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Fall Risk in Older Adults:

Roles of Self-Rated Vision, Home Modifications, and Limb Function

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Abstract

Objectives: To assess direct effects of self-rated vision, home modifications, and limb functioning, and moderating effects of self-rated vision on change in functioning of upper and lower limbs on fall risk in older adults.

Method: Logistic regression was used to analyze 2004 and 2006 waves of the Health and Retirement Study.

Results: Effects of self-rated vision and home modifications in predicting falls decreased after controlling functioning in upper and lower extremities. Declines/gains in functioning across short periods of time superseded self-rated vision in predicting falls. No evidence was found for a moderating effect of vision status on limb functioning.

Discussion: Poor self-rated vision may not be a good indicator of fall risk in older adults. Thus, for older adults with visual impairments, preserving residual limb functioning through exercise and activity has the important potential to reduce fall risk in addition to improving muscle and bone strength as well as improving balance and gait.

Keywords

falls; vision loss; limb function; home modification; older adults

People may fall at any time during their lives, but falling is of greater concern to older people because of age-related changes to the body that make older individuals more likely to experience a fall and serious injury as a result of a fall. It is estimated that a third of individuals aged 65 and over will fall in any given year, and that up to 20% of older fallers experience injuries related to their falls (Masud & Morris, 2001). A number of studies have identified risk factors for falling, including muscle weakness, a history of falls, gait deficit, balance deficit, impaired activities of daily living, and visual deficit (American Geriatrics Society, 2001). Considerable evidence has shown that attention to these risk factors can significantly reduce rates of falling (Abdelhafiz & Austin, 2003; Feldman & Chaudhury, 2008; Lord, Ward, Williams, & Strudwick, 1995), and that the most effective and cost-effective fall-reduction programs involve systemic fall-risk assessment with targeted interventions that include physical activity, medical management, and environmental

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inspection and hazard removal (Campbell & Robertson, 2006; Day et al., 2002; Pynoos, Rose, Rubenstein, Choi, & Sabata, 2006; Rubenstein, 2006). Bearing in mind findings that implicate interactions between multiple factors in causing falls, an important early step in creating effective fall-prevention programs for older adults is to understand relationships between the most common factors that predict falls.

Vision and Falls in Older Adults

Like falls, visual impairment is also more common in old age. More than one in four individuals over the age of 75 self-report some form of visual impairment (Horowitz, Brennan, & Reinhardt, 2005). Furthermore, as life expectancies continue to increase, the largest percentage of people who will experience significant vision loss is expected to shift toward an older age group, particularly those over the age of 75 (Crews, 1994).

The effects of vision loss and other systems on fall risk can be conceptualized in at least two ways (Steinman, 2008). The first perspective is an independent effects view, which posits that age-related changes to independent systems contribute separately to fall risk by reducing perceptual and physical functioning of the individual. The independent role of vision loss in falls has been explored from many perspectives. Various clinical measures of vision status have been associated independently with increased fall risk, including visual acuity (Ivers, Cumming, Mitchell, & Attebo, 1998; Lord & Dayhew, 2001), contrast sensitivity (De Boer et al., 2004; Ivers et al., 1998; Lord & Dayhew, 2001), depth perception (Lord & Dayhew, 2001), and loss in visual fields (Ivers et al., 1998; Lord, 2006). Researchers have also looked at the independent effects of vision loss in directly reducing mobility (Crews & Campbell, 2004) and functional capacity (West et al., 2002). Numerous studies have demonstrated that perceptual degradation caused by vision loss may directly interfere with an individual's ability to maneuver safely through the environment (Hassan, Lovie-Kitchin, & Woods, 2002; Patel et al., 2006; Soong, Lovie-Kitchin, & Brown, 2004).

A second way to conceptualize the effects of vision loss and declines in other systems on fall risk is an integrated effects view, which acknowledges the potential for systems to interact with other systems (Steinman, 2008). Under this view, losses in the visual system could moderate losses in functioning. According to Muller, Judd, and Yzerbyt (2005), moderating effects are found when one independent variable affects the magnitude of another, with respect to a dependent variable. In this scenario, losses in visual acuity could lead to synergistic changes in musculoskeletal functioning—a combined effect that is greater than effects that occur due to changes in either single system independently. According to Steinman (2008), changes in the musculoskeletal system may be moderated by declines in vision, such that losses are magnified, resulting in less stability and a greater likelihood of falling in old age. Steinman tested a moderating relationship between vision loss and declines in the musculoskeletal system; however, methodological difficulties made interpretation of results difficult, with respect to integrated effects. Specifically, Steinman considered both parameters (vision loss and limb functioning) at a common point in time; however, if vision loss moderates upper-limb functioning (ULF) and lower-limb functioning (LLF) as hypothesized, then vision loss would precede declines in physical functioning, with its moderating effects. Consequently, previous results made it difficult to infer, with

certainty, the role of moderating effects of vision loss on musculoskeletal decline in predicting falls.

Home Hazards, Home Modifications, and Falls

A second limitation in research by Steinman (2008) was that it did not control for potentially important factors that could influence fall risk, such as the presence of home modifications. The home environment has been implicated in approximately 50% to 70% of falls experienced by older people (Feldman & Chaudhury, 2008). Among community-dwelling older adults, up to 75% of falls occur in and around the home (Ellis & Trent, 2001; Schiller, Kramarow, & Day, 2007), with the majority of injuries occurring inside the home (Pynoos, Nishita, Cicero, & Caraviello, 2008; Schiller et al., 2007). The prevalence of hazards in homes of older people is high, with approximately 80% of homes containing at least one hazard, and 39% containing five or more hazards (Carter, Campbell, Sanson-Fisher, & Gillespie, 2000). According to Rogers, Rogers, Takeshima, and Islam (2004), the most common hazards found in the homes of older adults include inadequate lighting, unsafe/insecure floor surfaces, staircases with no railings, poorly designed or arranged furniture, and poorly designed tubs, toilets, and fixtures in the bathroom.

