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Central and Peripheral Visual Impairment and the Risk of Falls and Falls with Injury

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Abstract

Objective—To evaluate central and peripheral visual impairment as independent risk factors for falls and falls with injury among adults.

Design—Population-based prospective cohort study.

Participants—A total of 3,203 LALES participants.

Methods—Baseline presenting binocular central distance acuity was measured and impairment was classified as mild (20/40–20/63), moderate/severe (20/80 or worse). Peripheral visual impairment was classified as mild (−6dB<mean deviation<−2dB in worse eye), moderate/severe (mean deviation≤−6dB in worse eye).

Main outcome measures—Falls and falls with injury in the past 12 months were assessed by self-report at 4-year follow-up visit.

Results—Out of 3,203 individuals, 19% reported falls and 10% falls with injury; participants with falls were more likely to: be ≥ 60 years of age, be female, report lower income, have more than two co-morbidities, report alcohol use, report wearing bifocal glasses and report obesity. Among those who reported falls, 7% had central visual impairment (visual acuity≥20/40) compared to 4% who did not report falls; and 49% had peripheral visual impairment (mean deviation<−2dB) compared to 39% of those who did not report falls (both p-values<.0001). After adjusting for confounders, moderate to severe central and peripheral visual impairment were associated with increased risk for falls (odds ratio 2.36 95% confidence interval 1.02–5.45, p-trend= .04 and odds ratio 1.42 95% confidence interval 1.06–1.91, p-trend= .01, respectively) and with falls with injury (odds ratio 2.76 95% confidence interval 1.10–7.02, p-value= .03, and odds ratio 1.40 95% confidence interval .94–2.05, p-trend= .04, respectively).

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Conclusion—Both central and peripheral visual impairment were independently associated with increased risk for falls and falls with injury in a dose-response manner. Although vision related interventions for preventing falls have mainly focused on correcting central visual impairment, this study suggests that targeting both central and peripheral components may be necessary to reduce rates of falls and falls with injury related to vision loss effectively.

Falls and falls with injury are common and serious preventable problems faced by older adults. It is estimated that 35 to 40% of healthy, community dwelling individuals, over the age of 65 fall each year. [1, 2] Approximately 50% of individuals that fall report some degree of injury, and 7 to 18% require medical attention. [3, 4] Notably, falls are a common cause of hospital admissions for trauma and account for almost 90% of fractures. [5]

Vision impairment together with gait deficit and muscle weakness are among the most important clinical risk factors associated with falls. [6] However, prospective studies evaluating the association of specific measures of visual impairment with increased risk of falls and falls with injury have shown inconsistent results. [7] For example, several studies have found that impaired visual acuity increases the risk of falls [8, 9] and falls with injury [10, 11], while others have not. [12, 13] Similarly, various studies have shown that deficits in visual field increase the risk of falls [12, 14–16] while another studies showed no association with falls. [13] Interestingly, limited information on the independent effects of central visual acuity and peripheral visual fields on falls and falls with injury is available.

The Los Angeles Latino Eye Study (LALES), a large population-based cohort study, offers a unique opportunity to further evaluate the relationship between measures of central and peripheral visual impairment and risk of falls or falls with injury among adults, specifically of Latino ethnicity. Although the frequency of falls in Latino adults has been previously reported as 41% for adults between 59 to 75 years of age, [17] little is known about the impact of visual impairment on falls and falls with injury in this major growing minority group in the United States. 18

Methods

Data for this analysis were collected as part of LALES, a population-based longitudinal study of eye disease in Latinos living in Los Angeles, California, who were 40 years of age and older at the time of study enrollment. Details of the study design and data collected have been described previously. [19] Briefly, a census of all residential households in six census tracts in La Puente was completed to identify individuals eligible to be included in the study. Eligibility included Latino (self-described) men and women who were residing in any of the six census tracts at the time of enrollment. Eligible participants were given a verbal and written description of the study and invited to participate in a baseline home interview, a clinic examination between February 2000 and May 2003 and a 4 year follow-up visit between 2004 and 2008. Demographic and socioeconomic characteristics of participants were similar to those of Latino population in the United States.[19] All study procedures adhered to the principles outlined in the Declaration of Helsinki for research involving human subjects. Institutional Review Board Committee approval was obtained from the University of Southern California Institutional Review Board.

Socio-demographic and clinical data

A brief home interview was completed after informed consent was obtained, which included information on demographics, history of ocular conditions, access to health care, health insurance coverage for eye care, degree of acculturation and measures of general and vision-specific quality of life. Operational definitions for these variables were similar to those described in the Hispanic Health and Nutrition Examination Survey. 20 In addition, twelve self-reported medical conditions were measured by a systematic co-morbidity summation score, including the following: diabetes mellitus, arthritis, stroke or brain hemorrhage, high blood pressure, angina, heart attack, heart failure, asthma, skin cancer, other cancer, back problems, and deafness or hearing problems. Acculturation was measured by the short-form Cuellar Acculturation Scale 21 with scale scores ranging from one to five, with five representing the highest level of acculturation. General health related quality of life (HRQOL) was measured with the Medical Outcomes Study 12-item Short-Form Health Survey. 22 Data from the SF-12 were used to calculate the standard US norm-based SF-12 Physical Component Summary (PCS) and Mental Component Summary (MCS) scores; higher PCS and MCS scores represent better HRQOL. 23 Vision-targeted HRQOL was assessed by the National Eye Institute Visual Function Questionnaire (NEI VFQ-25); higher scores representing better vision HRQOL. 24, 25

Visual Impairment Measures: Baseline central visual impairment and peripheral visual impairment

At the study clinic, trained ophthalmologists and technicians used standardized protocols to perform ocular examination to assess measures of central and peripheral impairment.

