JAMDA 25 (2024) 789–795

JAMDA

journal homepage: www.jamda.com

Original Study

Association Between Visual Acuity and Prospective Fall Risk in Generally Healthy and Active Older Adults: The 3-Year DO-HEALTH Study

Maud Wieczorek PhD [a,b], Marlis Isler [a], Klara Landau MD [c], Matthias D. Becker MD [d,e,f], Bess Dawson-Hughes MD [g], Reto W. Kressig MD [h], Bruno Vellas MD [i,j], Endel John Orav PhD [k], René Rizzoli MD [l], John A. Kanis MD [m,n], Gabriele Armbrecht MD [o], José António P. Da Silva MD [p], Andreas Egli MD [a], Gregor Freystätter MD [a,b], Heike A. Bischoff-Ferrari MD, DrPH [a,b,q,*], for the DO-HEALTH Research group

[a] *Centre on Aging and Mobility, University of Zurich and City Hospital Zurich, Zurich, Switzerland*
[b] *Department of Aging Medicine and Aging Research, University of Zurich, Zurich, Switzerland*
[c] *Department of Ophthalmology, University Hospital Zurich, University of Zurich, Zurich, Switzerland*
[d] *Department of Ophthalmology, City Hospital Zurich, Zurich, Switzerland*
[e] *Department of Ophthalmology, University of Heidelberg, Heidelberg, Germany*
[f] *Spross Ophthalmology Research Institute, City Hospital Zurich, Zurich, Switzerland*
[g] *Jean Mayer USDA Human Nutrition Research Centre on Aging, Tufts University, Boston, MA, USA*
[h] *University Department of Geriatric Medicine FELIX PLATTER, and University of Basel, Basel, Switzerland*
[i] *Gérontopôle de Toulouse, Institut du Vieillissement, Centre Hospitalo-Universitaire de Toulouse, Toulouse, France*
[j] *UMR INSERM 1027, University of Toulouse III, Toulouse, France*
[k] *Department of Biostatistics, Harvard T.H. Chan School of Public Health, Boston, MA, USA*
[l] *Division of Bone Diseases, Geneva University Hospitals and Faculty of Medicine, Geneva, Switzerland*
[m] *Centre for Metabolic Diseases, University of Sheffield Medical School, Sheffield, United Kingdom*
[n] *Mary MacKillop Institute for Health Research, Australian Catholic University, Melbourne, Victoria, Australia*
[o] *Klinik für Radiologie, Charité – Universitätsmedizin Berlin, corporate member of Freie Universität Berlin and Humboldt-Universität zu Berlin, Berlin, Germany*
[p] *Institute for Clinical and Biomedical Research (iCBR), Faculty of Medicine, University of Coimbra and Centro Hospitalar e Universitário de Coimbra, Coimbra, Portugal*
[q] *University Hospital Toulouse, IHU HealthAge Toulouse, France*

Keywords:
DO-HEALTH
falls
injurious falls
older adults
visual acuity

A B S T R A C T

Objective: Although aging has a strong impact on visual acuity (VA) and falls, their interaction is understudied in generally healthy older adults. This study aimed to examine if and to what extent baseline VA is associated with an increased risk of all and injurious falls over 3 years in generally healthy community-dwelling older adults.
Design: Observational analysis of DO-HEALTH, a double-blind, randomized controlled trial.
Setting and Participants: Multicenter trial with 7 European centers: Zurich, Basel, Geneva (Switzerland), Berlin (Germany), Innsbruck (Austria), Toulouse (France), and Coimbra (Portugal), including 2157 community-dwelling adults aged 70 years and older without any major health events in the 5 years prior to enrollment, sufficient mobility, and good cognitive status.
Methods: The numbers of all and injurious falls were recorded prospectively by diary and in-person assessment every 3 months. Decreased VA at baseline was defined as better-eye VA lower than 1.0.

M.W. and M.I. shared first authorship.
G.F.and H.A.B. shared last authorship.

Funding source: The DO-HEALTH study was funded by the Seventh Research Framework Program of the European Commission (Grant Agreement no. 278588), and within this framework, also by the University of Zurich (Chair for Geriatric Medicine and Aging Research), DNP, Roche, NESTEC, Pfizer, and Streuli. The funding/supporting organizations had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; or decision to submit the manuscript for publication.