Modifying the home to reduce hazards seems like a reasonable intervention strategy for reducing or preventing falls; however, research findings are inconsistent about the impact of specific types of environmental factors and the presence of home modifications on fall-risk reduction. According to a study by van Bommel, Vandenbroucke, Westendorp, and Gussekloo (2005), older adults with a history of falls had no increased risk of falls due to a greater number of hazards in their homes; whereas, individuals with no preceding falls had greater risk when three or more hazards were present. By contrast, Clemson, Cumming, and Roland (1996) reported no practical differences in environmental hazards between the homes of people with recurrent falls and homes of other older people. With respect to home modification, Day et al. (2002) found that alone neither treatment of poor vision nor home-hazard management was statistically effective in reducing falls. Nevertheless, they reported a strong effect, when home hazard management was combined with other fall-prevention interventions, like exercise programs and treatment for vision problems. According to a review article by Lord, Menz, and Sherrington (2006), the majority of randomized control trials have found home modifications to have only limited impact on fall reduction. In cases when home modifications were found to be effective, home hazards interacted with the physical abilities of older adults such that reduction of hazards in the homes of more vigorous individuals reduced falls more than doing so in the homes of frail older people. In a meta-analysis of randomized trials containing environmental interventions, Clemson, Mackenzie, Ballinger, Close, and Cumming (2008) found that home assessment interventions that were comprehensive, well focused, and incorporated an environmental-fit perspective with adequate follow-up were most successful in significantly reducing falls. The greatest effects were associated with interventions with high-risk groups (i.e., people with a history of falls, hospitalization for falls, functional decline, or severe visual impairment). Thus, the literature underscores the complicated nature of environmental, physical, and behavioral interactions as precursors to falls in older adults.

Purpose of Study

The aim of the current study was to address shortcomings in previous research, by employing independent variables that accounted for weaknesses described above. In addition to assessing the direct effects of self-rated vision status and ULF and LLF, the current study controlled change in functioning of upper limbs and lower limbs across a 2-year period. Interaction terms computed from these change variables were used to test whether a significant moderating relationship exists between self-rated vision and functional status. The current study also controlled the main effects of home modification to determine the role of this variable in falls and fall risk. To control for fundamental physiological differences between men and women, analyses were conducted separately for each sex.

Method

Data Source and Variables

We analyzed data from the 2004 and 2006 panels of the University of Michigan's Health and Retirement Study (HRS). The HRS is a national longitudinal steady state survey that contacts participants every 2 years. In 2004, HRS continued data collection on four cohorts, made up of 18,491 Americans over the age of 55. A fifth replenishing cohort was added to the sample that year, making a total of 21,831. By comparison, in 1998 when the four original cohorts were merged, the sample was made up of 22,641 participants (aged above 51) and 25,725 at the study's inception (attrition of roughly 4% and 15%, respectively). In 2006, the study had 19,740 participants who were known to be living (attrition of roughly 13% compared to 1998, and 23% overall). Baseline responses of each cohort were taken via face-to-face interviews in the respondent's home. Follow-up interviews, including those in 2004 and 2006, were conducted via the telephone.

The sample for our study was composed of participants who were 65 years or older. Participants were excluded if they were known to have died between the 2004 and 2006 panels, or if they were institutionalized. Participants were also excluded from analyses if their interviews were conducted by proxy, due to the possibility that proxy respondents may not be knowledgeable about whether or not individuals had fallen. Finally, participants were excluded if they scored a 6 or lower out of 10 on the Telephone Interview of Cognitive Status (TICS). The aggregate TICS item measured general orientation to time and place and was assumed, for this study, to function as an indicator of the respondent's ability to report falls accurately. After all exclusion criteria were applied to the data, an initial unweighted sample size of 8,449 participants remained.

All independent variables were taken from the 2004 panel of HRS, with the exception of change in functioning measures, which were computed using both 2004 and 2006 data (described below). The dependent variable, a dichotomous measure of whether or not participants had fallen in the last 2 years, was taken from the 2006 panel and merged to 2004 data for subsequent analyses.

Sociodemographic measures.—Four sociodemographic characteristics of participants, including age, education, race, and presence of a spouse or partner in the household, were

statistically controlled. Age and education were coded and analyzed as continuous variables. Race and spouse/partner status were coded as dummy variables, with “White” and “no spouse/partner present” as reference categories.

Independent variables.—Key explanatory independent variables included measures of self-rated vision status, home modifications, change in ULF and LLF, and four interaction terms that were computed by multiplying vision status variables by change in ULF and LLF status. Other control variables included baseline ULF and LLF, self-rated pathology, depression, hearing status, total number of medications, and number of alcoholic drinks per day.

Vision.—In the HRS, vision status was assessed using an item that asked respondents to rate whether their eyesight was excellent, very good, good, fair, or poor when using glasses or corrective lenses. Respondents could also state that they were legally blind. This variable was recoded into two dummy variables—participants who were legally blind or who reported having poor eyesight were categorized together, whereas those who rated their eyesight as fair made up a second group. A third group of participants with good or better eyesight served as the reference category.

Home modifications.—Respondents representing each household were asked in 2004 whether within the last 2 years (since 2002) their homes or apartments had been modified to make it easier or safer for an older person or a disabled person to live there, or whether their homes were already handicap accessible prior to the 2002 interview. Responses were recoded into a dummy variable in which homes that were previously or recently modified were coded together against a reference group in which homes had never been modified. Household-level responses were applied to person-level participants who indicated that they resided in households with home modifications.

ULF/LLF.—Independent variables representing baseline functional disability in 2004 and change in functioning from 2004 to 2006 were quantified using measures of physical functioning found in the HRS. Participants were asked whether, due to health or physical problems, they had any difficulty performing 11 functional activities. For the baseline measures, 6 activities associated with ULF (i.e., sitting 2 hr, getting up from a chair, reaching arms, pulling/pushing large objects, lifting weights, and picking up a dime) were grouped together. Likewise, 5 activities associated with LLF (i.e., walking several blocks, walking one block, climbing stairs, climbing one flight of stairs, and stooping) were grouped together. Continuous variables representing baseline functioning were computed by summing the number of difficulties experienced within each (ULF and LLF) category in 2004.

