same degree as it reduces the rate of injurious falling.

Intervention costs

Intervention costs came from a NZ-based randomised controlled trial of HSAM in the general population.[22] We extracted cost data (ie, labour and material costs) for indoor components of the HSAM in households with one or more members aged 65 years or above. The net intervention cost per person was NZ $250 (95% UI NZ$165 to NZ$355), in 2011 dollar values.[22]

Additional methods details, scenario and uncertainty analyses

Specific details on transition probabilities and rates used in the model are detailed in the online supplementary web appendix. So are the details on the scenario analyses and uncertainty analyses performed.

RESULTS

Base analyses

For the total NZ population of older people, the modelled HSAM programme cost a total of NZ$145 (US$98) million (95% UI NZ$96 (US$65) million to NZ$206 (US$139) million) to implement nationally (table 1). The net health system costs (intervention costs plus health sector costs throughout the remaining lives of the modelled cohort) were NZ$110 (US$74) million (95% UI: cost saving to NZ$196 (US$132) million). Health impacts in this older population were 34 000 QALYs gained (95% UI: 2300 to 38 000). The estimated ICER was NZ $9000 (US$6000) per QALY gained (95% UI: cost saving to NZ $20 000 (US$13 000)) suggesting that the HSAM programme intervention would be highly cost-effective as per WHO standard thresholds.[23]

Scenario analyses

Scenario analyses are presented in table 1. Targeting HSAM only to older people with previous injurious falls (10% of the older population) lowered upfront programme costs (to NZ$18 million) and net health system costs (to NZ$6 million) and further improved cost-effectiveness (ICER=$2000 per QALY gained). But this resulted in lower total health gain (20 000 QALYs).

Targeting HSAM only to older people aged 75 years and above (44% of the older population) also lowered programme costs (to NZ$63 million) and net health system costs (to NZ$59 million), but reduced total health gain (9000 QALYs) and reduced cost-effectiveness (NZ$17 000 per QALY gained). Setting the discount rate to 0% and 6% also resulted in comparable ICERs of $8000 ($1000 to $16 000) and of $11 000 (cost saving to $25 000), respectively.

When HSAM was targeted to 'at-risk' older people (those aged 65 years and above with one or more previous injurious falls) but with declining intervention effectiveness over 10 years (linearly decreasing to nil), the ICER was smaller, but still highly cost-effective (ICER=$20 000 per QALY gained, 95% UI: $400 to $41 000). When intervention costs for HSAM targeted to at-risk older people aged 65 years and above were reduced by one-third, then the intervention's cost-effectiveness further improved, compared with the baseline model (ICER= $6000, 95% UI: cost saving to $13 000). To contextualise the results, we also considered the impact of a hypothetically improved HSAM intervention that eliminated all falls (ie, 100% effective). In this hypothetical scenario, the ICER would be $100 (95% UI: cost saving to $3000). Finally, when we modelled a different RR reduction for those with and without a history of prior injurious falls taken from a Cochrane systematic review[7] the HSAM was also highly cost-effective (ICER= $4800, 95% UI: cost saving to $22 200).

Uncertainty analyses

Uncertainty analyses for the key model parameters for incremental costs and QALYs gained are shown in tornado plots in the online supplementary appendix figure A2. For incremental costs, the parameter contributing the most uncertainty was the scaler for the probability of death from falling, with individual-level incremental cost ranging from a small cost saving of NZ $34 to additional costs of NZ$420. The scalers for cost of hospitalised and non-hospitalised falls and the probability of hospitalisation were the next most important sources of uncertainty. For QALYs gained, the parameter contributing the most uncertainty was the rate of falling, followed by the scaler for the probability of death from falling.

Population group and equity analyses

Health gain and cost-effectiveness were comparable for women and men, and for the Indigenous Māori and non-Māori populations in this community-dwelling population (table 2). The ICERs indicated that HSAM was highly cost-effective among all studied ethnic groups and genders.

