Preventing Falls in Older People: Outcome Evaluation of a Randomized Controlled Trial

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OBJECTIVES: To evaluate the outcome of an intervention to reduce hazards in the home on the rate of falls in seniors.

DESIGN: Randomized controlled trial, with follow-up of subjects for 1 year.

SETTING: Community-based study in Perth, Western Australia.

PARTICIPANTS: People age 70 and older.

INTERVENTION: One thousand eight hundred seventy-nine subjects were recruited and randomly allocated by household to the intervention and control groups in the ratio 1:2. Because of early withdrawals, 1,737 subjects commenced the study. All members of both groups received a single home visit from a research nurse. Intervention subjects (n = 570) were offered a home hazard assessment, information on hazard reduction, and the installation of safety devices, whereas control subjects (n = 1,167) received no safety devices or information on home hazard reduction.

MEASUREMENTS: Both groups recorded falls on a daily calendar. Reported falls were confirmed by a semistructured telephone interview and were assigned to one of three overlapping categories: all falls, falls inside the home, and falls involving environmental hazards in the home. Analysis was by multivariate modelling of rate ratios and odds ratios for falls, corrected for household clustering, using Poisson regression and logistic regression with robust variance estimation.

RESULTS: Overall, 86% of study subjects completed the 1 year of follow-up. The intervention was not associated with any significant reduction in falls or fall-related inju-ries. There was no significant reduction in the intervention group in the incidence rate of falls involving environmental hazards inside the home (adjusted rate ratio, 1.11; 95% CI = 0.82–1.50), or the proportion of the intervention group who fell because of hazards inside the home (adjusted odds ratio, 0.97; 95% CI = 0.74–1.28). No reduction was seen in the rate of all falls (adjusted rate ratio, 1.02; 95% CI = 0.83– 1.27) or the rate of falls inside the home (adjusted rate ratio, 1.17; 95% CI = 0.85–1.60). There was no significant reduction in the rate of injurious falls in intervention subjects (adjusted rate ratio, 0.92; 95% CI = 0.73–1.14).

CONCLUSIONS: The intervention failed to achieve a reduction in the occurrence of falls. This was most likely because the intervention strategies had a limited effect on the number of hazards in the homes of intervention subjects. The study provides evidence that a one-time intervention program of education, hazard assessment, and home modification to reduce fall hazards in the homes of healthy older people is not an effective strategy for the prevention of falls in seniors. **J Am Geriatr Soc 49:1448–1455, 2001.**
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Falls are a significant health problem for older people and the healthcare sector, because of the short- and long-term morbidity caused by fall injuries and the consequent demand for healthcare services.[1–5]

The majority of fall-related injuries occur in seniors living independently in the community, often as they move around their home and come into contact with environmental hazards.[6–9] This has led to the proposition that removal or modification of tripping and slipping hazards in the home can reduce falls by seniors.[9–16] Although this hypothesis has hitherto not been properly tested, it is a strategy of a number of current public health programs to prevent falls.[17,18]

This paper reports the findings of a randomized controlled trial to test the hypothesis that an intervention to encourage removal or modification of environmental hazards in the home will reduce the incidence of falls in com-

munity-dwelling seniors. Additional background details, the intervention strategies, and the impact of these strategies on the prevalence of fall hazards in the home are reported in an accompanying paper.[19]

METHODS

Study Design

The study was a randomized controlled trial with a clustered design such that the individual household was the unit for randomization. The target population was people age 70 and older living independently in the Perth metropolitan area. One or two subjects per household were allocated in a 2:1 ratio to either the control or intervention group and were requested to record all falls on a daily calendar. Follow-up of each subject was for 12 months, with recruitment commencing in July 1995 and follow-up ceasing in November 1996. Ethics approval for the research was obtained from the Human Rights Committee of The University of Western Australia.

Recruitment

Two recruitment strategies were used. The primary strategy recruited people selected at random from the State Electoral Roll (the index recruit), and a secondary strategy recruited seniors who cohabited with an index recruit (secondary recruits).