Change in functioning variables (ULF and LLF) were computed in two steps. First, dichotomous responses for each activity in 2006 were subtracted from responses of respective activities in 2004. Each activity, then, could have a value of 1 (indicating improvement of functioning between 2004 and 2006), 0 (indicating no change), or –1 (indicating decline of functioning). Next, these scores were summed, according to their ULF/LLF groupings; thus, scores for ULF could range from 6 (if the participant reported

difficulty in all six activities in 2004, but no difficulty in 2006) to –6 (if the participant reported no difficulties in 2004, but difficulties in all activities in 2006). Likewise, scores for LLF ranged from 5 to –5. In both groups, scores close to 0 indicated no or little change in the number of activities with which participants reported difficulties.

Interaction terms.—Four interaction terms were computed by multiplying indicators of each vision status (poor, fair) by ULF and LLF status. These new variables were used in analyses testing the moderating effects of vision on limb functioning.

Health and medical conditions.—Self-ratings of respondents' physical health were assessed in HRS, with respect to eight medical conditions that are commonly associated with old age. Participants were asked whether a doctor had ever told them that they had hypertension, diabetes, cancer, respiratory problems, heart conditions, stroke, psychiatric impairment, or arthritis. Each condition was coded into a dummy variable, with “responded no” as the reference category.

Within HRS, depression was measured using a shortened (nine item) version of the Center for Epidemiologic Studies Depression Scale (CES-D). Responses to items were reversed when appropriate and recoded into dichotomous variables. Items were then summed into a continuous variable, such that scores represented the number of items that were answered in the direction indicating depression—that is, higher scores indicated more depression (range = 0 to 9).

Hearing status was assessed in the HRS with an item that asked respondents to rate whether their hearing was excellent, very good, good, fair, or poor when using prescribed hearing aids as usual. This variable was recoded into a single dummy variable that compared participants with poor and fair hearing against a reference group of participants with good or better hearing.

Medications and alcohol.—Participants who reported experiencing any of the eight medical conditions were subsequently asked whether they were currently taking any medications to address those health problems. Participants who reported having heart problems were also asked whether they were taking medications for heart attack, angina, or congestive heart failure. As a measure of the number of medications used by participants, items were summed into a continuous variable. A total possible of 11 medications could be reported.

Alcohol use was quantified by dichotomizing an item that captured the number of drinks per day that participants consumed. If participants reported having two or fewer drinks per day, then they were categorized as non/rare drinkers versus a reference group who had three or more drinks per day (heavy drinker = 1).

Dependent variable.—Participants in the 2006 wave of the HRS were asked whether they had fallen in the last 2 years. Responses to this item were recoded and analyzed as a dichotomous variable (did fall = 1).

Analyses

Analyses were conducted using Statistical Package for Social Sciences, version 15.0 for Windows. Basic descriptive statistics, including means, standard deviations, and percentages, were calculated for selected sociodemographic variables, vision status, home modification, measures of physical function, health status, and falls. Independent sample *t* tests were conducted to determine statistical differences between women and men. Eta square (η^2) was calculated as an index of effect size to determine the practical significance of observed statistical differences. In accordance with recommendations by Green, Salkind, and Akey (2000), η^2 cutoffs of 0.01, 0.06, and 0.14 represent small, medium, and large effect sizes, respectively.

Main analyses consisted of two binary logistic regressions, differentiated by gender. Separate analyses were performed for women and men based on differences found in demographic and health variables (reported in Tables 1 and 2). Further justification for separate analyses is provided by literature that reports fundamental differences between sexes, with respect to the types of falls experienced (O'Neill et al., 1994), incidence of falling (Bath & Morgan, 1999), and differences in the muscle and bone structures of men and women (Frontera, Hughes, Lutz, & Evans, 1991; Hannan et al., 2000). Physiological differences between sexes portend different mechanisms that could be responsible for falls in women and men.

Originally, regressions contained variables controlling for number of medications and alcohol consumption (not shown); however, when these models were run, the variables did not statistically predict falling, and the likelihood ratio tests for models including these variables were not significant. Consequently, the variables were dropped from analyses and the regressions were rerun.

Independent variables were entered hierarchically in four blocks. In Model 1, sociodemographic variables, vision status, and home modifications variables were entered, followed by measures of physical functioning (Model 2), health and medical conditions (Model 3), and finally interaction terms (Model 4). Although the likelihood ratio tests indicated that models including interaction terms were not significant, they were retained in tables for the sake of discussion. Because tests of significance were likely to be biased by large sample sizes, the Nagelkerke pseudo R^2 —a logistic analogy to R^2 in ordinary least squares regression—was reported for each model as an index of effect size.

Results

Descriptive statistics for selected sociodemographic variables and results of independent *t* tests by gender are presented in Table 1. The mean age of participants in the sample was 74.1 years ($SD = 6.6$). Women were statistically older than men (74.4 vs. 73.7 years). Men had more education than women (12.7 vs. 12.3 years) and were statistically more likely than women to live with a spouse or partner (74.8% vs. 46.3%). A total of 90.6% of the sample was White, 6.8% were Black, and 2.5% identified themselves as some other race. According to standards cited by Green et al. (2000), effect sizes leading to observed statistical

differences of demographic variables were very small for age ($\eta^2 = .002$), small for education ($\eta^2 = .005$), and medium sized for coresidence status ($\eta^2 = .081$).

Table 2 displays descriptive statistics and results of independent sample *t* tests conducted to compare genders on the dependent variable (falls) as well as key explanatory variables and control variables. In total, about a third of the participants reported falling in 2006, since their last interviews in 2004. Women were statistically more likely than men to fall, $t = 4.26$, $p < .0005$, although this result was based on a very small effect size ($\eta^2 = .002$). With respect to vision status, women were statistically more likely than men to rate their vision as poor, $t = 4.01$, $p < .0005$; whereas, men were more likely to rate their vision as good or better, $t = -2.30$, $p < .05$. There was no statistical difference between percentages of men and women who rated their vision as fair. Effect sizes leading to differences in vision status were very small. Only 13.9% of the sample reported that they had modified their homes to accommodate disabilities. A statistically greater percentage of women, than men, had made home modifications (15.0% vs. 12.3%), $t = 3.61$, $p < .0005$; however, the effect size leading to this difference was very small ($\eta^2 = 0.002$).