* Address correspondence to Heike A. Bischoff-Ferrari, MD, DrPH, Department of Aging Medicine and Aging Research, Centre on Aging and Mobility, University of Zurich, Tièchestrasse 99, 8037 Zürich, Switzerland.
E-mail address: Heikea.Bischoff-Ferrari@uzh.ch (H.A. Bischoff-Ferrari).

https://doi.org/10.1016/j.jamda.2024.03.005

We applied negative binomial regression models for all and injurious falls, adjusted for age, sex, prior falls, treatment allocation, study site, baseline body mass index, and use of walking aids.
Results: Among the 2131 participants included in this analysis (mean age: 74.9 years, 61.7% were women, 82.6% at least moderately physically active), 1464 (68.7%) had decreased VA. Overall, 3290 falls including 2116 injurious falls were recorded over 3 years. Decreased VA at baseline was associated with a 22% increased incidence rate of all falls [adjusted incidence rate ratio (aIRR) = 1.22, 95% CI 1.07, 1.38, $P = .003$] and 20% increased incidence rate of injurious falls (aIRR = 1.20, 95% CI 1.05, 1.37, $P = .007$).
Conclusions and Implications: Our findings suggest that decreased VA is an independent predictor of an about 20% increased risk of all and injurious falls, highlighting the importance of regular eye examinations and VA measurements for fall prevention, even in generally healthy and active older adults.

The number of adults aged 65 years and older will increase in Europe[1] and globally,[2] leading to a rise in falls, occurring in approximately every third person aged 65 years each year and every other person aged 80 years each year, with half of them experiencing several falls.[3] Falls have a significant economic impact, with fall-related injuries ranking among the top 20 most costly medical conditions.[4] At the individual level, 20% of falls cause a serious injury,[5,6] leading to fear of falling in every third person,[7] resulting in self-restriction in activities[7] and admission to nursing homes.[8] Although the risk of falling is multifaceted, vision has been suggested to be a key contributor to this risk.[9] Notably, decreased visual acuity (VA), the most common visual deficit,[10] may be particularly important. Aging is associated with a deterioration in VA from the age of 50 years and with an increased incidence of eye pathologies.[11] Decreased VA not only affects the visual feedback itself but may also impair the vestibular system's control of postural balance.[12] Consequently, impairments in visual functions affect postural control and may be associated with an increased risk of falls.[12,13] However, literature reviews of prospective studies have concluded that evidence on the association between VA and falls among older adults remains limited and inconsistent.[9,14] The latter may in part be explained by the limited sample size of several studies,[15-19] and the retrospective reporting of falls,[16,20-23] which may lead to under-reporting of falls in these studies.[24]

The aim of the present study was to examine if and to what extent baseline VA was associated with the prospective incidence of all and injurious falls over 3 years of follow-up among generally healthy and active older adults from 5 European countries.

Methods

Participants and Study Design

This study is a post hoc observational analysis of the DO-HEALTH (Vitamin D_3−Omega 3−Home Exercise−Healthy Ageing and Longevity Trial) clinical trial, a 3-year, multicenter, double-blinded, randomized controlled clinical trial (NCT01745263).[25] A total of 2157 community-dwelling generally healthy adults aged 70 years and older were recruited from 7 centers in 5 European countries: Zurich, Basel, Geneva (Switzerland), Berlin (Germany), Innsbruck (Austria), Toulouse (France), and Coimbra (Portugal). Inclusion criteria were an absence of major health events in the 5 years prior to enrolment, sufficient mobility to come to the study centers, and good cognitive function with a Mini-Mental State Examination score of at least 24. In order to include participants with an increased risk of falling, recruitment was stratified to include approximately 40% of enrollees with falls in the 12 months prior to enrolment. Further details about the trial design and main findings can be found elsewhere.[26,27]

Outcomes

The outcomes were the total number of all falls and the total number of injurious falls experienced over the 3-year follow-up. Falling was defined as "unintentionally coming to rest on the ground, floor, or other lower level"; coming to rest against furniture or a wall was not considered a fall.[28] Injurious falls were defined as falls that led to any injury (ie, skin wound, significant bruising, or fracture). The numbers of all and injurious falls were recorded prospectively over the follow-up. Supported by a fall diary, all 2157 participants were asked whether they had sustained a fall in the last 3 months at each 3-monthly contact—by phone or during a clinical visit. In case a participant experienced a fall, a detailed and validated fall protocol was applied, collecting the fall circumstances, related injuries, treatment, and related health care utilization. The number of participants who sustained at least 1 fall over the follow-up was considered as a secondary outcome.