DISCUSSION

Main findings and interpretation

This study provides modelling-level evidence that the HSAM intervention produces considerable health gain and is highly cost-effective among older people in the high-income country setting of NZ. Targeting HSAM to older people with previous injurious falls reduces upfront intervention and incremental health system costs, as well as improves the cost-effectiveness. But it does reduce total health gain relative to the universal (all adults aged 65 years and above) approach. Targeting the intervention to only adults aged 75 years and above also reduced intervention and incremental health system costs, but reduces total health gain and cost-effectiveness (though the latter remains favourable).

All except for one[14] of the nine previously economic analyses of HSAM concluded that the intervention was cost-effective when compared with no HSAM. So this NZ study is compatible with this past work but it also adds an equity perspective that was missing from the previous literature. Nevertheless, it found that all groups benefited and there was no differential impact or differential cost-effectiveness by ethnicity and gender, suggesting that the intervention does not have the added advantage of reducing relative health inequalities.

Strengths and limitations

This study has five key strengths. First, we assumed two distinct risk groups with their own fall rates, based on history of injurious falls, determined from the national injury claim and hospitalisation registries. In contrast, in a previous model of different risk groups the probability of falling in these groups has been based on expert opinion.[15] Second, to our knowledge, this study is the first cost-effectiveness model of HSAM to model heterogeneity by key population characteristics, and to provide an equity perspective. Third, the study strongly relies on empirical data from national official registries to estimate the incidence of injurious falls, the associated healthcare use and the associated costs

Table 1 Scenario analyses with incremental costs, QALYs gained and ICERs (expected value analysis for population-level results for the lifetime of the modelled cohort of community-dwelling older people)

Intervention/output	Output	No HSAM—baseline)	Impact of HSAM compared with baseline
Baseline model (3% discount rate)			
Net cost (NZ$; 1000s)	Mean	$41 700 000	$111 000
	95% UI	($41 400 000 to $42 400 000)	(Cost saving to $197 000)
QALYs gained	Mean	4 100 000	34 000
	95% UI	(3 970 000 to 4 230 000)	(5490 to 65 300)
ICER	Mean		$9000
	Median		$4000
	95% UI		(Cost saving to $20 000)
HSAM targeted to 'at risk' older people aged 65 years and above with one or more previous injurious falls			
Net cost (NZ$; 1000s)	Mean	$41 700 000	$6170
	95% UI	($41 400 000 to $42 400 000)	(Cost saving to $29 900)
QALYs gained	Mean	4 100 000	20 100
	95% UI	(3 970 000 to 4 230 000)	(3010 to 40 300)
ICER	Mean		$2000
	Median		$700
	95% UI		(Cost saving to $4000)
HSAM targeted to older people aged 75 years and above			
Net cost (NZ$; 1000s)	Mean	$16 300 000	$59 100
	95% UI	($16 200 000 to $16 400 000)	($30 000 to $87 100)
QALYs gained	Mean	1 180 000	8750
	95% UI	(1 150 000 to 1 210 000)	(1400 to 16 700)
ICER	Mean		$17 000
	Median		$7000
	95% UI		($2000 to $34 000)
Discount rate 0% (otherwise same as baseline model)			
Net cost (NZ$; 1000s)	Mean	$55 900 000	$198 000
	95% UI	($55 700 000 to $56 400 000)	($95 200 to $294 000)
QALYs gained	Mean	5 160 000	48 200
	95% UI	(4 980 000 to 5 350 000)	(7930 to 92 400)
ICER	Mean		$8000
	Median		$4000
	95% UI		($1000 to $16 000)
Discount rate doubled to 6% (otherwise same as baseline model)			
Net cost (NZ$; 1000s)	Mean	$32 800 000	$71 800
	95% UI	($32 300 000 to $33 600 000)	(Cost saving to $167 000)
QALYs gained	Mean	3 390 000	25 300
	95% UI	(3 290 000 to 3 480 000)	(4030 to 49 100)
ICER	Mean		$11 000
	Median		$3000
	95% UI		(Cost saving to $25 000)
HSAM targeted to at-risk older people aged 65 years and above with one or more previous injurious falls with declining effectiveness over 10 years			
Net cost (NZ$; 1000s)	Mean	$41 700 000	$112 000
	95% UI	($41 400 000 to $42 400 000)	($20 700 to $184 000)
QALYs gained	Mean	4 100 000	16 500
	95% UI	(3 970 000 to 4 230 000)	(2660 to 33 000)
ICER	Mean		$20 000
	Median		$7000
	95% UI		($400 to $41 000)
HSAM targeted to at-risk older people aged 65 years and above with home modification costs reduced to one-third (government achieves economies of scale with purchasing interventions)			
Net cost (NZ$; 1000s)	Mean	$41 700 000	$64 800
	95% UI	($41 400 000 to $42 400 000)	(Cost saving to $137 000)
QALYs gained	Mean	4 100 000	34 000
	95% UI	(3 970 000 to 4 200 000)	(5490 to 65 300)
ICER	Mean		$6000
	Median		$2000
	95% UI		(Cost saving to $13 000)