Differences in functioning between women and men were found in baseline (2004) measures. Compared to men, women reported statistically more difficulties with ULF, $t = 17.56$, $p < .0005$, and LLF, $t = 15.62$, $p < .0005$. Eta square values (.036 and .029, respectively) indicated that these differences were based on small effect sizes. By comparison, no statistical differences were found in ULF or LLF between genders.

There were significant differences between women and men with respect to health and medical conditions. Women were statistically more likely to report the presence of hypertension, $t = 4.05$, $p < .0005$; psychiatric disorders, $t = 10.88$, $p < .0005$; and arthritis, $t = 12.87$, $p < .0005$. Women also reported experiencing greater depressive symptoms, per the modified CES-D instrument than men, $t = 10.82$, $p < .0005$. In comparison, men were statistically more likely to report having diabetes, $t = -4.50$, $p < .0005$; cancer, $t = -3.80$, $p < .0005$; heart problems, $t = -9.74$, $p < .0005$; stroke, $t = -2.47$, $p < .05$; and hearing impairments, $t = -12.81$, $p < .0005$. All of the statistical differences between women and men, with respect to health and medical conditions, were based on small or very small effect sizes.

Results of 2 logistic regressions that tested the effects of vision, home modifications, baseline and change in ULF and LLF, health, and interaction terms (representing vision by change in functioning) on falls are presented in Tables 3 and 4. For both women and men, age was a significant predictor of falling across all models. When all variables were included in the equation, education and race were significant predictors of falls for women, but not for men. For women, each additional year of education was associated with about a 4% increase in fall likelihood. Black women were about 29% less likely to fall than their White counterparts. Coresidence status was not a significant predictor for women or for men in any of the models.

Table 3 displays the main effects and interactions of vision status, home modifications, and functional status for women. In Model 1, which contained demographic, vision, and home

modification variables, poor vision (compared to good or better vision) was a significant predictor of falls, odds ratio (OR) = 1.737, $p < .0005$, as was fair vision, OR = 1.299, $p < .005$. In this first model, home modifications also significantly predicted falls in women; those who lived in homes that had been modified were about 25% more likely to fall than those whose homes had not been modified.

In Model 2, when baseline and change measures of functioning were included in the equation, the effects of vision status and home modifications disappeared; however, baseline measures of both ULF and LLF were strong predictors of falls. For each additional upper-limb activity with which women reported having difficulties at baseline, the likelihood of a fall increased by about 21%, $p < .0005$. Each additional lower-limb activity increased the likelihood of a fall by about 16%, $p < .0005$. Change in functioning between 2004 and 2006 also was a strong predictor of falls. For each upper-limb functional activity that participants lost the ability to perform during the 2-year time period, the likelihood of falling increased by about 10%, $p < .0005$. Similarly, each additional lower-limb functional activity lost was associated with about a 12% increase in fall likelihood, $p < .0005$. ULF and LLF remained a strong predictor in Models 3 and 4, when health status variables and interaction terms were added to equations, respectively. In the final model, baseline measures of functioning were highly significant. Although the effect of ULF became somewhat weaker (though it remained significant), the effects of LLF became stronger after health status and interaction terms were controlled. Other significant predictors of falls in women in the final model were diabetes, OR = 1.224, $p < .05$; psychiatric impairments, OR = 1.297, $p < .05$; and depression, OR = 1.055, $p < .005$. The interaction between poor eyesight and ULF was also statistically significant, OR = 0.816, $p < .05$; however, likelihood ratio test indicated that this model was not significantly different from Model 3. Between Model 1 and Model 4, Nagelkerke's R^2 increased from .031 to .109, suggesting good predictive efficacy of the key explanatory variables.

Table 4 displays the main effects and interactions of vision status, home modifications, and functional status for men. The pattern of results is similar to that of women with a few notable exceptions. As in women, poor vision and fair vision were associated with statistically greater likelihood of experiencing a fall for men, in Model 1. Compared to men who reported good or better vision, those with poor vision were almost twice as likely to experience a fall, OR = 1.980, $p < .0005$; whereas, men with fair vision were about 36% more likely to experience a fall, $p < .005$. However, the effects of vision disappeared in Model 2, after upper- and lower-limb functional measures were controlled. Home modifications were also a significant predictor of falls for men in Model 1. Those who reported living in homes with home modifications were about 51% more likely to report a fall than those without home modifications. This result carried through to the final model, when all other variables were added to the equation. After controlling for ULF and LLF, health status, and interaction terms, home modifications were still a significant predictor of falls for men, OR = 1.319, $p < .05$.

The effects of ULF and LLF were strong predictors of falls across models. In Model 4, baseline measures of functioning were highly significant, as were the effects of ULF, OR = 0.796, $p < .0005$, and LLF, OR = 0.839, $p < .0005$. Other significant predictors of falls in

men in the final model were diabetes, $OR = 1.339$, $p = .005$; psychiatric impairments, $OR = 1.608$, $p = .005$; and depression, $OR = 1.114$, $p = .0005$. None of the interaction terms were statistically significant. Between Models 1 and 4, Nagelkerke's R^2 increased from .033 to .151, suggesting good predictive efficacy of the key explanatory variables.

Discussion

A key finding of this study replicates important previous findings by Steinman (2008)—namely that effects of self-rated vision status in predicting falls is lessened as a result of controlling baseline functioning in upper and lower extremities. Furthermore, the current study extends earlier findings by showing that declines and/or gains in functioning across short periods of time may also supersede self-rated vision in predicting falls. However, consistent with previous findings, little evidence was found for a moderating effect of self-rated vision status on musculoskeletal health and functioning. Nevertheless, results reported here are important because they suggest that the relative strength of poor self-rated vision status may not be as good an indicator of fall risk in older adults as might otherwise be assumed. According to these results, independent measures of baseline functioning as well as recent declines in functional status in the upper and lower limbs are relatively more important predictors of falls. Thus, preserving residual limb functioning through exercise has the important potential to improve muscle function (McCartney, Hicks, Martin, & Webber, 1995) and bone strength (Wolff, van Croonenborg, Kemper, Kostense, & Twisk, 1999), while improving balance and gait (Daley & Spinks, 2000) and reducing fall risk (Carter, Kannus, & Khan, 2001).