<u>Central Visual Impairment</u>: presenting binocular central distance acuity for each participant was measured with the presenting correction (if any) at 4 meters with modified Early Treatment Diabetic Retinopathy Study distance charts transilluminated with the chart illuminator (Precision Vision, La Salle, Illinois, USA). Presenting binocular central distance acuity was scored as the total number of letters read correctly and converted to a logarithm of the minimum angle of resolution score (logMAR).

<u>Peripheral Visual Impairment</u>: visual field testing was completed to assess participant’s ability to detect objects in the periphery of their visual environment. Testing was performed separately in each eye with the Humphrey Automated Field Analyzer II (Swedish Interactive Thresholding Algorithm [SITA] Standard 24-2 program) (Carl Zeiss Meditec, Dublin, California, USA) and repeated for any abnormal results; results of the second test were recorded and qualitatively confirmed as peripheral visual impairment by two ophthalmologists.

Primary Outcomes: Recent falls and injury from falls

The following questions were asked during the in clinic interview at the 4 year follow-up visit to obtain data pertinent to falls and injury: “Have you had any fall in the past 12 months?” (yes/no) [26], “As a result of this fall or falls, did you suffer any injury?” (yes/no), “What type of injury or injuries did you suffer?” (bruise, cuts and/or scratches/broken wrist, broken rib, broken hip, other, specify).

Statistical Analysis

Means and proportions were used to describe the study population. Frequency of each covariate (age, gender, income, health insurance, vision insurance, alcohol use, body mass index, co-morbidities and use of bifocal glasses) were compared across history of recent falls and falls with injury using the test for trend. Spearman’s correlation coefficient was used to test for the correlation between central and peripheral visual impairment.

To test for possible non-linear relationships between central and peripheral vision loss and falls we used lowess smoothing techniques, likelihood ratio tests and fractional polynomials and found no substantial departure from linearity. Therefore, we modeled both central and peripheral visual impairment variables as categorical by severity levels. Central visual impairment was categorized based on the presenting binocular central distance acuity: normal

(<20/40 in both eyes), mild impairment (between 20/40 and 20/63), and moderate/severe impairment (20/80 or worse) as recommended by the World Health Organization [27]. Peripheral visual impairment was categorized into three levels: normal (MD≥ −2 dB in both eyes), mild (−6 dB <MD<−2 dB in the worse eye), moderate/severe (MD≤−6dB in the worse eye based on previously reported work. [28–30] Moderate and severe categories for both central and peripheral visual impairment were collapsed due to unstable sample sizes.

Unconditional multiple logistic regression was used to evaluate the association between central and peripheral visual impairment with falls and falls with injury after adjusting for confounders (age, gender, and number of co-morbidities). Other potential baseline covariates were considered for multivariable models such as income, health insurance, vision insurance, alcohol use, body mass index and use of bifocal glasses, but were excluded from the final models as they did not substantially change main effect estimates. Covariates that changed the beta coefficients ≥10% were retained in multivariable models. [31] Standard testing for collinearity (Tolerance and Variance Inflation Factor) showed that collinearity in the multivariable model did not affect the estimates. Odds ratios with 95% confidence intervals (CI) are reported. Two-sided p-values for individual variable categories and test for trends using the likelihood ratio test were calculated. Trend tests were done by assigning ordinal scores to variables and modeling as them as a continuous term.

To evaluate goodness of fit of the multivariable model we used the Hosmer and Lemeshow chi square goodness of fit test and found no statistically significant departure from fit (LRT 4.02 on 8 df, p-value= .86 and LRT 3.82 on 8 df, p-value= .87 for falls and falls with injury, respectively). Standard procedures were used for logistic regression model diagnostics [32] and we found no substantial deviation from goodness of fit.

To identify whether the risk of falling associated with central visual impairment was modified by peripheral visual impairment, we fit an unconditional logistic regression model containing a multiplicative interaction term. To test for statistical significance of the central-peripheral vision loss interaction term, we used the likelihood ratio test to compare models with and without the interaction term adjusted for age, gender and comorbidities.

All analysis were performed using STATA 9.2 (College Station, Texas, USA).

Results

Of the 7,789 eligible participants identified for LALES, 6,357 (82%) completed an ophthalmic examination at baseline. At the 4-year follow-up evaluation, 4,654 (73%) completed the clinical examination and 3,720 completed both the clinical and ophthalmic examination. The current analysis is restricted to 3,203 participants with complete information on recent falls and falls with injury, measures of visual impairment and covariates. The falls with injury models have 2 less participants (n=3,201) than the falls model (n=3,203) due to missing information for injury.