Continued

Table 1 Continued

Intervention/output	Output	No HSAM—baseline)	Impact of HSAM compared with baseline
Hypothetical intervention for context: HSAM targeted to at-risk older people aged 65 years and above with one or more previous injurious falls with 100% effectiveness			
Net cost (NZ$; 1000s)	Mean	$41 700 00	Cost saving
	95% UI	($41 400 000 to $42 400 000)	(Cost saving to $266 000)
QALYs gained	Mean	4 100 000	203 000
	95% UI	(3 970 000 to 4 230 000)	(96 400 to 302 000)
ICER	Mean		$100
	Median		$200
	95% UI		(Cost saving to $3000)
HSAM with risk-specific effectiveness, RR high-risk group=0.62 (95% CI=0.50 to 0.77), RR low-risk group=0.94 (0.84, 1.05) as per a Cochrane systematic review[7]			
Net cost (NZ$; 1000s)	Mean	$41 700 000	$108 800
	95% UI	($41 400 000 to $42 400 000)	(Cost saving to $204 500)
QALYs gained	Mean	4 100 000	42 800
	95% UI	(3 970 000 to 4 230 000)	(1800–86 200)
ICER	Mean		$5000
	Median		$3000
	95% UI		(Cost saving—$22 000)

ICERs rounded to the nearest $1000 or, if lower than $1000, to the nearest $100. Other values are rounded to three meaningful digits.
HSAM, home safety assessment and modification; ICER, incremental cost-effectiveness ratio; NZ, New Zealand; QALYs, quality-adjusted life-years; UI, uncertainty interval.

(rather than relying considerably on expert opinion), and ultimately QALY gains, net costs and cost-effectiveness. Fourth, the model also considers inflows and outflows of the target population from homes with and without HSAM. We assumed independence in estimating the rate of moving into and out of homes and of injurious falling in the low-risk and high-risk groups. Finally, the relative effectiveness and cost-effectiveness of targeting HSAM to community-dwelling older people at high risk of injurious falling (ie, with one or more injurious falls in the previous 5 years) and providing the intervention prospectively over time (as opposed to at one point in time) has not previously been studied.

Nevertheless, as with all modelling studies there are limitations. First, best practice guidelines for economic analyses of social determinants of health (including housing) interventions recommend that such analyses are conducted from a societal perspective to cover wider social benefits and costs beyond the health system and explicitly include valuation of impacts on health equity.[1] Our study was limited to a health system perspective, and so we did not capture any economic benefits from keeping employed older people in the workforce or being able to contribute to the informal economy, such as care for their grandchildren. Second, the model likely underestimates the health gain of the intervention due to modelling a cohort of older adults (65 years and above from 2011) only, meaning that the additional benefit from the intervention for people not included in the cohort, but who move into a modified house, would not be captured by our model. Indeed, even younger people moving into a modified house might achieve some fall prevention benefit.