Recruitment of Index Participants

The sampling frame was the population of people age 70 and older living independently in the Perth metropolitan area and listed on the State Electoral Roll and the White Pages telephone directory. A unique number was allocated to each person in the population, and a sample was selected using random numbers. After removal of deceased persons, by reference to a look-up table of registered deaths, and persons living at the same address as more than two other older people (to exclude people from an institutional setting), the sample was cross-linked to the electronic White Pages.[20]

A sample of this population was selected by choosing every fifth name on the cross-linked list, with oversampling of the population age 80 and older to match the age and sex distribution of the estimated resident population of the metropolitan area. A written invitation to participate in the study was sent to these 9,411 seniors, and telephone contact, with a maximum of four telephone calls to each person, was made in the week following dispatch of the letter.

Once telephone contact was made, the interviewer described the project in more detail, invited participation, and screened people who agreed to participate against the inclusion criteria.

Recruitment of Secondary Participants

Index recruits enrolled in the study were asked whether they shared the house with another person age 70 and older who might be eligible to participate. If so, separate telephone contact was made with this person, they were invited to participate, and the inclusion criteria were administered in an identical fashion to that used with the index recruit.

Inclusion Criteria

The inclusion criteria identified people who:

- were able to follow the study protocol (Subjects were required to be cognitively intact, able to speak and write in English.);
- could contribute substantial person-time to the study (Subjects anticipated living at home for at least 10 of the 12 coming months.);
- could make changes to the environment inside the home; and
- had not modified their home by the fitting of ramps or grab rails.

Allocation

The study population was divided into four strata, defined by age (<80 years and ≥80 years) and sex. Within these four age-sex strata, index recruits were allocated in a 2:1 ratio to either the control (C) or the intervention (I) group, in the order C-C-I. Recruitment and allocation were by different recruitment officers, who were unaware of each others' activities, and therefore the allocation of subjects was concealed before obtaining their agreement to participate and determining their experimental status from the applicable stratum of the allocation log. Secondary recruits were placed by necessity into the same intervention group as the primary recruit with whom they cohabited. Participants were unaware of their intervention status.

Home Visit

Seven research nurses were trained to conduct the home visits. Each research nurse was trained in the use of all study resources and conducted home visits to both intervention and control group members. Before the home visit, all participants were sent information on what the study would be asking of them. Members of the intervention group were sent additional information on the intervention and the fall reduction strategies to be offered.

Each participant was visited at home during the week after recruitment. The visit followed a structured protocol, which consisted of confirming the consent for participation in writing and educating participants on how to recognize a fall and how to complete the daily calendar.

Members of the intervention group were also offered the intervention at this home visit. The intervention consisted of three strategies: a home hazard assessment, the installation of free safety devices, and an educational strategy to empower seniors to remove or modify home hazards.[19]

Changes in Environmental Hazards in Intervention and Control Households

Control subjects may have acted to reduce the number of fall hazards in their homes, having been alerted by the daily calendar to the purpose of the study and potential causes of falls. The extent to which such action was taken was assessed by a postal questionnaire sent to the 1,091 control subjects and 527 intervention subjects who remained in the study 11 months after commencement. Responses were received from 1,043 control subjects (96%) and all intervention subjects, with less than 10% missing data for any question.

The change in hazard prevalence in response to the intervention was also evaluated by conducting a second home hazard assessment in a sample of 51 homes 11 months after the commencement of the study, as described in the accompanying report.[19]

Measures of Outcomes

A fall was defined as "an event that results in a person unintentionally coming to rest on the ground, floor or other lower level," an adaptation of that proposed by the Kellogg International Work Group.[21]

A daily calendar was used to record data on falls. Participants were asked to record the numbers of falls on every day in which they were in the study, suspending their recording only if they were absent from their home for two or more consecutive nights. Information on the location, mechanism, and time of each fall was collected. The completed calendar record was returned to the research team at the end of each month using a postage-paid envelope.

All reported falls were confirmed by telephone interview using a structured questionnaire, and further information was collected at that time on the circumstances and consequences of the fall. Sociodemographic data were collected on all participants during the recruitment interview.

Data Analysis

Tabular data were analyzed by frequency distributions using Microsoft Excel.[22] The 95% confidence limits were calculated using the normal approximations to the Poisson distribution for rates and to the binomial distribution for proportions. This enabled estimation of rate and proportion differences and their confidence intervals.