The mean age of this Latino adult population was 54 years at baseline (standard deviation=10), ranging from 40–93 years. The majority of participants were female (59%), had an annual income less than $20,000 (53%), and on average had 1.5 co-morbidities. Table 1 shows the frequency of demographic variables and covariates by falls and falls with injury status. Compared to those who did not report falls or falls with injury, individuals who did were statistically significantly older (≥ 60 years of age), more likely to be female, of lower annual income, more likely to report alcohol use, likely to report more co-morbidities, report wearing bifocal glasses and more likely to be obese. Additionally, individuals who reported falls and falls with injury had worse median composite NEI-VFQ HRQOL scores [(falls “no”= 92 vs. “yes”= 88; p-value=<0.001); (falls with injury “no”= 91 vs. “yes”= 88; p-value=<.0001)];

worse median SF-12 physical component scores [(falls “no”= 50 vs. falls “yes”= 42; p-value=<.0001); (falls with injury “no”= 50 vs. falls with injury “yes”= 40; p-value=<.0001)]; and worse median SF-12 mental component scores [(falls “no”= 56 vs. falls “yes”= 52; p-value=<.0001), (falls with injury “no”= 56 vs. falls with injury “yes”= 50; p-value=<.0001)]. There were no differences in acculturation scores between those who reported falls or falls with injury compared to those who did not (all groups 1.5, p-value for falls = .80 and for falls with injury p-value= .21).

At follow-up, 19% (621/3202) reported falls and 10% (306/3201) falls with injury. Among those who fell, 49% (306/621) reported injury of the following types: bruise (62%), cuts or scratches (39%), broken wrist (4%), broken rib (3%), or broken hip (1%) with some individuals reporting more than one type of injury. At baseline, 4% of the cohort had central visual impairment (≥20/40 in both eyes) while 41% had peripheral visual impairment (mean deviation< −2 dB in the worse eye) which is consistent with a previous LALES publication.[29] A substantial percentage of visual impairment diagnosed at baseline was already present in cohort members who were less than 60 years of age (43% of central visual impairment and 61% of peripheral visual impairment).

The correlation between central and peripheral vision impairment was modest and statistically significant (Spearman’s rho= −.27, p-value=<.0001).

Among those who reported falls, 7% had central visual impairment compared to 3.5% who did not (p-value<.0001); and 49% had peripheral visual impairment compared to 39% who did not report falls (p-trend<.0001). Similarly, 6% of those who reported falls with injury had central visual impairment compared to 4% who were not injured (p-trend= .006); and 51% had peripheral visual impairment compared to 40% who did not report falls with injury (p-trend<.0001). The proportion of falls and falls with injury was higher in those with increasing severity of central and peripheral vision impairment compared to those with no impairment, all p-trends <.007, (Figure 1).

Age-adjusted models showed that central visual impairment (≥ 20/40) and peripheral visual impairment (mean deviation < −2 dB) were both significantly and independently associated with increased risk of falls while only peripheral visual impairment was associated to falls with injury, (Table 2).

In multivariable models including both vision variables, age, gender and co-morbidities, we found that central and peripheral visual impairment were associated with increased risk of falls and falls with injury, (Table 2). Compared to individuals without central visual impairment, individuals who had moderate to severe impairment were 2.36 (95% Confidence Interval 1.02–5.45) times as likely to have reported a fall (p-trend=0.04) and 2.76 (95% Confidence Interval 1.10–7.02) times as likely to have reported falls with injury (p-value for moderate/severe category = .03). Similarly, compared to individuals without any peripheral visual impairment, those with moderate to severe impairment where 1.42 (95% Confidence Interval 1.06–1.91) times as likely to report falls (p-trend= .01) and 1.40 (95% Confidence Interval .94–2.05) times as likely to report falls with injury (p-trend= .04).

There was no evidence that peripheral visual impairment modified the association between central vision impairment and increased risk of falls or falls with injury, (p-value for interaction= .75 and .78, respectively).

Discussion

In this population-based prospective cohort study of Latino adults we showed that both central and peripheral visual impairment were associated with increased risk of falls and falls with

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injury independent of each other, age, gender and co-morbidities. Impairment in central vision increased the risk of falls 2.4 times and falls with injury 2.8 times, while peripheral vision loss increased their risk by 1.4 fold, for both outcomes. Furthermore, the risk of falls and falls with injury increased as the severity of both measures of visual impairment worsened, suggesting a dose-response relationship. In this cohort, the majority of individuals diagnosed with central vision impairment concomitantly had peripheral vision impairment (70%) while only 7% of those with peripheral vision impairment had central vision impairment. Altogether these data strongly suggest that correcting for central vision loss alone may be insufficient to effectively decrease the rates of falls and falls with injury due to vision impairment. Given that, once installed, peripheral visual impairment is mostly irreversible, identifying measures to prevent its development and or progression are warranted. On the other hand, patients may benefit by learning about the additive effect of having losses in both central and peripheral vision on the increased risk of falls when they are counseled about preventing falls by their clinicians.

Vision and the ability to respond to visual cues are important factors that aid individuals in avoiding falls and falls with injury. Deficits in central and peripheral vision can both produce incorrect sensory inputs through misjudgments of distances and/or misinterpretations of spatial information such as the correct nature of a ground surface, moving stimuli (congested pedestrian/vehicular traffic), or a shadow. [7] The visual system also plays a vital role in helping an individual retain balance while standing still and while moving; [33] and poor balance has been linked to falls and falls with injury. [34, 35] In a recent cross-sectional study both central and peripheral visual impairment were shown to increase the risk of poor balance after controlling for age, gender, race, BMI and number of co-morbidities; [36] however, after including all vision variables (e.g. visual acuity, visual field loss, and contrast sensitivity) in the multivariable model, only peripheral visual field remained statistically significant. Peripheral visual impairment has also been associated with increased risk of tripping over obstacles independent of age, gender, and race. [37]

This is the first study to show the independent effect of central and peripheral vision impairment on the increased risk of falls and falls with injury. Contrary to most studies, we included both measures of visual impairment in our multivariable models because peripheral visual field loss negatively confounded the relationship between central visual acuity and falls towards the null by 40% in the moderate/severe category as did central visual acuity on the relationship between peripheral visual field loss and falls by 11% in the moderate/severe category. Thus, by not including both measures of vision in our models we would have overestimated their effects on our two outcomes.