A second key finding of these analyses involves the effects of home modifications in predicting falls in older people. The presence of home modifications was included in analyses with the expectation that older individuals living in modified homes would experience decreased risk of falling. However, results suggested that in the HRS sample, the opposite was true. For both women and men whose homes were previously modified to accommodate disabilities, the risk of falling was greater when no other functional or health measures were controlled. This effect disappeared for women, but remained for men, when all other predictors were included in the regression equation. Overall, this pattern of results suggested that older individuals may primarily install home modifications in response to health conditions or events that would otherwise reduce their ability to live independently. Despite modifications to their homes, fall risk for these individuals could be higher due to physical impairments and functional difficulties, which initially prompted the installation of their home modifications. In other words, with respect to findings reported here and elsewhere in the literature, it is possible that presence of home modifications often predicts increased falling because persons who have them are those who need home modifications the most.

As an alternative, a preventive approach to modifying homes of older adults would focus on recommendation and provision of modifications universally, and without regard to the perceived or objective needs of the consumer, based on their physical health and functioning. Indeed, in some studies when home modifications have been found to reduce falls, the effect of the home environment is stronger for more vigorous older adults, compared to more frail

persons, who are less likely to have exposure to hazards when they exist (Lord et al., 2006). Although there are only a limited number of randomized intervention studies focusing on the environment, there is evidence that home modifications can have an important impact in reducing falls; however, benefits of home modifications are most likely to be seen in combination with other fall-prevention strategies and in a multifactorial interactive manner. Professional assessment, education, and installation of home modifications, when part of an integrated risk-management intervention, can be effective for improving functioning, decreasing fear of falling, and reducing the incidence of falls among older adults in the community (Close et al., 1999; Cumming et al., 1999; Day et al., 2002; Gillespie et al., 2003; Gitlin et al., 2006). In conjunction with other proven fall-prevention interventions, specific supportive features—such as grab bars in bathrooms, handrails on both sides of staircases, nonslip flooring, and adequate lighting (which provide universal benefits for all users regardless of age or physical functioning)—could potentially help to prevent falls and promote safety, even in homes of the most vigorous and healthy older adults.

Limitations

Although the results of this study are thought to accurately reflect important relationships between falls and various risk factors that could lead to falls, some limitations of the study should be acknowledged. First, there are several difficulties with the measurement of the dependent variable. To assess falls, HRS asked participants if they had fallen in the last 2 years. This extended period is troublesome because of the difficulties that participants may have accurately recalling falls that occurred in that duration (Ganz, Higashi, & Rubenstein, 2005). In an attempt to address issues of memory, we excluded participants with cognitive impairments, who may be more likely to experience a fall but less likely to report falls accurately due to forgetting. Thus, our results potentially represent a conservative bias, which may be less generalizable with respect to the true number of fallers in the older population at large. In addition, the HRS item does not define what is meant by a fall. One commonly accepted definition is that set forth in the International Classification of Diseases that calls a fall “an unexpected event where a person falls to the ground from an upper level or the same level” (Masud & Morris, 2001, p. 3). Nevertheless, no definition was given to HRS participants, so it cannot be assured that all participants interpreted the item in the same way. Therefore, problems with item validity could have resulted in inconsistent response patterns between participants that would make it difficult to compare this study with findings from similar studies where definitions were provided. Other fall-related questions that were asked in the HRS study pertained to the number of falls, and whether participants were injured in their falls. These items were not analyzed because low response rates and missing data would have resulted in reduced statistical power.

Similarly, a second limitation of the study relates to the subjective nature of the key explanatory variables. Participants were asked to self-report the status of their vision and their functional capacity, thus inviting subjectivity into responses that could influence the validity of items and introduce error into analyses. Although results based on self-rated measures are telling about the participant’s perceptions of their situation, it is likely that a similar study that used clinical measures of vision and musculoskeletal health would report stronger or weaker relationships between variables relative to the results reported here.

Another problem concerning key independent variables is the nonspecificity of the item regarding home modifications. Although the question only asks whether modifications to homes had been made in the previous 2 years, a more important query for the purposes of this study involves the types of modifications that were made. The range of home modifications is large and varies with respect to cost and scale. It is possible that participants of HRS biased their responses to include only major (more expensive) home modifications, such as ramps, widening doorways, or remodeling bathrooms, whereas other less expensive home modifications such as grab bars and improving lighting may be overlooked. Although it is not certain whether participants biased their responses to exclude smaller, but important, home modifications, such a bias would result in a weaker effect, with respect to predicting falls.

Finally, a third limitation of this study relates to the choice of independent control variables. Although models introduced here revealed important statistically significant relationships between variables that predicted falls, it is noteworthy that the amount of variance accounted for by the models was relatively small. The modest explanatory power of even the best models (10%–15%) suggests that some important variables that predict falls were absent from analyses. In comparison to previous research that employed similar control variables (Steinman, 2008), greater predictive power was found in the current study when the presence of home modifications was controlled. However, an even more rigorous analysis would identify and include other potentially important predictor variables such as activity levels and participation in exercise programs that would improve results and could add support to the hypothesis of this line of study. Nevertheless, our results are telling about the relative impact of self-rated vision and its relationship with other explanatory variables in causing falls. Further research should continue to explore interactive relationships between variables that are assumed to have important roles in whether or not older adults experience falls.