Table 2 Analyses by ethnicity and gender within the baseline model: incremental costs, QALYs gained and ICERs (expected value analysis per person for the lifetime of the modelled cohort, with 95% UI)

	No HSAM—baseline		HSAM compared with no HSAM —incremental		
Population group	Net cost in NZ$	QALYs gained	Net cost in NZ$	QALYs gained	ICER
Total population	$72 000 ($71 400 to $73 300)	7.08 (6.85 to 7.30)	$191 (Cost saving to $339)	0.058 (0.009 to 0.112)	$9000 (Cost saving to $20 000)
Māori (Indigenous New Zealanders)	$63 500 ($63 400 to $64 000)	5.77 (5.59 to 5.94)	$328 ($179 to $467)	0.046 (0.007 to 0.091)	$15 000 ($3000 to $28 000)
Māori: equity analysis†	$72 800 ($72 600 to $73 400)	7.81 (7.53 to 8.07)	$424 ($235 to $615)	0.071 (0.011 to 0.140)	$11 000 ($3000 to $19 000)
Non-Māori	$72 500 ($71 900 to $73 800)	7.16 (6.93 to 7.38)	$185 (Cost saving to $338)	0.060 (0.009 to 0.115)	$9000 (Cost saving to $19 000)
Men	$63 200 ($63 000 to $63 900)	6.82 (6.59 to 7.04)	$271 ($106 to $407)	0.059 (0.009 to 0.115)	$11 000 ($1000 to $21 000)
Men: equity analysis‡	$69 300 ($69 100 to $69 900)	7.65 (7.37 to 7.92)	$325 ($163 to $475)	0.071 (0.011 to 0.138)	$10 000 ($2000 to $18 000)
Women	$79 500 ($78 600 to $81 200)	7.30 (7.08 to 7.52)	$127 (Cost saving to $307)	0.059 (0.009 to 0.115)	$8000 (Cost saving to $19 000)

ICERs rounded to the nearest $1000. Other values are rounded to three meaningful digits.
†As Māori have higher background mortality rates and higher morbidity, this essentially 'penalises' health gain for Māori in the standard analyses. So we present an equity analysis with non-Māori morbidity and mortality rates applied to Māori (ie, expanding the envelope of potential health gain for Māori).
‡As men have higher background mortality rates, this essentially 'penalises' health gain for men in the analyses. So we present an equity analysis with women's morbidity and mortality rates applied to men.
HSAM, home safety assessment and modification; ICER, incremental cost-effectiveness ratio; NZ, New Zealand; QALYs, quality-adjusted life-years; UI, uncertainty interval.

Third, because New Zealand Health Tracker and the Accident Compensation Corporation injury claims registry were not individually linked, in combining counts for injurious falls from these registries, we may have slightly overestimated the number of injured fallers each year. For example, a person who fell with a hospitalisation would have been counted as an injured faller in the New Zealand Health Tracker data, and if the person fell again in the same year, but without requiring hospitalisation, they would have also appeared as an injured faller in the Accident Compensation Corporation injury claims registry, and thus would have been counted as two fallers. We assumed that the healthcare events registered in the official injury claims registry excluded hospitalisation, but a small number of hospitalisation events were likely included in the registry. Moreover, because a small number of hospitalisations were likely double counted (due to being registered in both the official hospitalisation and injury claims registries), health gains may have been slightly overestimated and hence the resulting ICER may have appeared more favourable than otherwise.

Fourth, in terms of non-fall-related background health costs, there were likely higher such costs for injured fallers than for other citizens of the same age and gender. But our model did not account for this. However, other factors might have shifted it in the other direction (eg, cost savings from preventing falls in younger people—especially in Western societies like NZ with relatively high levels of hazardous alcohol use). Fifth, while we assumed that the effectiveness measure on the rate of falling was equal to the rate of injurious falls, it is possible that HSAM has a different effect on all falls compared with just injurious falls.

Generalisability

This study is likely to have some generalisability to the general community-dwelling population of older adults (65 years and above) residing in private dwellings in other high-income countries. In particular, it may be generalisable to other countries with similar burden of disease from injurious falls and with substantially publicly funded health systems. Nevertheless, relatively low labour costs for the HSAM intervention may have reduced costs in NZ compared with other Organisation for Economic Co-operation and Development countries. In contrast, though health savings might be less in this model compared with countries with more expensive health systems on a per capita basis.