Previous longitudinal studies have not consistently found associations between central visual acuity or peripheral vision loss and falls. In 2007, a report from the Salisbury cohort showed that falling was associated with binocular visual field loss but not with presenting visual acuity, contrast sensitivity or stereo deficiency. [12] This study was smaller (n=2,375) than the LALES population, participants in the Salisbury cohort were older (mean 75.3 ± 5.3 years); largely non-Hispanic white and falls were evaluated prospectively using diaries. Furthermore, multivariable models did not adjust for other components of vision loss. However, prior results from this same cohort [13] using a predictive model, showed no association with any of the two vision measures when falls were evaluated retrospectively, as in our study. Our results are consistent with other longitudinal studies that have found that both measures of visual impairment are associated with falls [38] or have found that either visual acuity [8, 39] or visual field loss [9, 14, 16] are associated to falls and falls with injury.

Preventive interventions targeting risk factors for falls and falls with injury have mostly been conducted among adults over the age of 65[40]. While some interventions that included vision loss correction among this age group have shown a statistically significant reduction in falls,

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41, 42 others have not. 43, 44 Although falls and falls with injury are predominately a problem in the elderly, deficits in central and peripheral vision can occur in all age groups. A substantial proportion of visual impairment was present in this cohort before the age of 60 (43% of central visual impairment and 61% of peripheral visual impairment) when they individuals are not yet at higher risk of falling or having an injury from falls, compared to those over the age of 60. These results suggest that individuals who are approaching ages of increased risk for falls, may benefit by the implementation of interventions such as exercise, withdrawal of psychoactive medication and home-adjustments, known to reduce the rate of falls [7] early on (40–59 years of age) when other important risk factors for falls and falls with injury such as co-morbidities or poly pharmacy are not present.

Although it was not the intention of this paper to develop a predictive model for falls and falls with injury, interestingly, our data show that use of bifocals and being obese were statistically significant risk factors for both falls outcomes in univariable models. These covariates were not included in the multivariable model due to lack of confounding effect on the relationship between vision variables and our outcomes. However, in a separate multivariable model, bifocal use was no longer statistically significantly associated to falls or falls with injury, after adjusting for age, gender and co-morbidities (Odds Ratio 1.21 95% Confidence Interval .99–1.5, p-trend= .06 and Odds Ratio 1.17 95%m Confidence Interval .89–1.53, p-trend= .26, respectively). Although multifocal glasses have been shown to increase the risk of falls[45], the population in this study was on average older (76.5 ± 5.1 years), had a higher prevalence of use of multifocal glasses, and of falls, thus most likely represents a different population than the LALES participants. On the other hand, obesity was statistically significantly associated to falls and falls with injury after adjusting for age and gender (Odds Ratio 1.37 95% Confidence Interval I 1.00–1.87, p-trend <.0001 and Odds Ratio 1.64 95% Confidence Interval 1.04–2.58, p-trend= .0008, respectively) in our study which is consistent with previous reports. 37,46

The strengths of this study include the large sample size, addressing issues of temporality between the exposure and the outcome by measuring vision loss at baseline and falls after four years of follow-up, and having objectively assessed measures of vision loss through a comprehensive ophthalmological clinical exam. We also included a broad range of age groups and assessed not only falls but falls with injury which is directly responsible for the morbidity caused by falls. One possible limitation is loss to follow up and exclusion of individuals with incomplete data which could have introduced selection bias to our study if participants with falls and visual impairment were less likely to participate in the follow-up examination. To evaluate this issue we compared baseline characteristics of our study sample with the original cohort sample and found that they were comparable with respect to gender, employment, income, health insurance and vision health insurance status. Therefore, we estimate that any difference in rates of falls or falls with injury across individuals with and without visual impairment was most likely non-differential and would not explain a positive finding. Misclassification of falls frequency due to reporting bias may have occurred since previous studies have shown that elderly adults may fail to recall falls over the preceding 3–12 months, but recall more accurately for the preceding 12 full months when compared to other time windows. 26 Our study participants were asked to report falls during the previous 12 months and were not aware of the study hypothesis. Our definition of falls was more sensitive and less specific than other definitions used in previous studies such as “falls to the ground” or “against an object” as recommended by Lord[7]. This may have resulted in higher reporting of falls among our Latino sample. Some a priori known confounders of the relationship between visual impairment and falls were not included in our models (not available for this study) which could have lead to residual confounding (e.g. the presence of poor lighting in the context of the falls, use of poly pharmacy, impaired depth perception and contrast sensitivity). Finally, many individuals who reported falling and falling with injury were not found to have central or

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peripheral vision loss, thus other important predictors not evaluated here explain the remaining proportion of falls and falls with injury.

In conclusion in this study we show that both central and peripheral vision impairment independently increase the risk for falls and falls with injury in a dose-response manner among Latino adults. Although vision related interventions for preventing falls have mainly focused on correcting central visual impairment, this study suggests that targeting both central and peripheral components may be necessary to effectively reduce rates of falls and falls with injury related to vision loss. Lastly, younger patients may benefit by receiving preventive interventions for falls when they are initially diagnosed with visual impairment and have not yet had an injurious fall.

