ORIGINAL ARTICLE

# Reducing hazard related falls in people 75 years and older with significant visual impairment: how did a successful program work?

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**Background:** In a randomized controlled trial testing a home safety program designed to prevent falls in older people with severe visual impairment, it was shown that the program, delivered by an experienced occupational therapist, significantly reduced the numbers of falls both at home and away from home.
**Objectives:** To investigate whether the success of the home safety assessment and modification intervention in reducing falls resulted directly from modification of home hazards or from behavioral modifications, or both.
**Methods:** Participants were 391 community living women and men aged 75 years and older with visual acuity 6/24 meters or worse; 92% (361 of 391) completed one year of follow up. Main outcome measures were type and number of hazards and risky behavior identified in the home and garden of those receiving the home safety program, compliance with home safety recommendations reported at six months, location of all falls for all study participants during the trial, and environmental hazards associated with each fall.
**Results:** The numbers of falls at home related to an environmental hazard and those with no hazard involved were both reduced by the home safety program (n = 100 participants) compared with the group receiving social visits (n = 96) (incidence rate ratios = 0.40 (95% confidence interval, 0.21 to 0.74) and 0.43 (0.21 to 0.90), respectively).
**Conclusions:** The overall reduction in falls by the home safety program must result from some mechanism in addition to the removal or modification of hazards or provision of new equipment.

Older people with visual impairment fall more often than those with normal sight.[1–3] Although falls generally result from multiple contributing factors,[4 5] it may be that environmental hazards are a more common cause of falls in this population. People with visual impairment may not see a hazard, may overcorrect while stepping around a perceived hazard, and may have difficulty in identifying sources of support if they stumble.

We conducted a randomized controlled trial to test the efficacy and cost-effectiveness of two interventions aimed at reducing falls in a population aged 75 years and older whose visual impairment was sufficiently severe to entitle them to be registered with the Royal New Zealand Foundation of the Blind.[6] We tested a program to address safety in the home environment by identifying and then recommending the removal or modification of hazards, providing new equipment or making behavioral changes, and a program of strength and balance retraining (the Otago Exercise Programme[7]) plus vitamin D supplements. We found that the home safety program but not the exercise program significantly reduced the number of falls in study participants during the one year trial (incidence rate ratios = 0.59 (95% confidence interval (CI), 0.42 to 0.83) and 1.15 (0.82 to 1.61), respectively).

The efficacy of the home safety program, rather than being limited to the home environment where the intervention took place, also resulted in a significant reduction in falls away from home (ratio of incidence rate ratios 0.60 (95% CI, 0.31 to 1.17)).[6] Therefore it was not clear whether some mechanism apart from the removal of environmental hazards or behavioral changes led, or partially led, to the significant reduction in falls both at home and away from home.

The purpose of this paper was to investigate whether or not the success of the home safety intervention in reducing falls in people with poor vision resulted directly from removal or alteration of home hazards and behavioral modifications.

## METHODS

### Overview of the trial

This was a randomized controlled trial (international standard randomized controlled trial number ISRCTN15342873) with a 2×2 factorial design and one year of follow up. The main outcome results, the sample size calculation which was based on the number of falls, the randomization process, details of the exercise intervention, assessments conducted at baseline, and the flow of participants through the trial have been reported.[6] The Otago and Auckland ethics committees gave ethical approval for the study.

Women and men (n = 391) in Dunedin and Auckland, New Zealand, were recruited from the register of the Royal New Zealand Foundation of the Blind and from patients attending low vision clinics. Those who were 75 years and older, had a distance visual acuity of 6/24 meters or worse in the better eye after the best possible correction, and lived in the community, were ambulatory, and understood the requirements of the trial, were invited to participate. The majority (88%) reported they had age related macular degeneration.

After baseline assessments were completed, individual participants in each of the two cities were randomly allocated to receive the following interventions:

- a home safety program (n = 100);
- the Otago Exercise Programme[7] plus vitamin D supplements (n = 97);
- both the home safety program and the exercise program (n = 98);
- social visits only (n = 96).