Conclusion

The practical implications of this study merit some discussion. Although certainly, older adults with visual impairments can and do benefit from vision rehabilitation techniques that train consumers to use their residual vision effectively to respond to fall hazards and by creating home environments that are safer with respect to fall prevention, results reported here also suggest the importance of maintaining good physical fitness as a high priority for older people with visual impairments. Physical fitness, especially in the lower limbs, is important for recovering and avoiding a fall after a misstep. Similarly, fitness in upper limbs is important for maintaining balance and for avoiding injury after a fall. Nevertheless, getting adequate exercise—whether through daily functional activities, leisure, and/or social activities or through participation in exercise programs—is likely to be more difficult for older adults with visual impairments due to the independent effects of vision loss in day-to-day life. The independent effects of vision loss, which may make mobility more difficult, are also likely to reduce the practicality of attending rehabilitation/exercise programs, unless support mechanisms are provided to meet special needs of older adults who are visually impaired. Furthermore, exercise programs that are developed for older people with visual impairments can be enhanced by taking into consideration differences between sexes, with respect to the types of chronic diseases and other factors that affect people differently as they

age. Thus, this study has the potential to inform developers of health/functioning programs for older adults with visual impairments, insofar as programs will take into consideration the unique circumstances and needs of individuals within the older population.

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References

- Abdelhafiz AH, Austin CA. Visual factors should be assessed in older people presenting with falls or hip fracture *Age and Ageing*. 2003; 32:26–30. [PubMed: 12540344]
- American Geriatrics Society Guideline for the prevention of falls in older persons *Journal of the American Geriatrics Society*. 2001; 49:664–672. [PubMed: 11380764]
- Bath PA, Morgan K. Differential risk factor profiles for indoor and outdoor falls in older people living at home in Nottingham, UK *European Journal of Epidemiology*. 1999; 15:65–73. [PubMed: 10098998]
- Campbell AJ, Robertson MC. Implementation of multifactorial interventions for fall and fracture prevention *Age and Ageing*. 2006; 35(Suppl. 2):60–64. [PubMed: 16364935]
- Carter ND, Kannus P, Khan KM. Exercise in the prevention of falls in older people *Sports Medicine*. 2001; 31:427–438. [PubMed: 11394562]
- Carter SE, Campbell EM, Sanson-Fisher RW, Gillespie WJ. Accidents in older people living at home: A community-based study assessing prevalence, type, location and injuries *Australia New Zealand Journal of Public Health*. 2000; 24:633–636.
- Clemson L, Cumming RG, Roland M. Case-control study of hazards in the home and risk of falls and hip fractures *Age and Ageing*. 1996; 25:97–101. [PubMed: 8670535]
- Clemson L, Mackenzie L, Ballinger C, Close JCT, Cumming RG. Environmental interventions to prevent falls in community-dwelling older people: A meta-analysis of randomized trials *Journal of Aging and Health*. 2008; 20:954–971. [PubMed: 18815408]
- Close J, Ellis M, Hooper R, Glucksman E, Jackson S, Swift C. Prevention of falls in the elderly trial (PROFET): A randomised controlled trial *Lancet*. 1999; 353(9147):93–97. [PubMed: 10023893]
- Crews JE, (1994). Aging and disability: The issues for the 1990s; . In Boone SE, Watson D, ; , & Bagley M. (Eds.), *The challenge to independence: Vision and hearing loss among older adults* (pp. 47–60). University of Arkansas: Rehabilitation Research and Training Center for Persons who are Deaf or Hard of Hearing .
- Crews JE, Campbell VA. Vision impairment and hearing loss among community-dwelling older Americans: Implications for health and functioning *American Journal of Public Health*. 2004; 94:823–829. [PubMed: 15117707]
- Cumming RG, Szonyi TM, Salkeld G, O'Neill E, Westbury C, Frampton G. Home visits by an occupational therapist for assessment and modification of environmental hazards: A randomized trial of falls prevention. *Journal of the American Geriatrics Society*. 1999; 47:1397–1402. [PubMed: 10591231]
- Daley MJ, Spinks WL. Exercise, mobility, and aging *Sports Medicine*. 2000; 29:1–12. [PubMed: 10688279]
- Day L, Fildes B, Gordon I, Fitzharris M, Flamer H, Lord S. Randomised factorial trial of falls prevention among older people living in their own homes *British Medical Journal*. 2002; 325(7356):128. [PubMed: 12130606]
- De Boer MR, Pluijm SMF, Lips P, Moll AC, Volker-Dieben HJ, Deeg DJH. Different aspects of visual impairment as risk factors for falls and fractures in older men and women *Journal of Bone and Mineral Research*. 2004; 19:1539–1547. [PubMed: 15312256]
- Ellis AA, Trent RB. Do the risks and consequences of hospitalized fall injuries among older adults in California vary by type of fall? *Journals of Gerontology. Series A: Biological Sciences and Medical Sciences*. 2001; 56:M686–M692. [PubMed: 11682576]