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References

1. Downton JH, Andrews K. Prevalence, characteristics and factors associated with falls among the elderly living at home. Aging (Milano) 1991;3:219–28. [PubMed: 1764490]
2. Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. N Engl J Med 1988;319:1701–7. [PubMed: 3205267]
3. Reinsch S, MacRae P, Lachenbruch PA, Tobis JS. Attempts to prevent falls and injury: a prospective community study. Gerontologist 1992;32:450–6. [PubMed: 1427246]
4. Tinetti ME, Baker DI, McAvay G, et al. A multifactorial intervention to reduce the risk of falling among elderly people living in the community. N Engl J Med 1994;331:821–7. [PubMed: 8078528]
5. Fife D, Barancik JI. Northeastern Ohio Trauma Study III: incidence of fractures. Ann Emerg Med 1985;14:244–8. [PubMed: 3977148]
6. American Geriatrics Society, British Geriatrics Society, American Academy of Orthopaedic Surgeons Panel on Falls Prevention. Guideline for the prevention of falls in older persons. J Am Geriatr Soc 2001;49:664–72. [PubMed: 11380764]
7. Lord, SR.; Sherrington, C.; Menz, HB.; Close, JC. Falls in Older People: Risk Factors and Strategies for Prevention. 2. Cambridge, UK: Cambridge University Press; 2007. p. 72-4.
8. Coleman AL, Stone K, Ewing SK, et al. Higher risk of multiple falls among elderly women who lose visual acuity. Ophthalmology 2004;111:857–62. [PubMed: 15121359]
9. Klein BE, Moss SE, Klein R, et al. Associations of visual function with physical outcomes and limitations 5 years later in an older population: the Beaver Dam Eye Study. Ophthalmology 2003;110:644–50. [PubMed: 12689880]
10. de Boer MR, Pluijm SM, Lips P, et al. Different aspects of visual impairment as risk factors for falls and fractures in older men and women. J Bone Miner Res 2004;19:1539–47. [PubMed: 15312256]
11. Nevitt MC, Cummings SR, Hudes ES. Risk factors for injurious falls: a prospective study. J Gerontol 1991;46:M164–70. [PubMed: 1890282]
12. Freeman EE, Munoz B, Rubin G, West SK. Visual field loss increases the risk of falls in older adults: the Salisbury Eye Evaluation. Invest Ophthalmol Vis Sci 2007;48:4445–50. [PubMed: 17898264]
13. Friedman SM, Munoz B, West SK, et al. Falls and fear of falling: which comes first? A longitudinal prediction model suggests strategies for primary and secondary prevention. J Am Geriatr Soc 2002;50:1329–35. [PubMed: 12164987]
14. Coleman AL, Cummings SR, Yu F, et al. Study of Osteoporotic Fractures. Binocular visual-field loss increases the risk of future falls in older white women. J Am Geriatr Soc 2007;55:357–64. [PubMed: 17341237]
15. Klein BE, Klein R, Lee KE, Cruickshanks KJ. Performance-based and self-assessed measures of visual function as related to history of falls, hip fractures, and measured gait time: the Beaver Dam Eye Study. Ophthalmology 1998;105:160–4. [PubMed: 9442793]