**Table 1** Hazards and risky behavior identified at the initial home visit to home safety program participants, recommendations agreed for action, and compliance with the recommendations at six months

| Location/type of hazard (relevant number of homes) | Participants or homes with hazard identified (n = 194) | Recommendations for change with participant agreeable (n = 194) | Recommendations actioned/partially actioned at 6 months (n = 169) |
|---|---|---|---|
| *External traffic ways* | | | |
| Steps/stairs (n = 172) | 90 | 60 | 45 |
| Path/driveways (n = 191) | 64 | 38 | 23 |
| Hand rails | | | |
| Stairs (n = 115) | 56 | 49 | 45 |
| Ramps (n = 25) | 2 | 1 | 1 |
| Doormat at entrance (n = 187) | 40 | 28 | 20 |
| Garage (n = 128) | 13 | 6 | 4 |
| Doorway to home (n = 194) | 12 | 8 | 5 |
| Exterior lighting (n = 194) | 9 | 4 | 3 |
| Gates (n = 80) | 7 | 4 | 4 |
| Ramps (n = 30) | 6 | 3 | 3 |
| *Internal spaces* | | | |
| Floor mats (n = 187) | 146 | 64 | 58 |
| Indoor lighting (n = 194) | 77 | 39 | 20 |
| Grab rails | | | |
| Shower (n = 122) | 26 | 14 | 13 |
| Bath (n = 67) | 22 | 14 | 13 |
| Toilet (n = 109) | 22 | 10 | 8 |
| Kitchen workplace (n = 194) | 51 | 24 | 20 |
| Internal walkways (n = 194) | 44 | 27 | 19 |
| Shower (n = 129) | 36 | 26 | 22 |
| Bath (n = 90) | 34 | 14 | 7 |
| Floors and carpets (n = 194) | 26 | 8 | 6 |
| Tidiness/cleanliness (n = 194) | 17 | 4 | 3 |
| Steps/stairs (n = 49) | 16 | 6 | 3 |
| Seating (n = 194) | 16 | 12 | 8 |
| Hand rails | | | |
| Stairs (n = 42) | 12 | 5 | 4 |
| Ramps (n = 4) | 0 | 0 | |
| Toilet area (n = 194) | 12 | 3 | 1 |
| Doorways (n = 194) | 6 | 2 | 1 |
| Bed (n = 194) | 4 | 2 | 1 |
| Ramps (n = 4) | 3 | 0 | 0 |
| *Other* | | | |
| Mobility aid (n = 171) | 24 | 24 | 21 |
| Footwear (n = 194) | 9 | 8 | 6 |
| Therapeutic drugs (n = 191) | 1 | 1 | 1 |

## Home safety program

The home safety assessment and modification program was specifically designed for people with severe visual impairments. Occupational therapists (one in each of the two cities) attended a two day training course before visiting each person randomized to receive the home safety program. Although not a formal component of the intervention, the clinical approach by the occupational therapists was guided by the client centered Canadian Model of Occupational Performance. They used a modified version of the Westmead home safety assessment checklist[8] to identify potential hazards, lack of equipment, and risky behavior which might lead to falls, and to prompt a discussion about actions for reducing or minimizing the hazards. Agreement was reached with the participant about which particular actions would be undertaken and whether the person, a family member, the occupational therapist, or some other agency would carry out the recommendation. This was confirmed in a follow up letter to the participant. The occupational therapist facilitated the provision of new equipment and payment from a variety of usual sources, depending on the price and type of item. Referrals were made to the Royal New Zealand Foundation of the Blind for assessment for mobility aids and other services, and to community occupational therapists for the installation of safety equipment such as hand rails and shower stools. A second home visit was needed when certain providers required the occupational therapist to confirm that the equipment had been installed.

## Exercise program

The one year exercise intervention consisted of the Otago Exercise Programme,[7] modified for those with severe visual acuity loss, with vitamin D supplementation. The physiotherapist individually prescribed the exercises during five home visits. Participants were expected to exercise at least three times a week (about 30 minutes a session) and to walk, if walking outside could be done safely, at least twice a week for a year. For the months with no scheduled home visit the physiotherapist telephoned to encourage the person to maintain motivation and discuss any problems.