Potential policy and research implications

Given the results of this study and the other international literature (see *Introduction*), HSAM is likely to be a highly cost-effective policy intervention to reduce injurious falls in community-dwelling older people in high-income country settings. If upfront intervention costs are a concern, then targeting this intervention to older adults with a prior injurious fall could potentially be an optimal place for policymakers to start, as it would provide the opportunity to collect better data on the exact costs and feasibility of the intervention, before scaling HSAM up. However, HSAM is unlikely to impact on relative health inequalities and so policymakers should look to other interventions to achieve this particular goal.

In settings where a government could not mobilise resources for an HSAM intervention, it could still consider researching the effectiveness and cost-effectiveness of such alternative options as: (i) running a mass media education campaign to encourage do-it-yourself home modifications to reduce the risk of falls, (ii) regulations that require all rental properties to have state-of-the-art home modifications for falls prevention and/or (iii) regulations that require all newly built homes to have such modifications. Of these interventions, it is possible that the rental property intervention might have greater scope for equity gain by benefiting the lower income elderly who disproportionately use rental accommodation.

Conclusions

This study provides modelling-level evidence that the HSAM intervention can produce considerable health gain and is likely to be highly cost-effective among older people in a high-income country setting. Targeting HSAM to older people with previous injurious falls appeared to reduce upfront intervention costs and improved the cost-effectiveness, but reduced total health gain. While the HSAM intervention benefited all gender and ethnic groups of the older population, it did so equally and so did not contribute to changes in relative inequalities.

What is already known on this subject

- There is good evidence that home safety assessment and modification (HSAM) is both effective and cost-effective for preventing falls in older people.
- But there are many aspects which are still unclear such as the relative cost-effectiveness of targeting HSAM to people with previous injurious falls, targeting certain age groups (eg, those aged 75 years and above), and the impacts on health inequalities.

What this study adds

- This study found that HSAM was likely to be highly cost-effective in this national population (at US$6000 per quality-adjusted life-years gained, 95% uncertainty interval: cost saving to US$13 000).
- Targeting HSAM only to older people with previous injurious falls was even more cost-effective, suggesting that this is where programmes with limited start-up funds could begin.
- There was no evidence for differential cost-effectiveness by gender or by ethnicity (Indigenous New Zealanders: Māori vs non-Māori).

Acknowledgements We thank the Ministry of Health for access to the official hospitalisation registry and the Accident Compensation Corporation for provision of the aggregated data from the official accident compensation claims registry. Any views/conclusions in this publication are those of the authors and may not reflect the position of the Ministry of Health or Accident Compensation Corporation. We also thank Associate Professor Michael Keall and Dr Nevil Pierse (both University of Otago) who provided assistance and cost data from their randomised controlled trial. We also thank Professor Michael Baker and Dr Melissa McLeod (both University of Otago) for their feedback on an earlier draft of this paper.

Contributors FP lead the overall study design and development. GK lead and all other authors contributed to model development. FP lead and all authors contributed to the interpretation of findings and the development of the manuscript.

Funding This study was conducted as part of the BODE^3 of the University of Otago. This programme is primarily funded by the Health Research Council of New Zealand (grant no: 10/248). This study was funded through this programme and also the University of Otago via a Health Sciences Career Development Postdoctoral Fellowship to Pega. No financial disclosures were reported by the authors of this paper.