- Feldman F, Chaudhury H. Falls and the physical environment: A review and a new multifactorial falls-risk conceptual framework *Canadian Journal of Occupational Therapy*. 2008; 75:82–95.
- Frontera WR, Hughes VA, Lutz KJ, Evans WJ. A cross-sectional study of muscle strength and mass in 45- to 78-yr-old men and women *Journal of Applied Physiology*. 1991; 71:644–650. [PubMed: 1938738]
- Ganz DA, Higashi T, Rubenstein LZ. Monitoring falls in cohort studies of community-dwelling older people: Effect of the recall interval *Journal of the American Geriatrics Society*. 2005; 53:2190–2194. [PubMed: 16398908]
- Gillespie LD, Gillespie WJ, Robertson MC, Lamb SE, Cumming RG, Rowe BH. Interventions for preventing falls in elderly people *Cochrane Database of Systematic Reviews*. 2003; 4:CD000340.
- Gitlin LN, Winter L, Dennis MP, Corcoran M, Schinfeld S, Hauck WW. A randomized trial of a multicomponent home intervention to reduce functional difficulties in older adults *Journal of the American Geriatrics Society*. 2006; 54:809–816. [PubMed: 16696748]
- Green SB, Salkind NJ, & Akey TM. (2000). *Using SPSS for windows: Analyzing and understanding data* (2nd ed..). Upper Saddle River, NJ: Prentice Hall .
- Hannan MT, Felson DT, Dawson-Hughes B, Tucker KL, Cupples LA, Wilson PWF. Risk factors for longitudinal bone loss in elderly men and women: The Framingham osteoporosis study *Journal of Bone and Mineral Research*. 2000; 15:710–720. [PubMed: 10780863]
- Hassan SE, Lovie-Kitchin JE, Woods RL. Vision and mobility performance of subjects with age-related macular degeneration *Optometry and Vision Science*. 2002; 79:697–707. [PubMed: 12462538]
- Horowitz A, Brennan M, Reinhardt JP. Prevalence and risk factors for self-reported visual impairment among middle-aged and older adults *Research on Aging*. 2005; 27:307–326.
- Ivers RQ, Cumming RG, Mitchell P, Attebo K. Visual impairment and falls in older adults: The Blue Mountains eye study *Journal of the American Geriatrics Society*. 1998; 46:58–64. [PubMed: 9434666]
- Lord SR. Visual risk factors for falls in older people *Age and Ageing*. 2006; 35(Suppl. 2):ii42–ii45. [PubMed: 16926203]
- Lord SR, Dayhew J. Visual risk factors for falls in older people *Journal of the American Geriatrics Society*. 2001; 49:508–515. [PubMed: 11380741]
- Lord SR, Menz HB, Sherrington C. Home environment risk factors for falls in older people and the efficacy of home modifications *Age and Ageing*. 2006; 35(Suppl. 2):55–59.
- Lord SR, Ward JA, Williams P, Strudwick M. The effect of a 12-month exercise trial on balance, strength, and falls in older women: A randomized controlled trial *Journal of the American Geriatrics Society*. 1995; 43:1198–1206. [PubMed: 7594152]
- Masud T, Morris RO. Epidemiology of falls *Age and Ageing*. 2001; 30(Suppl. 4):3–7.
- McCartney N, Hicks A, Martin J, Webber C. Long-term resistance training in the elderly: Effects on dynamic strength, exercise capacity, muscle, and bone *Journals of Gerontology. Series A: Biological Sciences and Medical Sciences*. 1995; 50:B97–B104. [PubMed: 7874586]
- Muller D, Judd CM, Yzerbyt VY. When moderation is mediated and mediation is moderated *Journal of Personality and Social Psychology*. 2005; 89:852–863. [PubMed: 16393020]
- O'Neill TW, Varlow J, Silman AJ, Reeve J, Reid DM, Todd C. Age and sex influences on fall characteristics *Annals of the Rheumatic Diseases*. 1994; 53:773–775. [PubMed: 7826141]
- Patel I, Turano KA, Broman AT, Bandeen-Roche K, Munoz B, West SK. Measures of visual function and percentage of preferred walking speed in older adults: The Salisbury eye evaluation project *Investigative Ophthalmology Visual Science*. 2006; 47:65–71. [PubMed: 16384945]
- Pynoos J, Nishita C, Cicero C, Caraviello R. Aging in place, housing, and the law *Elder Law Journal*. 2008; 16:77–105.
- Pynoos J, Rose D, Rubenstein L, Choi IH, & Sabata D. (2006). Evidence-based interventions in fall prevention. In S. M. Enguidanos (Ed.), *Evidence-based interventions for community dwelling older adults* (pp. 55–73). New York: Hawthorn .
- Rogers ME, Rogers NL, Takeshima N, Islam MM. Reducing the risk of falls in the homes of older adults *Journal of Housing for the Elderly*. 2004; 18:29–39.

- Rubenstein LZ. Falls in older people: Epidemiology, risk factors and strategies for prevention *Age and Ageing*. 2006; 35(Suppl. 2):37–41. [PubMed: 16364932]
- Schiller JS, Kramarow EA, , & Day AN. (2007). Fall injury episodes among noninstitutionalized older adults: United states, 2001–2003. Hyattsville, MD: National Center for Health Statistics .
- Soong GP, Lovie-Kitchin JE, Brown B. Measurements of preferred walking speed in subjects with central and peripheral vision loss *Ophthalmic and Physiological Optics*. 2004; 24:291–295. [PubMed: 15228506]
- Steinman BA. Self-reported vision, upper/lower limb disability, and fall risk in older adults *Journal of Applied Gerontology*. 2008; 27:406–423.
- van Bommel T, Vandenbroucke JP, Westendorp RGJ, Gussekloo J. In an observational study elderly patients had an increased risk of falling due to home hazards *Journal of Clinical Epidemiology*. 2005; 58:63–67. [PubMed: 15649672]
- West CG, Gildengorin G, Haegerstrom-Portnoy G, Schneck ME, Lott L, Brabyn JA. Is vision function related to physical functional ability in older adults? *Journal of the American Geriatrics Society*. 2002; 50:136–145. [PubMed: 12028258]
- Wolff I, van Croonenborg JJ, Kemper HCG, Kostense PJ, Twisk JWR. The effect of exercise training programs on bone mass: A meta-analysis of published controlled trials in pre- and postmenopausal women *Osteoporosis International*. 1999; 9:1–12.

Table 1
Demographic Descriptive Statistics by Gender (Weighted Data)

	Women (<i>n</i> = 4,950)	Men (<i>n</i> = 3,500)	Total (<i>N</i> = 8,450)	<i>t</i> (<i>df</i>)	η^2
Age	74.4 (<i>SD</i> = 6.7)	73.7 (<i>SD</i> = 6.5)	74.1 (<i>SD</i> = 6.6)	4.44 (8,448) ***	0.002
Education	12.3 (<i>SD</i> = 2.7)	12.7 (<i>SD</i> = 3.2)	12.5 (<i>SD</i> = 2.9)	-6.49 (8,431) ***	0.005
Race					
White	89.9%	91.7%	90.6%	-2.71 (8,448)	
Black	7.5%	5.8%	6.8%	2.97 (8,448)	
Other	2.6%	2.5%	2.5%	0.26 (8,448)	
Spouse/partner	46.3%	74.8%	58.1%	-27.33 (8,442) ***	0.081

 $p < .0005$.