16. Ramrattan RS, Wolfs RC, Panda-Jonas S, et al. Prevalence and causes of visual field loss in the elderly and associations with impairment in daily functioning: the Rotterdam Study. Arch Ophthalmol 2001;119:1788–94. [PubMed: 11735788]
17. Schwartz AV, Villa ML, Prill M, et al. Falls in older Mexican-American women. J Am Geriatr Soc 1999;47:1371–8. [PubMed: 10573450]
18. U.S. Hispanic population surpasses 45 million: Now 15 percent of total. Washington, D.C: U.S. Census Bureau; May 12008 [Accessed April 19, 2009]. [press release]Available at: http://www.census.gov/Press-Release/www/releases/archives/population/011910.html
19. Varma R, Paz SH, Azen SP, et al. Los Angeles Latino Eye Study Group. The Los Angeles Latino Eye Study: design, methods, and baseline data. Ophthalmology 2004;111:1121–31. [PubMed: 15177962]
20. Solis JM, Marks G, Garcia M, Shelton D. Acculturation, access to care, and use of preventive services by Hispanics: finding from NHANES 1982–84. Am J Public Health 1990;80(suppOl):11–9. [PubMed: 9187576]
21. Cuellar I, Harris L, Jasso R. An acculturation scale for Mexican American normal and clinical populations. Hisp J Behav Sci 1980;2:199–217.
22. Ware J Jr, Kosinski M, Keller SD. A 12-item short-form health survey: construction of scales and preliminary tests of reliability and validity. Med Care 1996;34:220–33. [PubMed: 8628042]
23. Ware, JE.; Kosinski, M.; Keller, SD. New Engl Med Cent. 2. Vol. 31. Boston, MA: Health Inst; 1995. SF-12: How to Score the SF-12 Physical and Mental Health Summary Scales; p. 41
24. Mangione CM, Lee PP, Gutierrez PR, et al. National Eye Institute Visual Function Questionnaire Field Test Investigators. Development of the 25-item National Eye Institute Visual Function Questionnaire. Arch Ophthalmol 2001;119:1050–8. [PubMed: 11448327]
25. Mangione CM, Lee PP, Pitts J, et al. NEI-VFQ Field Test Investigators. Psychometric properties of the National Eye Institute Visual Function Questionnaire (NEI-VFQ). Arch Ophthalmol 1998;116:1496–504. [PubMed: 9823352]
26. Cummings SR, Nevitt MC, Kidd S. Forgetting falls: the limited accuracy of recall of falls in the elderly. J Am Geriatr Soc 1988;36:613–6. [PubMed: 3385114]
27. World Health Organization. Magnitude and causes of visual impairment. 2004 [Accessed April 19, 2009]. Available at: http://v2020.org/core/core_picker/download.asp?documenttable=libraryfiles&id=764
28. Cello KE, Nelson-Quigg JM, Johnson CA. Frequency doubling technology perimetry for detection of glaucomatous visual field loss. Am J Ophthalmol 2000;129:314–22. [PubMed: 10704546]
29. McKean-Cowdin R, Varma R, Wu J, et al. Los Angeles Latino Eye Study Group. Severity of visual field loss and health-related quality of life. Am J Ophthalmol 2007;143:1013–23. [PubMed: 17399676]
30. McKean-Cowdin R, Wang Y, Wu J, et al. Los Angeles Latino Eye Study Group. Impact of visual field loss on health-related quality of life in glaucoma: the Los Angeles Latino Eye Study. Ophthalmology 2008;115:941–8. [PubMed: 17997485]
31. Bursac, Z.; Gauss, CH.; Williams, DK.; Hosmer, DW. Purposeful selection of variables in logistic regression; Source Code Biol Med. 2008 [Accessed June 3, 2009]. p. 17[serial online]Available at: http://www.scfbm.org/content/3/1/17
32. Hosmer, DW.; Lemeshow, S. Applied Logistic Regression. 2. New York: Wiley; 2000. p. 143-200.
33. Black A, Wood J. Vision and falls. Clin Exp Optom 2005;88:212–22. [PubMed: 16083415]
34. Maki BE, Holliday PJ, Topper AK. A prospective study of postural balance and risk of falling in an ambulatory and independent elderly population. J Gerontol 1994;49:M72–84. [PubMed: 8126355]
35. Vellas BJ, Wayne SJ, Romero L, et al. One-leg balance is an important predictor of injurious falls in older persons. J Am Geriatr Soc 1997;45:735–8. [PubMed: 9180669]
36. Freeman EE, Broman AT, Turano KA, West SK. Motion-detection threshold and measures of balance in older adults: the SEE Project. Invest Ophthalmol Vis Sci 2008;49:5257–63. [PubMed: 18719087]
37. Turano KA, Broman AT, Bandeen-Roche K, et al. SEE Project Team. Association of visual field loss and mobility performance in older adults: Salisbury Eye Evaluation Study. Optom Vis Sci 2004;81:298–307. [PubMed: 15181354]

38. Lord SR, Dayhew J. Visual risk factors for falls in older people. J Am Geriatr Soc 2001;49:508–15. [PubMed: 11380741]
39. Koski K, Luukinen H, Laippala P, Kivela SL. Risk factors for major injurious falls among the home-dwelling elderly by functional abilities: a prospective population-based study. Gerontology 1998;44:232–8. [PubMed: 9657085]
40. Gillespie LD, Robertson MC, Gillespie WJ, et al. Interventions for preventing falls in older people living in the community. Cochrane Database Syst Rev 2009;(2):CD007146. [PubMed: 19370674]
41. Harwood RH, Foss AJ, Osborn F, et al. Falls and health status in elderly women following first eye cataract surgery: a randomised controlled trial. Br J Ophthalmol 2005;89:53–9. [PubMed: 15615747]
42. Day, L.; Fildes, B.; Gordon, I., et al. Randomised factorial trial of falls prevention among older people living in their own homes; BMJ. 2002 [Accessed June 3, 2009]. p. 128Available at: http://www.bmj.com/cgi/reprint/325/7356/128
43. Cumming RG, Ivers R, Clemson L, et al. Improving vision to prevent falls in frail older people: a randomized trial. J Am Geriatr Soc 2007;55:175–81. [PubMed: 17302652]
44. Foss AJ, Harwood RH, Osborn F, et al. Falls and health status in elderly women following second eye cataract surgery: a randomised controlled trial. Age Ageing 2006;35:66–71. [PubMed: 16364936]
45. Lord, SR.; Sherrington, C.; Menz, HB.; Close, JC. Falls in Older People: Risk Factors and Strategies for Prevention. 2. Cambridge, UK: Cambridge University Press; 2007. p. 72-4.
46. Lord SR, Dayhew J, Howland A. Multifocal glasses impair edge-contrast sensitivity and depth perception and increase the risk of falls in older people. J Am Geriatr Soc 2002;50:1760–6. [PubMed: 12410892]
47. Finkelstein EA, Chen H, Prabhu M, et al. The relationship between obesity and injuries among U.S. adults. Am J Health Promot 2007;21:460–8. [PubMed: 17515011]
48. Lord, SR.; Sherrington, C.; Menz, HB.; Close, JC. Falls in Older People: Risk Factors and Strategies for Prevention. 2. Cambridge, UK: Cambridge University Press; 2007. p. 173-75.