Exposure

Baseline VA, defined by the ability to distinguish objects at a specific distance,[29] was measured using Landolt rings at a 5-m distance. The Landolt optotype is a figure resembling a C-shape with an opening that is one-fifth of its outer diameter.[30,31] Participants were asked to identify the direction of the opening in the Landolt ring, with optotypes getting progressively smaller. The test was continued until less than 50% of the rings per line were recognized correctly. Participants used their usual visual aids during the test, if available. VA was measured in decimal values and ranged from 0.1 to 1.25, with higher values indicating better VA. Each eye was examined separately, and the higher value between the right and left eye, the so-called better-eye VA, was used as the main exposure. Decreased VA was defined as baseline better-eye VA lower than 1.00, whereas normal VA was defined as baseline better-eye VA equal to or greater than 1.0, in alignment with previous research and the World Health Organization's latest World Report on Vision.[15,32]

Baseline Covariates

Participants' characteristics such as age, sex, and body mass index (BMI) were collected at baseline. Comorbidities were assessed with the Self-Administered Comorbidity Questionnaire by Sangha et al.[33] Frailty status was defined according to the Fried physical frailty phenotype.[34] Polypharmacy was defined as the use of 5 or more medications.[35] Frequency of physical activity (0, 1-2, $\geq$3 times per week) was measured using the Nurses' Health Study questionnaire.[36]

Statistical Analysis

Baseline demographic and clinical characteristics of the study population are presented overall and for participants with decreased and normal VA, separately. Differences between the 2 groups with and without decreased VA were tested using the Wilcoxon rank sum test, *t* test, or χ^2 test, for non-normal, normal, and categorical variables, respectively.

For all and injurious falls, separate negative binomial regression models were fit with an offset of log of person-years in the study. Person-years were calculated from randomization to drop-out, to death, or the end of the trial. The primary exposure was decreased VA, and adjusted models controlled for age, sex, prior falls, treatment allocation, study center, baseline BMI, and baseline use of walking aids.

Potential effect modifications by sex, age, and history of falls in the relationship between baseline VA and the number of all and injurious falls were investigated by adding interaction terms between the exposure and subgroups of sex, age (70-74 and ≥75 years), and history of falls in the 12 months prior to enrollment (yes or no) in the multivariable models. Subgroup analyses were performed in case of statistical significance of the respective interaction terms.

In a sensitivity analysis, additional adjustment was made on the baseline number of comorbidities, baseline frailty status, baseline polypharmacy, and baseline physical activity levels. As cataract surgery significantly improves VA[37] and has been shown to reduce fall incidence,[38] we excluded participants who underwent eye surgery for cataract (n = 373) in a second sensitivity analysis. Finally, in a third sensitivity analysis, we excluded participants reporting the use of multifocal glasses (n = 220) because these visual aids were found to be associated with an increased risk of falls.[39] All results are expressed as incidence rates, and incidence rate ratios along with 95% CIs for all and injurious falls and presented for participants with decreased and normal VA at baseline. The odds of falling at least once were modeled using logistic regression models with an offset of the log of person-years in the study, controlling for the same covariates as in the main analysis. Statistical analyses involved using SAS, version 9.4. A 2-sided *P* value <.05 was considered statistically significant.

Ethics

The Cantonal Ethical Committee of the Canton of Zurich approved this ancillary analysis (BASEC-Nr 2021-02125). Informed consent was obtained from all individual participants included in the study.

Results

Baseline Characteristics of the Study Population

Of the 2157 DO-HEALTH trial participants, 26 (1.2%) had missing information on VA at baseline so that 2131 participants were included in this analysis. Among them, 1464 (68.7%) had a decreased VA at baseline. The distribution of baseline better-eye VA in our study population is presented in greater detail in Supplementary Figure 1.