Multivariate modelling was used to estimate the incidence rate ratio of falls (Poisson regression) or the odds ratio of falling (logistic regression) in the intervention group versus the control group while adjusting for potential confounders, which may have been unbalanced even after randomization. Results of both unadjusted and adjusted analyses are presented. Overdispersion of the data occurred because of clustering by household and the lack of true independence of fall events due to the likelihood of falling being influenced by the occurrence of previous falls. Poisson regression incorporating a frailty term using the program RPoisson[23] as implemented in Stata was used to estimate rate ratios and robust standard errors.[24] The degree of correlation between the rates of falls in subjects living in the same house was estimated for each outcome measure by Kendall's tau (frailty variance/2 + frailty variance)[25] in three populations: (1) the whole study cohort, (2) people who fell, and (3) people with a history of falling.

Seven explanatory variables were included in the multivariate models: member of the control or intervention group, age (in years), sex, fall in the year before recruitment, use of a walking aid inside the house, recruitment method (index or secondary recruit), and one or two participants from the household (sole participant). The offset in the Poisson regression models was the number of days of observation a person contributed to the study, so that rates were calculated as falls per person-day and reported as falls per person-year (PY).

RESULTS

Recruitment Results

Overall, 1,561 people, 27% of those contacted by telephone, entered the study as index recruits, and an additional 318 subjects were recruited by the secondary recruitment strategy (Figure 1). The main reason for potential index recruits not satisfying the inclusion criteria was the presence of grab rails in their home. All potential secondary recruits were included.

The 1,879 subjects were randomized to the intervention group (n = 635) or the control group (n = 1,244). Before the initial home visit, 142 subjects withdrew, leaving 1,737 subjects, 570 in the intervention group and 1,167 in the control group. Age, sex, and use of a walking aid were equally distributed between the two experimental groups (Table 1). The intervention group had a lower proportion of sole participants because of more-successful recruitment of secondary recruits into the intervention group and a lower proportion of index recruits because of greater early loss of index recruits.

Loss to Follow-Up

In addition to the 142 subjects who did not commence follow-up, 122 subjects failed to complete the full year of follow-up. These 122 subjects comprised 46 intervention group subjects, who each contributed an average of 0.6 PY to the study, and 76 control group subjects, who each contributed an average of 0.5 PY to the study. The main reasons that subjects left the study were that they moved, became ill, or died. Two hundred sixty-four subjects were lost from the study, with the loss of 111 (17.5%) subjects from the intervention group being significantly larger than the loss of 153 subjects (12.3%) from the control group; $P < .010$.

Epidemiology of Falls

One thousand one hundred forty-five falls occurred during 1,609 PY of follow-up. About one-third of the cohort fell at least once; the overall rate of falls was 71.17/100 PY.
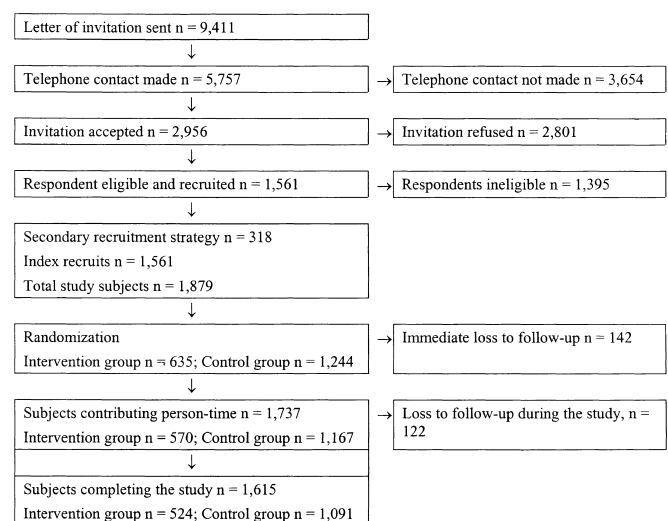

Figure 1. Recruitment results.

Table 1. Distribution of Subject Characteristics in the Intervention and Control Groups

| Characteristics	Intervention Group n = 570		Control Group n = 1,167	
	n	%	n	%
Female	306	54	602	52
Falls in past year	149	26	315	27
Use of walking aid	37	6	60	5
Index recruits	452	79	986	84
Sole participant	336	59	805	69
Average age (yrs)	76		76	

The rate of falls was higher in women than in men and increased with age in both sexes.