## Social visits

Research staff made two home visits lasting an hour each during the first six months of the trial to participants who were not randomized to either the exercise or the home safety programs.

## Outcome measures

The environmental hazards and any risky behavior observed in each home at the initial visit were coded from the

**Table 2** Location of falls associated with an environmental hazard for each group

| Location | Home safety + exercise programs (n = 98) | | Home safety program alone (n = 100) | | Exercise program alone (n = 97) | | Social visits (n = 96) | | Total (n = 391) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total falls | Hazard related falls (% total falls) | Total falls | Hazard related falls (% total falls) | Total falls | Hazard related falls (% total falls) | Total falls | Hazard related falls(% total falls) | Total falls | Hazard related falls (% total falls) |
| *At home* | | | | | | | | | | |
| Bedroom | 18 | 5 (28%) | 8 | 6 (75%) | 24 | 7 (29%) | 22 | 9 (41%) | 72 | 27 (38%) |
| Living or dining room | 14 | 8 (57%) | 7 | 4 (57%) | 14 | 3 (21%) | 22 | 11 (50%) | 57 | 26 (46%) |
| Kitchen | 1 | 1 (100%) | 7 | 4 (57%) | 5 | 1 (20%) | 8 | 4 (50%) | 21 | 10 (48%) |
| Stairs | 3 | 3 (100%) | 1 | 1 (100%) | 3 | 3 (100%) | 6 | 6 (100%) | 13 | 13 (100%) |
| Hallway | 2 | 0 (0) | 4 | 2 (50%) | 7 | 2 (29%) | 3 | 1 (33%) | 16 | 5 (31%) |
| Bathroom | 5 | 4 (80%) | 7 | 0 (0) | 1 | 0 (0) | 10 | 4 (40%) | 23 | 8 (35%) |
| Entrance to home | 11 | 10 (91%) | 4 | 2 (50%) | 6 | 5 (83%) | 10 | 8 (80%) | 31 | 25 (81%) |
| Other inside own home | 5 | 1 (20%) | 2 | 2 (100%) | 2 | 0 (0) | 9 | 2 (22%) | 18 | 5 (28%) |
| Outside in own property | 24 | 13 (54%) | 8 | 4 (50%) | 15 | 10 (67%) | 21 | 14 (67%) | 68 | 41 (60%) |
| Total at home | 83 | 45 (54%) | 48 | 25 (52%) | 77 | 31 (40%) | 111 | 59 (53%) | 319 | 160 (50%) |
| *Away from home* | | | | | | | | | | |
| Outside | 11 | 11 (100%) | 5 | 4 (80%) | 21 | 18 (86%) | 12 | 10 (83%) | 49 | 43 (88%) |
| Inside building | 3 | 2 (67%) | 6 | 5 (83%) | 6 | 4 (67%) | 15 | 9 (60%) | 30 | 20 (67%) |
| Transport related | 2 | 2 (100%) | – | – | 8 | 7 (88%) | 2 | 1 (50%) | 12 | 10 (83%) |
| Total away from home | 16 | 15 (94%) | 11 | 9 (82%) | 35 | 29 (83%) | 29 | 20 (69%) | 91 | 73 (80%) |
| Total (known mechanism and location) | 99 | 60 (61%) | 59 | 34 (58%) | 112 | 60 (54%) | 140 | 79 (56%) | 410 | 233 (57%) |
| Mechanism not known | 2 | | 3 | | 2 | | 4 | | 11 | |
| Location not known | 7 | | 2 | | 6 | | 7 | | 22 | |
| Total during trial | 108 | | 64 | | 120 | | 151 | | 443 | |

Incidence rate ratio for hazard related falls for the home safety program only group (n = 100) *v* social visits (n = 96 ) 0.40 (95% confidence interval 0.21 to 0.74) and for non-hazard related falls 0.43 (0.21 to 0.90).

assessment checklist. Agreed recommendations for change were documented. Adherence to the recommendations was evaluated during a telephone interview by the occupational therapist six months after study entry. The participant reported whether each agreed recommendation for home modifications and behavior change had been actioned, partially actioned, or not carried out.