The baseline characteristics of the study population are presented in Table 1. Overall, the mean age was 74.9 (SD: 4.4) years and 1315 (61.7%) were women. As intended by the trial recruitment strategy, 41.8% of participants experienced a fall in the year preceding the randomization. At baseline, participants with decreased VA were more likely to be women ($P < .001$), to be older ($P = .001$), to have a higher BMI ($P = .003$), to have a higher number of comorbidities ($P < .001$), to be less physically active ($P < .001$), to use walking aids at baseline ($P = .009$), to have polypharmacy ($P < .001$), and to be at least prefrail or frail ($P < .001$), compared to participants with normal VA.

Decreased Visual Acuity and Incidence Rates of All falls

The distribution of all falls within the study population with further stratification by VA group is presented in Figure 1A and C. Over

Table 1
Baseline Characteristics of the Study Population

	Decreased Visual Acuity (n = 1464; 68.7)	Normal Visual Acuity (n = 667; 31.3)	*P* Value*	Overall (N = 2131)
Sex, n (%)			<.001	
Men	510 (34.8)	306 (45.9)		816 (38.3)
Women	954 (65.2)	361 (54.1)		1315 (61.7)
Age, y, mean (SD)	75.5 (4.7)	73.7 (3.5)	<.001	74.9 (4.4)
Age categories, n (%)				
70-74 y	770 (52.6)	453 (67.9)		1223 (57.4)
≥75 y	694 (47.4)	214 (32.1)		908 (42.6)
BMI, mean (SD)	26.5 (4.3)	25.9 (4.2)	.003	26.3 (4.3)
Prior fall, n (%)	617 (42.14)	274 (41.1)	.64	891 (41.8)
Number of comorbidities, mean (SD)†	1.9 (1.5)	1.3 (1.2)	<.001	1.7 (1.4)
Physical activity level, n (%)‡			<.001	
None	306 (20.9)	65 (9.8)		371 (17.4)
1-2 times per week	446 (30.5)	196 (29.4)		642 (30.2)
≥3 times per week	711 (48.6)	405 (60.8)		1116 (52.4)
Use of walking aids at baseline, n (%)	35 (2.4)	5 (0.8)	.009	40 (1.9)
Polypharmacy, n (%)§	450 (30.7)	127 (19.0)	<.001	577 (27.1)
Frailty status, n (%)‖			<.001	
Robust	714 (49.7)	408 (61.5)		1122 (53.5)
Prefrail	663 (46.2)	251 (37.9)		914 (43.5)
Frail	59 (4.1)	4 (0.6)		63 (3.0)

*Differences between participants with decreased and normal visual acuity at baseline were assessed by an independent *t* test for continuous variables and χ^2 tests for categorical variables.
†Self-reported number of comorbidities was assessed by the Sangha questionnaire, range 0-13.
‡Frequency of physical activity was measured using the Nurses' Health Study questionnaire.
§Polypharmacy was defined as the concomitant use of 5 or more medications.
‖Frailty status was defined using the Fried Physical Frailty Phenotype, which evaluates 5 criteria: fatigue (self-reported), unintentional weight loss (self-reported loss of more than 5% of total body weight), reduced physical activity (self-reported), slowness (impaired walking speed), and weakness (low grip strength). Participants are classified as at least prefrail when 1 or more of the criteria are presented and otherwise classified as robust.