Just over one-third of falls (n = 421) occurred inside the participants' homes, the most frequent locations being the bedroom, the lounge room, at the front and back doors, the kitchen, and the bathroom. Two-thirds of the falls (n = 281) that occurred inside the home involved an environmental hazard. The hazards most frequently implicated in falls were furniture (25%), steps (19%), wet and slippery floors (13%), objects on the floor (9%), and mats and rugs (7%). The relative frequency with which environmental hazards were involved in falls was the same in both the intervention and control groups.

The rate of injurious falls was 28.90/100PY, with 45% of fall events (n = 465) causing injury. One in 10 fall events required medical assistance; there were 37 fractures, including four subjects with a fractured neck of the femur. Other common injuries were cuts and grazes, bruises, and soft tissue injuries such as sprains.

Falls in People Who Withdrew

The rate of falls in the 122 subjects who withdrew before completion of follow-up was almost twice as high as that in subjects who completed the follow-up period (136.69/100PY vs 71.17/100PY), giving a significant rate difference of 65.52/100PY (95% CI = 34.91–96.13). In subjects who withdrew, the rate of falls was higher in the intervention
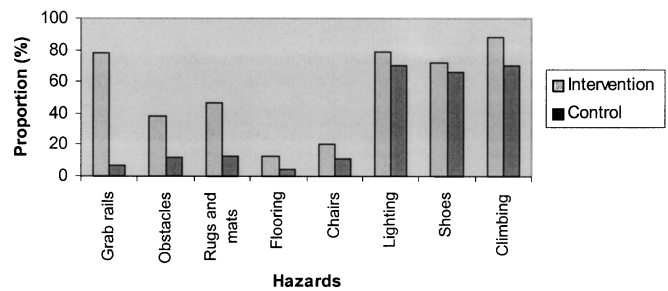
Figure 2. Proportion of subjects in the intervention and control groups reporting actions to reduce fall hazards and reduce unsafe behaviors.

group than in the control group (156.59/100PY vs 124.47/100PY), although the rate difference of 32.13/100PY (95% CI = -32.13–96.34), albeit large, was not significant.

Intragroup Correlation Between Households and Falls

Kendall's tau was >0.4 for all three fall outcomes, indicating that the rates of falls in subjects who lived in the same house were correlated. The correlation was highest for all inside falls (0.70 for the whole population and 0.75 for people with a history of falling) and lowest for falls on inside hazards (0.47 and 0.41, respectively). In people who fell, the frailty variance for all falls was zero, indicating that living in the same household had no influence on the rate of repeated falls in people who fell at least once.

Changes in Environmental Hazards in Intervention and Control Households

Members of the control group acted to reduce their fall risk, with 74.4% reporting that they were taking more care to avoid falls and 15.8% reporting action to reduce fall risks in their home. However, the proportion of subjects who acted to reduce fall hazards was significantly higher in the intervention group than in the control group for all hazards examined: installation of grab rails (78.1% vs 6.7%), removal of obstacles (38.1% vs 12.0%), removal or stabilization of rugs and mats (46.7% vs 13.3%), repair of damaged flooring (12.9% vs 4.4%), improving the height of chairs (19.5% vs 10.6%), and improving poor lighting (78.6% vs 69.5%). A significantly higher propor-

Table 2. Change in Home Hazards and Hazardous Rooms in the 51 Homes Reassessed

Hazards	Change in Hazards or Hazardous Rooms, per House		
	Mean number	95% CI	% change
Hazards that were reduced in the retest sample			
All steps	0.06	−0.04–0.16	1.35
Unsafe steps	0.61	0.28–0.94	15.80
All rugs/mats per house	1.27	0.60–1.94	8.92
Unsafe rugs/mats per house	1.57	0.91–2.24	13.51
Rooms with trailing cords	0.43	0.10–0.76	26.22
Rooms with an unsafe favourite chair	0.10	0.02–0.18	11.90
Hazards that were increased in the re-test sample			
Rooms with obstacles	0.06	−0.27–0.39	6.06

CI = confidence interval.