Falls were defined as ''unintentionally coming to rest on the ground, floor, or other lower level''.[9] Falls were monitored for one year for each person using return addressed, postage paid, tear off monthly postcard calendars. The independent assessor in each city (GAC and KH) telephoned participants to record the circumstances of the falls. They remained blind to group allocation. One of the assessors (GAC) coded the location of each fall and up to two environmental hazards, if any were associated with the fall. Hazards included objects such as furniture, cords, loose mats, footwear, steps, stairs, curbs, wet surfaces, and footpath irregularities—that is, objects or environmental conditions with the potential to disturb balance and contribute to a fall. We defined a hazard related fall as a fall in which at least one hazard was implicated. Falls were divided into those occurring ''at home'' (inside the person's home or in their own property, which included entrance ways and the garden) and ''away from home''.

### Statistical analysis

Data were analyzed on an intention to treat basis using the statistical packages Stata Release 7 and SPSS 11. We summarized the hazards identified at the initial home visit and compliance with recommendations for change for all those receiving the home safety program. We summarized the types of hazard associated with all falls and the location of falls for all participants in the trial.

The trial had a 2×2 factorial design, and our main outcome analysis showed that there was an unexpected significant interaction between the exercise and the home safety programs (interaction ratio for falls = 2.28 (95% CI, 1.17 to 4.45)).[6] As this indicates a different pattern in the reduction of falls by the home safety and exercise programs (the home safety program significantly reduced falls; the exercise program did not), it is possible that the two programs may have affected the risk associated with an environmental hazard in different ways. Therefore to estimate the effect of the home safety program on hazard related and non-hazard-related falls, we confined our comparison of fall events to the group receiving the home safety program alone (n = 100) with those receiving the social visits (n = 96).[10] We compared the number of hazard related falls (dependent variable) at home (inside the person's home, at entrances, and in the garden), the location where environmental and behavioral changes were made, between these two groups (independent variable) using a negative binomial regression model.[11] We adjusted for individual follow up times (exposure) of participants in the trial. We repeated the model using non-hazard-related falls as the dependent variable. We included all falls in the two groups in our analyses—that is, until the first of the following events: the person died, withdrew from the trial, or completed 12 months.

## RESULTS

### Home safety program delivery and follow up

The occupational therapists made an initial home visit to 194 of the 198 participants allocated to receive the home safety program; four refused the visit. In all, 903 hazards were recorded on the checklists at this visit, an average of 4.7 hazards per home, and 508 recommendations for change, or 2.6 per person, were made by the occupational therapist and agreed to by the participants. The location of the hazards identified and the recommendations for change are summarized in table 1. Removal, modification, or replacement of loose mats inside the home or at the entrance (92 recommendations), repairing or painting contrast strips on outside steps (60), installation of hand rails for outside stairways (50), improving lighting (43), and installing grab rails in the bathroom, shower, or toilet (38) were the most common recommendations suggested and agreed to by the participants.

The six month follow up telephone call was completed by the occupational therapists for 85% of home safety group participants (169 of 198). The reasons for not completing the six month follow up, apart from the four who refused the initial visit, were that no recommendations for change were made at the initial home visit for 10 participants (5%), three had died, eight had moved to long term care, and four were lost to follow up.

At follow up 90% (152 of 169) reported complying partially or completely with one or more of the recommendations made by the occupational therapist, with action taken on an average of 2.3 recommendations per participant. In all, 78 participants reported fully or partially complying with the recommendations to remove, repair, modify, or replace loose mats inside the home or at the entrance (table 1). In 46 homes hand rails had been installed or repaired and in 45 homes some action had been taken to improve the safety and visibility of steps or stairways leading to the entrance. Grab rails had been installed in 34 bathrooms or toilets, safety matting or a stool had been provided for 22 showers, lighting had been improved in 23 homes, and 21 mobility aids were provided or repaired.