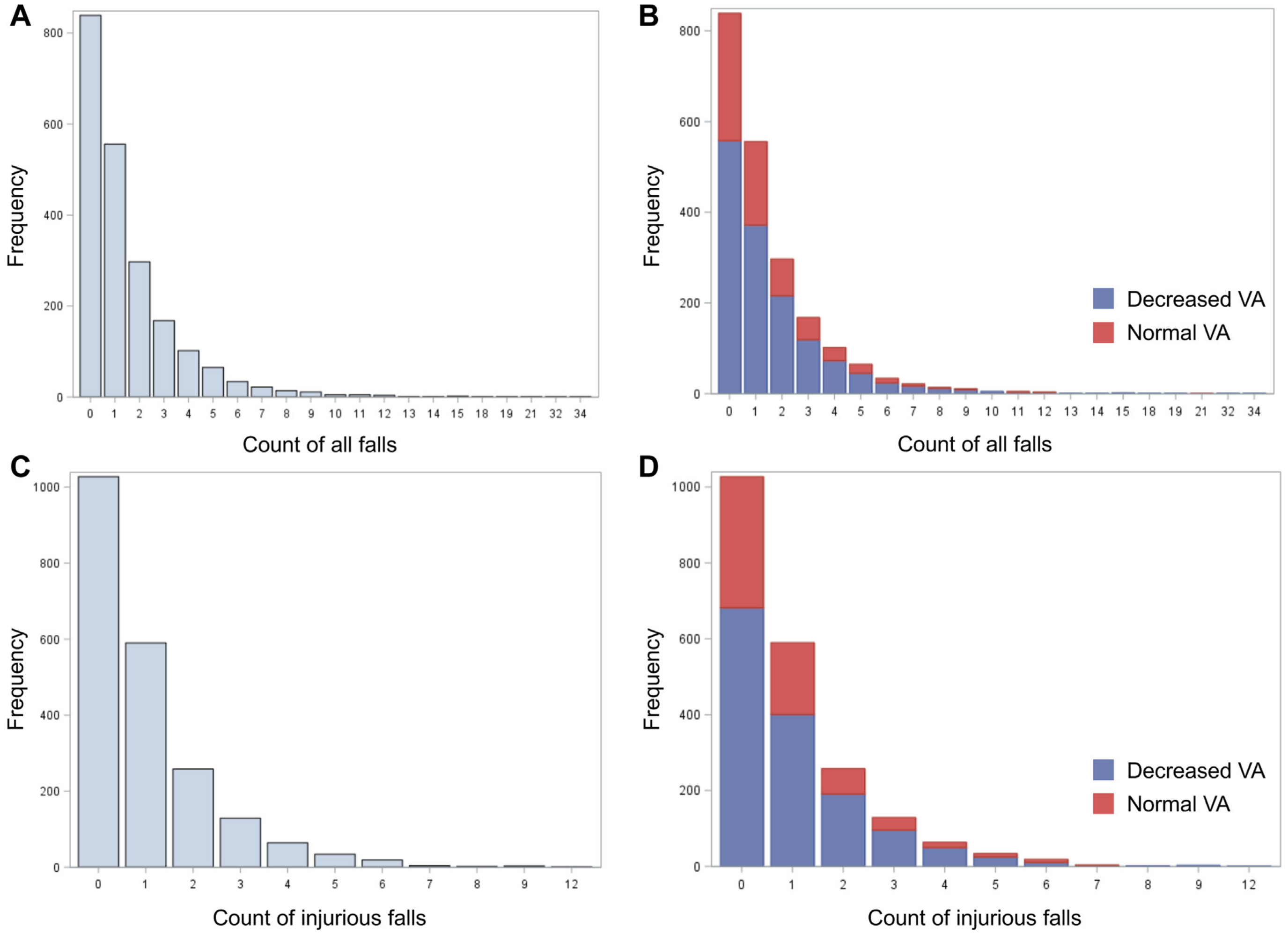


Fig. 1. Distribution of all and injurious falls in the study population and across visual acuity groups. Panel A presents the overall distribution of all falls within the study population, whereas Panel C focuses on the distribution of injurious falls. Panels B and D provide a breakdown of the distribution of all falls and injurious falls, respectively, among participants categorized by visual acuity as either decreased or normal.

the 3 years of follow-up, a total of 2397 and 893 falls were recorded among participants who had decreased and normal VA at baseline, respectively. This reflects a crude incidence rate of all falls of 0.60 (95% CI 0.56, 0.64) in participants with decreased VA and 0.48 (95% CI 0.43, 0.53) with normal VA, per person-year.

In the multivariate analysis, adjusting for study site, sex, age, previous fall, baseline BMI, and baseline use of walking aids, decreased VA at baseline was associated with a 22% increased incidence rate of all falls (IRR = 1.22, 95% CI 1.07, 1.38, $P = .003$) (Table 2).