Table 2
Percentage Falls, Vision, Home Modifications, Health Status, and Mean Number of
Upper- and Lower-Limb Disabilities by Gender (Weighted Data)

	Women (<i>n</i> = 4,950)	Men (<i>n</i> = 3,500)	Total (<i>N</i> = 8,450)	<i>t</i> (<i>df</i>)	η^2
Fall in last 2 years	34.7%	30.2%	32.9%	4.26 (8,192) ***	0.002
Vision					
Poor	6.1%	4.1%	5.2%	4.01 (8,442) ***	0.002
Fair	15.5%	15.6%	15.6%	0.11 (8,442) ^a	
Good	78.3%	80.4%	79.2%	-2.30 (8,442) *	0.001
Home modifications	15.0%	12.3%	13.9%	3.61 (8,410) ***	0.002
Baseline ULF	1.53	0.96	1.29	17.56 (8,207) ***	0.036
Baseline LLF	(<i>SD</i> = 1.56) 2.19	(<i>SD</i> = 1.26) 1.57	(<i>SD</i> = 1.28) 1.93	15.62 (8,082) ***	0.029
ULF	(<i>SD</i> = 1.79) -0.18	(<i>SD</i> = 1.71) -0.15	(<i>SD</i> = 1.93) -0.17	-1.41 (8,207) ^a	
LLF	(<i>SD</i> = 1.25) -0.23	(<i>SD</i> = 1.10) -0.20	(<i>SD</i> = 1.19) -0.22	-1.29 (8,067) ^a	
Hypertension	(<i>SD</i> = 1.11) 60.7%	(<i>SD</i> = 1.12) 56.3%	(<i>SD</i> = 1.12) 58.8%	4.05 (8,439) ***	0.002
Diabetes	16.3%	20.1%	17.9%	-4.50 (8,434) ***	0.002
Cancer	16.4%	19.6%	17.7%	-3.80 (8,427) ***	0.002
Respiratory	9.9%	10.7%	10.3%	-1.21 (8,439) ^a	
Heart	25.3%	35.0%	29.3%	-9.74 (8,436) ***	0.011
Stroke	8.0%	9.5%	8.6%	-2.47 (8,440) *	0.001
Psychiatric	15.1%	7.4%	11.9%	10.88 (8,438) ***	0.014
Arthritis	72.5%	59.2%	67.0%	12.87 (8,436) ***	0.019
Hearing Impairment	19.4%	31.4%	24.3%	-12.81 (8,442) ***	0.019
Depression	2.0	1.5	1.77	10.82 (8,339) ***	0.014

Note: ULF = upper-limb functioning; LLF = lower-limb functioning.

^a. *p* value was not significant.

* *p* < .05.

*** *p* < .0005.

Table 3
Odds Ratios Representing Independent and Moderating Effects of Key Explanatory Variables and Control Variables for Women

Independent Variable	Model 1	Model 2	Model 3	Model 4
Demographics				
Age	1.031 ***	1.022 ***	1.024 ***	1.024 ***
Education (years)	1.010	1.035 *	1.043 **	1.043 **
Race (White, reference)				
Black	0.776	0.700 *	0.708 *	0.714 *
Other	0.845	0.852	0.881	0.882
Spouse/partner (no, reference)	0.028	0.898	0.934	0.933
Vision (good vision, reference)				
Poor eyesight	1.737 ***	1.219	1.089	1.014
Fair eyesight	1.299 **	1.057	0.989	1.004
Home modifications	1.252 *	1.068	1.043	1.043
Baseline ULF		1.214 ***	1.165 ***	1.162 ***
Baseline LLF		1.164 ***	1.122 ***	1.123 ***
ULF		0.899 ***	0.911 **	0.930 *
LLF		0.878 ***	0.891 ***	0.876 ***
Health (no, reference)				
Hypertension			1.032	1.030
Diabetes			1.231 *	1.224 *
Cancer			1.025	1.029
Respiratory			1.013	1.019
Heart condition			1.155	1.158
Stroke			1.110	1.103
Psychiatric impairment			1.297 *	1.297 *
Arthritis			1.175	1.175
Depression			1.053 **	1.055 **
Hearing impairment			1.004	1.001
Interaction terms				
Poor eyesight by ULF				0.816 *
Fair eyesight by ULF				0.984
Poor eyesight by LLF				0.967
Fair eyesight by LLF				1.100
-2 log likelihood	5403.358	5193.866	5156.899	5150.818
Nagelkerke R^2	.031	.096	.107	.109

Note: ULF = upper-limb functioning; LLF = lower-limb functioning. Weighted data ($N = 4,950$).

* $p < .05$.

**
 p .005.

 $p < .0005$.

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Table 4
Odds Ratios Representing Independent and Moderating Effects of Key Explanatory Variables and Control Variables for Men

Independent Variable	Model 1	Model 2	Model 3	Model 4
Demographics				
Age	1.030 ***	1.015 *	1.020 **	1.020 **
Education (years)	0.980	1.009	1.018	1.018
Race (White, reference)				
Black	0.821	0.755	0.778	0.786
Other	0.944	0.909	0.937	0.938
Spouse/partner (no, reference)	0.948	0.984	1.062	1.063
Vision (good vision, reference)				
Poor eyesight	1.980 ***	1.352	1.133	1.193
Fair eyesight	1.362 **	1.027	0.929	0.929
Home modifications	1.511 ***	1.332 *	1.316 *	1.319 *
Baseline ULF		1.311 ***	1.239 ***	1.243 ***
Baseline LLF		1.204 ***	1.144 ***	1.143 ***
ULF		0.799 ***	0.808 ***	0.796 ***
LLF		0.830 ***	0.841 ***	0.839 ***
Health (no, reference)				
Hypertension			0.892	0.894
Diabetes			1.342 **	1.339 **
Cancer			0.803 *	0.812 *
Respiratory			1.028	1.030
Heart condition			1.039	1.033
Stroke			1.175	1.167
Psychiatric impairment			1.607 **	1.608 **
Arthritis			1.123	1.119
Depression			1.114 ***	1.114 ***
Hearing impairment			1.059	1.061
Interaction terms				
Poor eyesight by ULF				1.131
Fair eyesight by ULF				1.036
Poor eyesight by LLF				1.176
Fair eyesight by LLF				0.977
-2 log likelihood	3851.187	3623.004	3567.579	3565.365
Nagelkerke R^2	.033	.128	.150	.151

Note: Note: ULF = upper-limb functioning; LLF = lower-limb functioning. Weighted data ($N = 3,500$).

* $p < .05$.

**
 p .005.

 $p < .0005$.

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