Table 3. Rate of Falls on Environmental Hazards Inside the Home by Age, Sex, and Experimental Status

Subjects	Intervention Group Rate per 100PY	Control Group Rate per 100PY	Rate difference	95% CI
All persons	18.12	17.15	0.97	−3.43–5.73
Men <80 years	10.24	10.58	0.34	−5.83–5.15
Men ≥80 years	29.07	17.59	11.48	−5.66–28.31
All men	13.96	12.17	1.77	−3.80–7.32
Women <80 years	19.07	21.07	1.99	−9.14–5.20
Women ≥80 years	31.44	24.83	6.61	−10.35–23.38
All women	21.73	21.83	0.09	−6.78–6.60

PY = person years; CI = confidence interval.

tion of intervention subjects also reported safer behaviors, such as wearing safer shoes (71.9% vs 65.5%) and avoiding climbing (88.2% vs 70.1%) (Figure 2).

Home hazard reassessment showed that there had been a significant reduction in four of the five most prevalent hazards in the homes of members of the intervention group (Table 2). The use of nonslip tape on steps significantly reduced the mean number of hazardous steps per house by 0.61 (95% CI = 0.28–0.94); the mean number of unsafe rugs and mats per house was reduced by 1.57 (95% CI = 0.91–2.24); the mean reduction in trailing cords was 0.43 (95% CI = 0.10–0.76); and the mean reduction in the number chairs with seats too high for the user was 0.10 (95% CI = 0.02–0.18).

There was a small, nonsignificant increase in the mean number of rooms per house with obstacles that could be tripped over. There was no change in the prevalence of other hazards such as poor lighting or unsafe flooring, which were much more difficult to modify or remove.

Effect of the Intervention on the Rate of Falls

Rates of falls were calculated for each of three outcomes: falls on environmental hazards inside the home, all inside falls, and all falls. For each of the three outcomes, experi-

mental groups were compared using the unadjusted and adjusted incidence rate ratios and odds ratios for falls on environmental hazards in the home, the effect of the intervention on specific age and sex groups was compared using rate differences (Tables 3 and 4).

Falls on Environmental Hazards Inside the Home

The rate of falls on environmental hazards inside the home in the control and intervention groups was similar, being 18.12/100PY in the intervention group and 17.15/100PY in the control group. The intervention had no significant effect on the rate of falls on environmental hazards inside the home (adjusted rate ratio, 1.11; 95% CI = 0.82–1.50). Covariates significantly associated with an increased rate of falls on environmental hazards were history of falling (relative risk (RR) 2.09) and use of a walking aid inside the home (RR 1.94).

Falls Inside the Home

There was no significant difference in the rate of falls inside the home experienced by the intervention and control groups (26.90/100PY in the intervention group vs 25.82/100PY in controls). The intervention had no significant effect on the rate of falls inside the home (adjusted rate ratio,

Table 4. Adjusted and Unadjusted Rate Ratios and Odds Ratios for Three Fall Outcomes

Fall Outcome	Rate of Falls			
	Unadjusted IRR	95% CI	Adjusted IRR	95% CI
Falls on environmental hazards inside the home	1.08	0.80–1.48	1.11	0.82–1.50
Falls inside the home	1.14	0.78–1.66	1.17	0.85–1.60
All falls	1.01	0.79–1.28	1.02	0.83–1.27

	Risk of Falls			
	Unadjusted OR	95% CI	Adjusted OR	95% CI
Falls on environmental hazards inside the home	1.01	0.75–1.36	0.97	0.74–1.28
Falls inside home	0.97	0.74–1.26	0.97	0.78–1.28
All falls	0.92	0.75–1.14	0.93	0.75–1.15

Note: The model was adjusted for the covariates of age, sex, history of falling, sole participation, recruitment method and use of a walking aid.
IRR = incidence rate ratio; OR = odds ratio; CI = confidence interval.

1.17; 95% CI = 0.85–1.60). Covariates significantly associated with an increased rate of falls were age (RR 1.04), history of falling (RR 2.26), being a sole participant in a household (RR 1.70), and use of a walking aid (RR 2.33).

All Falls

A similar pattern was seen for all falls, with no significant difference in fall rates between the intervention and control groups (68.87/100PY in the intervention group vs 72.28/100PY in controls). The intervention had no significant effect on the rate of all falls (adjusted rate ratio, 1.02; 95% CI = 0.83–1.27). Covariates significantly associated with an increased rate of all falls were age (RR 1.03), history of falling (RR 2.28), and being the sole participant (RR 1.38).