Decreased Visual Acuity and Incidence Rates of Injurious falls

The distribution of the number of injurious falls, both overall and by VA groups, is presented in Figure 1B and D. A total of 1531 and 585 injurious falls were recorded among participants who had decreased and normal VA at baseline, respectively. This reflects a crude incidence rate of injurious falls in participants with decreased VA of 0.38 (95% CI 0.36, 0.41) and 0.31 (95% CI 0.28, 0.35) with normal VA, per person-year.

In the multivariate analysis, adjusting for study site, sex, age, previous fall, baseline BMI, and baseline use of walking aids, decreased VA at baseline was associated with a 20% increased incidence rate of injurious falls (IRR = 1.20, 95% CI 1.05, 1.37, $P = .007$) (Table 3).

Subgroup Analyses

We did not proceed with the subgroup analyses as we did not find any indication of effect modification by sex ($P = .82$ and $P = .43$, for all and injurious falls respectively), age ($P = .93$ and $P = .41$, for all and injurious falls respectively), and prior falls ($P = .69$ and $P = .72$, for all and injurious falls respectively) in the association between VA and both all and injurious falls.

Sensitivity Analyses

When further controlling for baseline frailty status, number of comorbidities, and polypharmacy, decreased VA at baseline was associated with a 20% increased incidence rate of all falls (IRR = 1.20, 95% CI 1.06, 1.37, $P = .005$) and a 19% increased incidence rate for injurious falls (IRR = 1.19, 95% CI 1.04, 1.36, $P = .011$) (Supplementary Table 1). Also, when we excluded participants who underwent cataract surgery over the follow-up, decreased VA at baseline was still associated with a 22% increased incidence rate of all falls (IRR = 1.22, 95% CI 1.06, 1.41, $P = .006$) and 22% increased incidence rate of injurious falls (IRR = 1.22, 95% CI 1.05, 1.41, $P = .012$) (Supplementary Table 2). Further, when we excluded participants who reported the use of multifocal glasses, participants with decreased VA at baseline had a 22% increased incidence rate of all

Table 2
Incidence Rates of All Falls Among participants With and Without Decreased Visual Acuity at Baseline

	Decreased Visual Acuity (n = 1464; 68.7%)	Normal Visual Acuity (n = 667; 31.3%)
No. of all falls	2397	893
Crude estimates		
Incidence rate of all falls (95% CI), per person-year	0.60 (0.56, 0.64)	0.48 (0.43, 0.53)
Incidence rate ratio (95% CI)	1.25 (1.10, 1.41)	
P value	<.001	
Adjusted estimates		
Incidence rate of all falls (95% CI), per person-year	0.54 (0.51, 0.58)	0.45 (0.40, 0.50)
Incidence rate ratio (95% CI)	1.22 (1.07, 1.38)	
P value	.003	

The association between baseline visual acuity and all falls was assessed using negative binomial regression models with an offset of the log of person-years in the study. The crude model is unadjusted, and the adjusted model controls for study site, sex, age, previous fall, baseline body mass index, and baseline use of walking aids.

falls (IRR = 1.22, 95% CI 1.06, 1.40, *P* = .005) and an 18% increased incidence rate of injurious falls (IRR = 1.18, 95% CI 1.03, 1.36, *P* = .021) (Supplementary Table 3).

Decreased Visual Acuity and Odds of Falling at Least Once

In total, 906 participants with decreased VA sustained at least 1 fall over the follow-up whereas there were 386 participants who fell at least once among those with normal VA at baseline.

In crude analysis, participants with decreased VA had a 23% increased odds of falling at least once over the follow-up, compared with their counterparts with normal VA (OR = 1.23, 95% CI 1.01, 1.49, *P* = .038). However, after adjusting for confounding variables, this association was no longer statistically significant (Supplementary Table 4).

Discussion

In this prospective study among 2131 generally healthy and active community-dwelling older adults from 5 European countries, decreased VA at baseline was associated with about a 20% increased incidence rate of all and injurious falls, independent of key risk factors for falls including age and history of falls in the 12 months prior to enrollment. The robustness of these findings was confirmed by 3 sensitivity analyses, adjusting for additional potential confounders including baseline frailty status, number of comorbidities, and polypharmacy, and excluded participants who underwent cataract surgery or those who were wearing multifocal glasses.