There were no differences in the numbers of recommendations agreed to or actioned by participants receiving the home safety program only, compared with those receiving both the home safety and the exercise programs (mean (SD) number of recommendations agreed to = 2.5 (2.2) and 2.7 (1.9), respectively, for the two groups ($p = 0.446$); and number of recommendations actioned or partially actioned = 2.2 (1.8) and 2.4 (1.7) ($p = 0.310$).

### Hazard related and non-hazard-related falls

The location of all falls during the trial and the numbers of falls in each location that were associated with an environmental hazard are summarized for the four groups in table 2. There were 443 falls reported during the one year trial, 410 for which both the location and circumstances were known. Of these, 251 (61% of 410) occurred inside the person's home and 68 outside in the person's own property; 91 falls (22% of 410) occurred away from home. In 233 falls (57% of 410) recorded during the trial, an environmental factor was clearly associated with the fall. Of hazard related falls, 160 (39% of 410) occurred at home, and 73 (18%) away from home. For 10 falls, a second hazard was also associated with the fall.

Steps, stairs, and kerbs were the most common hazard associated with a fall (70 falls, 30% of all hazard related falls; 46 at home and 24 away from home) (table 3). A piece of furniture (36) or other object (65) together made up 42% of the hazards, 14 falls (6% of hazards) resulted from a wet surface, 12 (5%) were associated with an irregular footpath, 12 (5%) with a loose mat, and eight (3%) were attributed to footwear.

The comparison of the numbers of falls at home (inside the home, at entrances, or in the garden) associated with an environmental hazard and those with no hazard involved showed that both hazard related and non-hazard-related falls were reduced by a similar amount for those in the home safety program only group (n = 100 participants) compared with the group receiving social visits (n = 96). For hazard related falls at home (25 *v* 59 falls) the incidence rate ratio

**Table 3** Description of hazards associated with falls*

| Hazard | Home safety program (n = 198) | No home safety program (n = 193) | Total (n = 391) |
|---|---|---|---|
| *Inside own home* | | | |
| Furniture | 8 | 23 | 31 |
| Miscellaneous object | 9 | 13 | 22 |
| Steps/stairs | 6 | 7 | 13 |
| Loose mat | 2 | 8 | 10 |
| Wet surface | 4 | 1 | 5 |
| Footwear | 3 | 4 | 7 |
| Cords on floor | 4 | 0 | 4 |
| Other | 6 | 1 | 7 |
| *Entrance to home* | | | |
| Steps/stairs | 11 | 9 | 20 |
| Loose mat | 0 | 1 | 1 |
| Wet surface | 1 | 2 | 3 |
| Other | 0 | 3 | 3 |
| *Outside in own property* | | | |
| Miscellaneous object | 8 | 14 | 22 |
| Steps/footpath | 7 | 6 | 13 |
| Wet surface | 0 | 2 | 2 |
| Other | 2 | 2 | 4 |
| *Away from home* | | | |
| Outside | | | |
| Miscellaneous object | 3 | 12 | 15 |
| Footpath irregularities | 5 | 7 | 12 |
| Steps/stairs | 4 | 8 | 12 |
| Wet surface | 0 | 3 | 3 |
| Other | 3 | 1 | 4 |
| Inside building | | | |
| Furniture | 2 | 3 | 5 |
| Loose mat | 1 | 0 | 1 |
| Steps/stairs | 0 | 4 | 4 |
| Miscellaneous object | 2 | 3 | 5 |
| Wet surface | 0 | 1 | 1 |
| Other | 2 | 2 | 4 |
| Transport related | | | |
| Steps/stairs | 1 | 7 | 8 |
| Footwear | 1 | 0 | 1 |
| Miscellaneous object | 0 | 1 | 1 |
| Total hazards | 95 | 148 | 243 |

*For 10 of the falls, two hazards were associated with the fall.

was 0.40 (95% CI, 0.21 to 0.74); and for non-hazard-related falls (23 *v* 52 falls) the incidence rate ratio was 0.43 (0.21 to 0.90).