Competing interests None declared.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1 WHO. *The economics of social determinants of health and health inequalities*. Geneva, Switzerland: World Health Organization (WHO), 2013.
2 Thomson H, Thomas S, Sellstrom E, *et al*. Housing improvements for health and associated socio-economic outcomes. *Cochrane Database Syst Rev* 2013;2:CD008657.
3 Fenwick E, Macdonald C, Thomson H. Economic analysis of the health impacts of housing improvement studies: a systematic review. *J Epidemiol Community Health* 2013;67:835–45.
4 Pega F, Wilson N. A systematic review of health economic analyses of housing improvement interventions and insecticide-treated bednets in the home. *PLoS ONE* (in press).
5 Cumming RG, Thomas M, Szonyi G, *et al*. Home visits by an occupational therapist for assessment and modification of environmental hazards: a randomized trial of falls prevention. *J Am Geriatr Soc* 1999;47:1397–402.
6 Pynoos J, Steinman BA, Nguyen AQ. Environmental assessment and modification as fall-prevention strategies for older adults. *Clin Geriatr Med* 2010;26:633–44.
7 Gillespie LD, Robertson MC, Gillespie WJ, *et al*. Interventions for preventing falls in older people living in the community. *Cochrane Database Syst Rev* 2012;9:CD007146.
8 World Health Organization. Falls: fact sheet No. 344 http://www.who.int/mediacentre/factsheets/fs344/en/2012
9 Frick KD, Kung JY, Parrish JM, *et al*. Evaluating the cost-effectiveness of fall prevention programs that reduce fall-related hip fractures in older adults. *J Am Geriatr Soc* 2010;58:136–41.
10 Jutkowitz E, Gitlin LN, Pizzi LT, *et al*. Cost effectiveness of a home-based intervention that helps functionally vulnerable older adults age in place at home. *J Aging Res* 2012;2012:680265.
11 Kochera A. Falls among older persons and the role of the home: an analysis of cost, incidence, and potential savings from home modification. *Issue Brief (Public Policy Inst (Am Assoc Retired Pers))* 2002:1–14.
12 Ling C, Henderson S, Henderson R, *et al*. Cost benefit considerations of preventing elderly falls through environmental modifications to homes in Hana, Maui. *Hawaii Med J* 2008;67:65–8.
13 Smith RD, Widiatmoko D. The cost-effectiveness of home assessment and modification to reduce falls in the elderly. *Aust N Z J Public Health* 1998;22:436–40.
14 Salkeld G, Cumming RG, O'Neill E, *et al*. The cost effectiveness of a home hazard reduction program to reduce falls among older persons. *Aust N Z J Public Health* 2000;24:265–71.
15 Church J, Goodall S, Norman R, *et al*. The cost-effectiveness of falls prevention interventions for older community-dwelling Australians. *Aust N Z J Public Health* 2012;36:241–8.
16 Campbell AJ, Robertson MC, La Grow SJ, *et al*. Randomised controlled trial of prevention of falls in people aged > or=75 with severe visual impairment: the VIP trial. *BMJ* 2005;331:817.
17 Blakely T, Foster R, Wilson N, BODE³ Team. *Burden of Disease Epidemiology, Equity and Cost-Effectiveness (BODE3) Study Protocol. Version 2.1. Technical Report No.3*. Wellington: Department of Public Health, University of Otago, December 2012. http://www.otago.ac.nz/wellington/otago042986.pdf
18 Salomon JA, Vos T, Hogan DR, *et al*. Common values in assessing health outcomes from disease and injury: disability weights measurement study for the Global Burden of Disease Study 2010. *Lancet* 2012;380:2129–43.
19 Ministry of Health, Accident Compensation Corporation. *Injury-related health loss: a report from the New Zealand Burden of Diseases, Injuries and Risk Factors Study 2006–2016*. Wellington, New Zealand: Ministry of Health, 2013.
20 Blakely T, Atkinson J, Kvizhinadze G, *et al*. Updated New Zealand health system cost estimates from health events by sex, age and proximity to death: further improvements in the age of 'big data'. *N Z Med J* 2015;128:13–23.
21 Turner S, Arthur G, Lyons RA, *et al*. Modification of the home environment for the reduction of injuries. *Cochrane Database Syst Rev* 2011(2):CD003600.
22 Keall MD, Pierse N, Howden-Chapman P, *et al*. Home modifications to reduce injuries from falls in the Home Injury Prevention Intervention (HIPI) study: a cluster-randomised controlled trial. *Lancet* 2015;385:231–8.
23 WHO. *Cost effectiveness and strategic planning (WHO-CHOICE): cost-effectiveness thresholds*. World Health Organization (WHO), 2014. http://www.who.int/choice/costs/CER_thresholds/en/

Home safety assessment and modification to reduce injurious falls in community-dwelling older adults: cost -utility and equity analysis

Frank Pega, Giorgi Kvizhinadze, Tony Blakely, June Atkinson and Nick Wilson

Inj Prev published online May 24, 2016