These findings bring new evidence on the relationship between VA and the prospective incidence of falls among community-dwelling older adults and complement previous longitudinal findings. In a 1-year prospective cohort study following 428 Finnish women, Kulmala et al[15] reported that women with vision impairment (defined as VA lower than 1.0) had a nonsignificantly higher incidence rate of falls compared to women with normal VA (IRR = 1.5, 95% CI 0.6, 4.2, *P* = .39). Another prospective study among 280 community-dwelling older adults in Taiwan found that baseline VA was not associated with the number of falls experienced over 2 years (IRR = 1.0, 95% CI 0.8, 1.3).[17] The inconsistency between these findings and ours may be due to the smaller sample size and shorter follow-ups of these studies compared with the DO-HEALTH trial.[15] Also, the authors of these 2 studies did not assess the association between VA and injurious falls.

Further comparison of our findings with the literature appears limited as most of the studies investigating the relationship between VA and falls considered the number of participants experiencing 1 or more falls during follow-up as an outcome, rather than the number of falls experienced. In a meta-analysis of 15 prospective studies published in 2010, vision impairment was found to be significantly associated with a 1.4-fold increased odds of falling at least once among community-dwelling adults aged ≥65 years.[14] However, evidence from more recent prospective cohort studies that were not included in this meta-analysis remains conflicting, pointing toward an absence of a significant association between objectively measured VA and increased odds of falling[40,41] or a significant association between visual impairment and higher odds of falling.[23] These conflicting results may be explained by the heterogeneity in the recording of the fall events. The particular importance of a prospective and frequent fall ascertainment was demonstrated in the meta-analysis of Deandrea et al.[14] The authors found a stronger association between vision impairment and the odds of all falls when they only included studies with a high-frequency fall assessment (OR = 1.35, 95% CI 1.18, 1.54, in all studies, and OR = 1.51, 95% CI 1.29, 1.78, in studies with high frequency of fall assessment).[14]

When considering the number of participants who sustained at least 1 fall as a secondary outcome, our study, which used high-frequency fall assessments over 3 years, reported that participants with decreased VA had a 23% increased odds of falling at least once over the follow-up period, compared with those with normal VA. However, the initial association between visual acuity and sustaining at least 1 fall over the follow-up was no longer statistically significant after adjusting for potential confounding variables. This suggests that the relationship between VA and fall risk may be influenced by multiple factors beyond VA alone, underscoring the importance of considering a wide range of potential confounders in such analyses. The use of different eye testing charts across studies is an additional point that precludes optimal comparisons between studies and data pooling.[9] Although the WHO defines visual impairment as having a VA lower than 0.5 in the better eye, along with considering other aspects like color vision and contrast sensitivity,[32] definitions of decreased VA or visual impairment varied widely across different studies.[9] Our findings showing a significantly increased incidence rate of falls and injurious falls in individuals with better-eye VA lower than 1.0 suggest that the WHO definition may be too conservative with regard to fall risk assessment and prevention, especially in generally healthy community-dwelling older adults.

Table 3
Incidence Rates of Injurious Falls Among Participants With and Without Decreased Visual Acuity at Baseline

	Decreased Visual Acuity (n = 1464; 68.7%)	Normal Visual Acuity (n = 667; 31.3%)
No. of injurious falls	1531	585
Crude estimates		
Incidence rate of injurious falls (95% CI), per person-year	0.38 (0.36, 0.41)	0.31 (0.28, 0.35)
Incidence rate ratio (95% CI)	1.22 (1.07, 1.38)	
P- value	.002	
Adjusted estimates		
Incidence rate of injurious falls (95% CI), per person-year	0.35 (0.33, 0.38)	0.30 (0.26, 0.33)
Incidence rate ratio (95% CI)	1.20 (1.05, 1.37)	
P value	.007	

The association between baseline visual acuity and injurious falls was assessed using negative binomial regression models with an offset of the log of person-years in the study. The crude model is unadjusted and the adjusted model controls for study site, sex, age, previous fall, baseline body mass index, and baseline use of walking aids.