## DISCUSSION

The home safety assessment and modification program tested in this randomized controlled trial was effective in preventing falls in older people with severe visual impairment. In this study we investigated why the home safety program worked. We examined the type and location of recommendations for change made by the occupational therapists, the circumstances of all falls during the trial, and the number of falls that were associated with an environmental hazard. There are three potential mechanisms whereby falls during the trial might have been prevented.

The simplest explanation would be that the removal of hazards in this particularly susceptible population of people with visual impairment decreased the number of slips and trips they experienced. The environment was better adapted to their disability. In an Australian study testing a home safety program, a similar proportion of participants complied with recommendations, and falls were reduced by 25% in those older people with a history of a previous fall.[12] Although removal of hazards in our study may have contributed to the lower fall rate—hazard related falls were significantly reduced—this was not the sole explanation. Both non-hazard-related and hazard related falls at home were reduced by a similar amount. In addition, falls away from home were reduced to a similar degree, as also shown in the Australian study.[12]

An alternative explanation is that the individual advice provided by the occupational therapist enabled the elderly visually impaired person to negotiate environmental hazards, both within the home and outside, more safely. The implication of this explanation is that such advice needs to be specific to the needs of the individual and is best delivered by a trained professional such as an occupational therapist. The study by Stevens and colleagues provides some support for this in that the intervention delivered by a research nurse was effective in reducing the number of home hazards but not effective in reducing falls inside the home, hazard related falls, or all falls.[13] In all successful environmental modification fall prevention trials, the interventions have been based on an occupational therapist's assessment.[6 12 14]

A third and less comfortable explanation for the reduction in falls would be that the occupational therapist's visit, in which falls and the need for safety and prevention were discussed, led to an overall reduction in activity and thus risk of falling. In this trial there was a significant interaction between the exercise intervention, which stressed increased activity, and the home modification intervention.[6] It is possible that the occupational therapist's intervention is less effective when the person is also being encouraged to be more active. This would be so if part of the success of the occupational therapist was a result of subsequent limitation of activity. We did test the effect of the interventions on activity levels using the Human Activity Profile, which showed no change, but this measure may not be sufficiently sensitive for this purpose. A more detailed and valid assessment in a trial of participants' activity levels before and after an occupational therapist's fall prevention visit would clarify this important issue.

It is also possible that the fall reduction in this trial resulted from a combination of reasons that vary from person to person.

### Limitations of the study

When originally planning the study, we had not expected an interaction effect between the home safety and exercise program. As a result, the study sample size was based on the number of falls expected during the one year follow up time for all participants.

Hazards in the home were assessed for those receiving the home safety program only. Thus we do not know if the homes differed across groups. However, given the sample size it is most unlikely that there were important differences

### Key points

- Older people with poor vision are at increased risk of falling.
- A home safety assessment and modification program delivered by an experienced occupational therapist was effective in reducing falls both at home and away from home in older people with severe visual impairment.
- Falls at home associated with an environmental hazard were reduced by the same amount as non-hazard-related falls.
- The overall reduction in falls by the home safety program must result from some mechanism in addition to the removal or modification of hazards or provision of new equipment.

between the homes of the intervention and the control groups. Compliance to recommendations was self report only.

### Implications for health care service

The average cost per person for delivering the program in 2004 was $NZ325 (SD 292) (average £117, €172, $US215). The major cost items were the occupational therapist's time and travel costs, the services provided to participants, and the installation of new equipment. This compares favorably with the costs of other fall prevention programs.

Current evidence indicates that if home modification programs are to be successful in reducing falls they must be delivered to selected populations such as those with severe visual impairment and those recently discharged from hospital. All successful randomized controlled trials have used an occupational therapist to deliver the program.

### Conclusions

The significant reduction in falls in this study of elderly people with severe vision loss was not restricted to falls associated with an environmental hazard. An occupational therapist's home safety assessment, advice, and facilitation of appropriate modifications resulted in a significant reduction of both hazard related falls and those with no environmental hazard implicated.

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