Effect of the Intervention on Falls in People with a Propensity to Fall

It is possible that people with a propensity to fall were more responsive to the intervention than subjects in general. To investigate this, the rates of falls in subjects who reported a fall in the year before the study and in subjects who fell during the study were examined separately. In neither of these subgroups did the rate of falls for any of the three fall outcomes significantly differ between the intervention group and controls.

Effect of the Intervention on the Proportion of Fallers

The intervention had no significant effect on the proportion of people who fell on environmental hazards inside the home (adjusted odds ratio (OR), 0.97; 95% CI = 0.74–1.28), the proportion of people who fell inside the home (adjusted OR, 0.97; 95% CI = 0.78–1.28), or the proportion of people who fell anywhere (adjusted OR, 0.93; 95% CI = 0.75–1.15).

Effect of the Intervention on the Rate of Fall-Related Injuries

Two injury outcomes were examined: all fall-related injuries and fall-related injuries that were severe enough for the participant to seek medical attention. The intervention had no significant effect on the rate of all injuries or the rate of serious injuries (adjusted rate ratios, 0.92/100PY; 95% CI = 0.73–1.14, and 0.98/100PY; 95% CI = 0.66–1.45, respectively).

DISCUSSION

This randomized controlled trial evaluated the outcome of an intervention to reduce home hazards and thereby to reduce the incidence of falls in older people. After 1 year, there was no significant change in the rate of falls, the rate of fall injuries, or the proportion of fallers in the intervention group compared with the control group. The rate of falls on hazards inside the home, the fall outcome most specific to the intended effect of the intervention, was not reduced in intervention subjects.

The pattern of falls seen in study subjects was similar to that described in other published studies, with one-third of the cohort falling at least once and the rate of falls being higher in women than in men and increasing with age.[26,27] The environmental hazards in the home involved in falls were similar to those reported in other studies, although

the relative importance of several hazards differed.[6,28,29] In this study, furniture acted as a tripping hazard as well as being involved in falls when people sat down or stood up; furniture was associated with 25% of falls. In other studies, furniture, especially chairs, was mainly involved in falls that occurred on change of posture and accounted for up to 11% of falls[28] and 19% to 23% of falls causing fractures.[6,29] Steps were involved in 19% of falls in this study, whereas in other studies they were involved in 11% or fewer of falls.[6,28] Floor rugs were involved in 7% of falls in this study, whereas in other published studies they were involved in up to 20% of falls.[6,28,29]

The lack of effect of the intervention on the rate of falls may have resulted from failure to achieve a sufficient reduction in the number of hazards in the intervention homes or may have resulted from incorrect theoretical assumptions about the causal relationship between home hazards and falls.

The intervention did not render homes hazard free and failed to reduce the number of relevant hazards sufficiently to reduce the occurrence of falls. Comparison of the study results with the intervention strategies revealed three factors contributing to the lack of a substantial reduction in the rate of falls on home hazards: the intervention achieved only modest reductions in the prevalence of the hazards it targeted, failed to target important hazards that were frequently involved in falls, and failed to modify structural hazards adequately.

The theoretical causal relationship underpinning the intervention was that environmental hazards are a necessary cause of falls, with a direct correspondence between the prevalence of home hazards and the rate of falls inside the home. In practice, not all hazards are modifiable. The results of the study could be explained if modifiable environmental hazards are component causes of falls in older people but that, singularly or even collectively, they are not a necessary cause of falls and are not even responsible for a high etiological fraction of falls. Thus, a reduction in modifiable environmental hazards alone can at best produce a modest reduction in the rate of falls. Furthermore, there is no perfect intervention available to reduce modifiable hazards, and the present trial has demonstrated that even a program with dedicated objectives and resources has had only a small impact on the prevalence of modifiable hazards in the home. The lack of observable outcome could therefore be because of the combination of a weak intervention and a relatively weak component cause.

The only controlled study to find that an intervention to improve home safety was associated with a reduction in the rate of falls in older persons was not able to ascribe the reduction in falls directly to a reduction in hazard prevalence, because falls within and falls outside the home were both reduced.[30] The authors concluded that the effectiveness of the intervention was due to the intervention being delivered by occupational therapists, who would have greater standing with study subjects and so made a greater impression. However, objective measures of compliance, with recommendations to remove or modify hazards, were similar to those achieved in the present study.