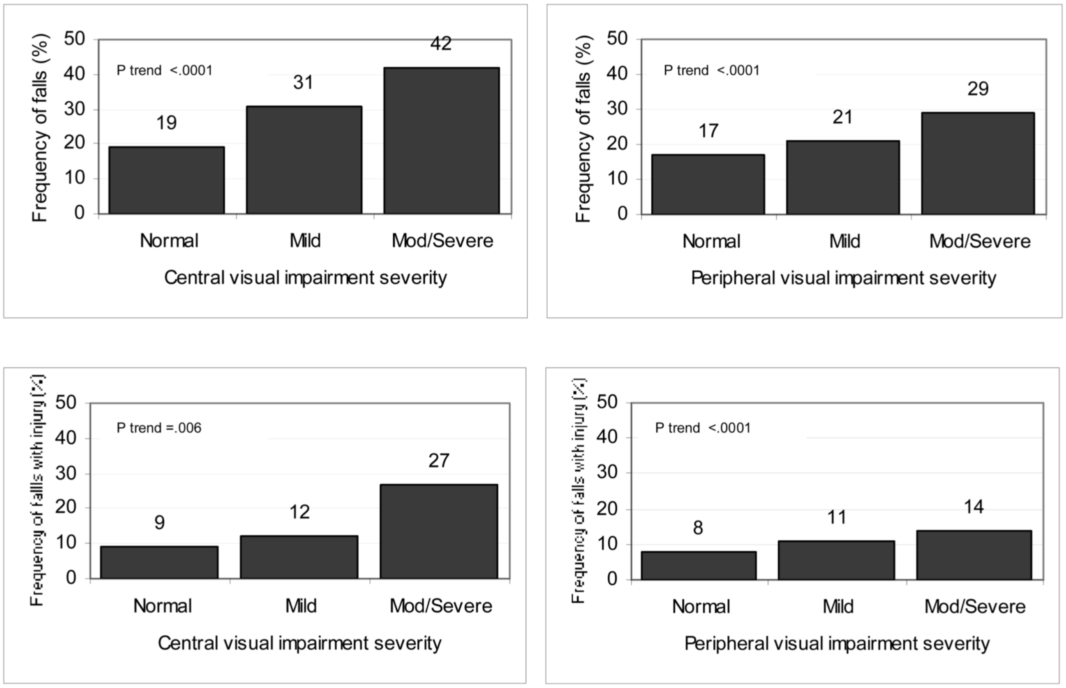

Figure 1.

Falls and falls with injury[a] stratified by severity of central[b] and peripheral[c] visual impairment.

a. Falls with Injury (n=3201) model has 2 less individuals than falls model (n=3203) due to missing data.

b. 2 Severity categories for central visual impairment: normal (< 20/40 in both eyes), n= 3069; mild (20/40–20/63), n=108; moderate/severe (20/80 or worse), n=46.

c. Severity categories for peripheral visual impairment: normal (mean deviation ≥ −2 dB in both eyes), n=1889; mild (−6 dB<mean deviation<−2 dB in the worse eye), n=984; moderate/severe (mean deviation≤−6 dB in worse eye), n=330.

Table 1

Baseline covariates and severity of central and peripheral visual impairment across frequency (%) of falls and falls with injury in the past 12 months at 4 year follow-up.

	Falls (*n*= 3203)			Falls with Injury (*n*=3201)[a]		
	No (*n*=2582)	Yes (*n*=621)	P_{TREND}	No (*n*=2895)	Yes (*n*=306)	P_{TREND}
Age *(years)*						
40–49	1052 (41%)	184 (30%)		1136 (39%)	100 (33%)	
50–59	825 (32%)	200 (32%)		927 (32%)	97 (32%)	
60–69	491 (19%)	143 (23%)		571 (20%)	62 (20%)	
70+	214 (8%)	94 (15%)	**<.0001**	261 (9%)	47 (15%)	**0.001**
Gender						
Male	1115 (43%)	193 (31%)		1208 (42%)	100 (33%)	
Female	1467 (57%)	428 (69%)	**<.0001**	1687 (58%)	206 (67%)	**0.002**
Income						
≤20,000	1222 (47%)	353 (57%)		1400 (48%)	173 (57%)	
>20,000	1360 (53%)	268 (43%)	**<.0001**	1495 (52%)	133 (43%)	**0.007**
Health Insurance						
No	852 (33%)	189 (30%)		960 (33%)	80 (26%)	
Yes	1730 (67%)	432 (70%)	**0.22**	1935 (67%)	226 (74%)	**0.01**
Vision Insurance						
No	1220 (47%)	279 (45%)		1368 (47%)	129 (42%)	
Yes	1362 (53%)	342 (55%)	**0.30**	1527 (53%)	177 (58%)	**0.09**
Alcohol Use [b]						
No	454 (28%)	143 (37%)		524 (19%)	73 (36%)	
Yes	1151 (72%)	246 (63%)	**0.001**	1269 (71%)	128 (64%)	**0.04**
Co-morbidities [c]						
0	901 (35%)	140 (22%)		966 (33%)	75 (25%)	
1	709 (28%)	143 (23%)		784 (27%)	67 (22%)	
2	475 (18%)	122 (20%)		542 (19%)	55 (18%)	
3+	497 (19%)	216 (35%)	**<.0001**	603 (21%)	109 (35%)	**<.0001**

	Falls (n= 3203)			Falls with Injury (n=3201)[a]		
	No (n=2582)	**Yes** (n=621)	P_{TREND}	**No** (n=2895)	**Yes** (n=306)	P_{TREND}
Bifocals						
No	1822 (71%)	375 (60%)		2008 (69%)	187 (61%)	
Yes	760 (29%)	246 (40%)	<***.0001***	887 (31%)	119 (39%)	***0.003***
BMI [d]						
Normal	270 (11%)	57 (9%)		304 (11%)	23 (8%)	
Overweight	1,013 (40%)	193 (31%)		1,109 (39%)	97 (32%)	
Obese	1,278 (50%)|	367 (60%)	<***.0001***	1,462 (51%)	183 (60%)	***0.002***
CVI [e]						
Normal	2492 (96%)	577 (93%)		2781 (96%)	286 (94%)	
Mild	75 (3%)	33 (5%)		95 (3%)	13 (4%)	
Mod/Severe	15 (1%)	11 (2%)	<***.0001***	19 (1%)	7 (2%)	***0.006***
PVI [f]						
Normal	1574 (61%)	315 (50%)		1737 (60%)	151 (49%)	
Mild	774 (30%)	210 (34%)		874 (30%)	109 (36%)	
Mod/Severe	234 (9%)	96 (16%)	<***.0001***	284 (10%)	46 (15%)	<***.0001***

[a] Falls with injury model has 2 less individuals than falls model due to missing data

[b] Responses for alcohol use and falls had 1185 missing values and falls with injury 1208 missing values.

[c] Co-morbidities: diabetes mellitus, arthritis, stroke or brain hemorrhage, high blood pressure, angina, heart attack, asthma, skin cancer, other cancer, back problems, and deafness or hearing problems.

[d] Body mass index (BMI): normal (18.5–24.9), overweight (25.0–29.9), obese (>30.0). For falls model BMI has 25 missing values and for falls with injury model 23.

[e] Central vision impairment (CVI) categories: none (<20/40 in both eyes), mild (20/40–20/63); moderate/severe (20/80 or worse).

[f] Peripheral vision impairment (PVI) categories: none (mean deviation ≥ -2 dB in both eyes), mild (-6 dB<mean deviation<-2 dB in the worse eye), moderate/severe (mean deviation≤ -6 dB in the worse eye).

Table 2

Multivariable association between central and peripheral visual impairment at baseline and risk for falls and falls with injury at 4 year follow-up.

	Model A[a]				Model B[b]			
	Falls *(n=3203)*		Falls with Injury *(n=3201)*[2]		Falls *(n=3203)*		Falls with Injury *(n=3201)*[2]	
	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*
CVI[c]								
Normal	1		1		1		1	
Mild	1.43 (.97–2.21)	.10	1.05 (.57–1.93)	.87	1.28 (.82–2.00)	.27	.93 (.51–1.73)	.83
Mod/Severe	2.01 (.89–4.56)	.09	2.45 (.98–6.10)	.06	2.36 (1.02–5.45)	.05	2.76 (1.10–7.02)	.03
P ***TREND***		***.03***		***.15***		***.04***		***.19***
PVI[d]								
Normal	1		1		1		1	
Mild	1.25 (1.03–1.53)	.03	1.37 (1.05–1.78)	.02	1.18 (.97–1.44)	.10	1.30 (1.00–1.70)	.05
Mod/Severe	1.59 (1.19–2.12)	.002	1.54 (1.05–2.26)	.03	1.42 (1.06–1.91)	.02	1.40 (.94–2.05)	.10
P ***TREND***		***.0007***		***.007***		***.01***		***.04***
Age *(years)*								
40–49	1		1		1		1	
50–59	1.35 (1.08–1.69)	.007	1.16 (.86–1.56)	.31	1.21 (.96–1.51)	.10	1.04 (.77–1.41)	.78
60–69	1.53 (1.19–1.96)	.001	1.14 (.82–1.60)	.45	1.25 (.97–1.63)	.08	.95 (.67–1.35)	.78
70+	2.10 (1.56–2.84)	.000	1.72 (1.16–2.54)	.006	1.67 (1.21–2.28)	.002	1.37 (.91–2.06)	.13
P ***TREND***		***<.0001***		***.02***		***.002***		***.34***
Gender								
Male	-		-		1		1	
Female	-		-	-	1.65 (1.36–2.00)		1.44 (1.12–1.85)	
P ***TREND***						***<.0001***		***.005***
Co-morbidities[e]								
0	-		-		1		1	
1	-		-		1.20 (.93–1.55)	.17	1.05 (.74–1.48)	.80
2	-		-		1.45 (1.10–1.91)	.008	1.21 (.84–1.76)	.30

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	Model A[a]				Model B[b]			
	Falls *(n=3203)*		Falls with Injury *(n=3201)*[2]		Falls *(n=3203)*		Falls with Injury *(n=3201)*[2]	
	OR (95% CI)	***p***	**OR (95% CI)**	***p***	**OR (95% CI)**	***p***	**OR (95% CI)**	***p***
3+	-		-	-	2.26 (1.74–2.91)	<.0001	2.05 (1.47–2.87)	<.0001
P $_{TREND}$						***<.0001***		***<.0001***

OR=odds ratio; CI=confidence interval

[a] All variables were adjusted for each other in models A and B.

[b] Falls with injury model has 2 less individuals than falls model due to missing data.

[c] Central Vision Impairment (CVI) categories: none (< 20/40 in both eyes), mild (20/40–20/63); moderate/severe (20/80 or worse).

[d] Peripheral Vision Impairment (PVI) categories: none (mean deviation ≥−2 dB in both eyes), mild (−6 dB<mean deviation<−2 dB in the worse eye), moderate/severe (mean deviation≤−6 in the worse eye).

[e] Co-morbidities: diabetes mellitus, arthritis, stroke or brain hemorrhage, high blood pressure, angina, heart attack, asthma, skin cancer, other cancer, back problems, and deafness or hearing problems.