The study finding that the intervention was not associated with any reduction in the rate of falls or proportion of older people who fell may have been influenced by defi-

ciencies in the study design. Three potential sources of error should be considered: the possibility that the control group reduced the prevalence of home hazards also (Hawthorne effect), the differential withdrawal of subjects from the intervention and control groups, and the different composition of the two experimental groups with respect to single participant households and index recruits.

The lack of a significant reduction in falls in the intervention group compared with the controls could have been due to failure to achieve an adequate difference in exposure to the intervention between the two experimental groups. For this to account for the study findings would have required the Hawthorne effect to have been greater than the effect of the intervention itself. This is unlikely and is not supported by the results of the questionnaire, which showed higher activity to reduce hazards in the intervention group.

Of the 264 subjects who withdrew from the study, 111 were from the intervention group, a number disproportionate to the size of the group. A sensitivity analysis was conducted to ascertain whether it was plausible that the true rate of falls in intervention subjects may have been significantly higher or lower than the rate in control subjects and that this was masked by the differential loss to follow-up. Two scenarios were examined, each assuming different but plausible rates of falls in control subjects who withdrew, and the hypothetical rate of falls in the intervention group required to give a fall rate significantly higher or lower than that in the control group was calculated. Under both scenarios, a rate of falls in the intervention group that was significantly less than that in the control group was very unlikely, but it was plausible that the rate of falls in the intervention group was significantly higher than that in the control group.[31] This implies that the intervention could have been associated with a higher rate of falls, which was not observed, because the intervention subjects at highest risk of falling withdrew from the study. This in turn would imply a causal association between exposure to the intervention and a higher rate of falls or a failure of randomization leading to an imbalance of confounders.

For the intervention strategies to have increased the rate of falls in the intervention group would have required the number of environmental hazards to have increased, which was not consistent with the impact evaluation, or for the intervention subjects to have adopted behaviors conferring a higher risk. Not only does the former supposition go against the observed changes in hazards, but, also, many of the hazards involved in falls were not targeted by the intervention (furniture and furnishings) or were not amenable to significant change (structural hazards such as steps and slippery floors). The questionnaire responses indicated that intervention members were taking more care to avoid high-risk behavior such as climbing. It is theoretically possible that the intervention could have induced a feeling of greater safety in intervention group members. This may have been translated into less care in avoiding hazards, particularly if the study subjects had taken action to reduce hazards.

Explanatory variables known to be unevenly distributed across the control and intervention groups were "single participant from the household" and "index recruitment status."

Should error due to imbalance on these measured variables have affected the rates of falling, higher rates would have been expected in the control group, with its overrepresentation of index recruits and single-participant households. The influence of these variables would be active in the crude analysis but were controlled in the multivariate models by inclusion in the regressions.

Because none of these explanations seems plausible, it is likely that any increase in the rate of falls on environmental hazards was due to random error, rather than a systematic error or a truly detrimental effect of the intervention.

Several researchers have questioned the effectiveness of a hazard reduction strategy in preventing falls, based on the multiplicity of hazards involved in falls[9] and the lack of correspondence between the number of hazards in homes and the falls reported by householders.[32] Experience from this study suggests that the major challenges to the development of an effective home hazard reduction intervention suitable for healthy older people are to gain the commitment of the target population and to develop effective and practical hazard reduction strategies. These improvements are possible.

The intervention could be delivered in ways that would gain greater acceptance by the target group, such as by providing less-restricted messages and using multifaceted communication strategies. The hazards addressed by future intervention strategies should correspond more closely to the hazards frequently involved in falls and should preferably involve safer housing design and construction to ensure that structural hazards are minimized.

There is a role for further research in the science of preventing falls on environmental hazards. The knowledge base that underpins interventions for hazard reduction is limited. The association between home hazards and falls needs to be better understood, to elucidate the biomechanics of falls on hazards and the characteristics of hazards that cause falls.

This study is the first randomized controlled trial to investigate the effect of a single intervention strategy, home hazard reduction, on the rate and risk of falling in older people. Objective assessment of the weaknesses in the study design showed that they did not unduly detract from the ability of the study to evaluate the intervention. The study also had particular strengths, including the overall design, the analytical methods used, and the assessment of clustering. Most importantly, the study provides evidence that this intervention is insufficiently potent or targeted to reduce the incidence of falls in healthy older people.

ACKNOWLEDGMENTS

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