From a physiological standpoint, accurate postural control and balance involve coordination between visual, vestibular, and proprioceptive feedback. The dominance of the visual information in this process is illustrated by the fact that postural sway increases between 20% and 70% when eyes are closed.[42] In addition, it has been shown that somatosensory and vestibular systems deteriorate disproportionately with age, leading to an overreliance on visual feedback for maintaining balance.[12,13] Thus, impairments in visual functions may contribute significantly to the risk of falls.[12,13] Despite the increased incidence of eye pathologies in older age,[11] the utilization of eye care among older adults remains low; only 37% of older adults living in high-income countries reported having an eye examination in the previous year.[43] Therefore, raising awareness among older adults and clinicians about the importance of regular eye examinations may contribute to improving eye health and reducing the incidence and the burden of falls in this population.[44]

Our study has several strengths. Falls were recorded prospectively with a fall diary as well as by in-person interviews every 3 months over 3 years, limiting potential recall bias. Further, the validity of our results was supported by the adjustments made on a wide range of potential confounders and in performing several sensitivity analyses. Although logarithmic scales like ETDRS charts are often recommended for research purposes,[45] the use of Landolt rings to measure VA remains one of the strengths of our study. This choice aligns with the prevalent use of decimal VA in routine testing in general ophthalmology clinics and is supported by the recognized validity and reliability of the Landolt rings.[31]

However, a few limitations need consideration. First, because our study was conducted among generally healthy community-dwelling older adults, our results are less generalizable to more vulnerable populations including those in post-acute and long-term care environments. In addition, it remains unclear if participants were wearing their usual visual aids at the time of their falls. As a result, we cannot exclude that VA might have been worse when the fall occurred and the potential protective effect of consistent eyewear use on fall rates warrants further investigation in future studies. Additionally, although our study provides important insights into the relationship between visual acuity and falls, visual acuity represents one specific aspect of the complex visual function system. Other components, such as contrast sensitivity and depth perception, may also play critical roles in navigating the environment and contributing to the risk of falls.[46] Thus, further research is needed to explore how these additional visual functions contribute to fall risk in the target population. Finally, because of the observational nature of our study, causality cannot be inferred from the results, and despite adjustment for key potential confounders, we cannot exclude the possibility that the associations between decreased VA and falls may be explained in part by residual confounding.

Conclusions and Implications

In conclusion, our findings suggest that decreased VA is an independent predictor of an about 20% increased risk of all and injurious falls, highlighting the importance of regular eye examinations and VA measurements for fall prevention, even in generally healthy and active older adults. From a policy perspective, these results advocate for the integration of comprehensive visual health assessments into routine health care screenings for older adults. Implementing such policies could significantly reduce fall risk, potentially leading to decreased health care costs and improved quality of life for the older population.

Disclosure

As part of the DO-HEALTH independent and investigator-initiated clinical trial, H.A.B.-F. reports, as the principal investigator of the DO-HEALTH trial, grants from the European Commission, the University of Zurich, Nestec, Pfizer Consumer Healthcare, and Streuli Pharma, and nonfinancial support from DSM Nutritional Products and Roche Diagnostics. Further, H.A.B.-F. reports speaker fees from Wild, Pfizer, Vifor, Mylan, Roche Diagnostics, and independent and investigator-initiated grants from Pfizer and from Vifor, outside of the submitted work. E.J.O. was also funded by DO-HEALTH. J.A.K. is a director of Osteoporosis Research Ltd. that maintains FRAX. M.D.B. reports speaking engagements for Roche Pharma (Schweiz) AG and consulting roles for Hoffmann-La Roche Ltd., Roche Pharma (Schweiz) AG, and ZEISS meditec (Deutschland). He is a lead user for Oertli (Schweiz) and holds patents and equity in Ophthorobotics AG. His contracted research includes work with Roche Pharma (Schweiz) AG, Novertis Pharma Schweiz AG, Chengdu Kanghong, and Bayer (Schweiz) AG. He has also received grant support from the W.H. Spross Stiftung zur Förderung der Augenheilkunde and the Stiftung für wissenschaftliche Forschung am Stadtspital Zürich. All other authors declare no competing interests.

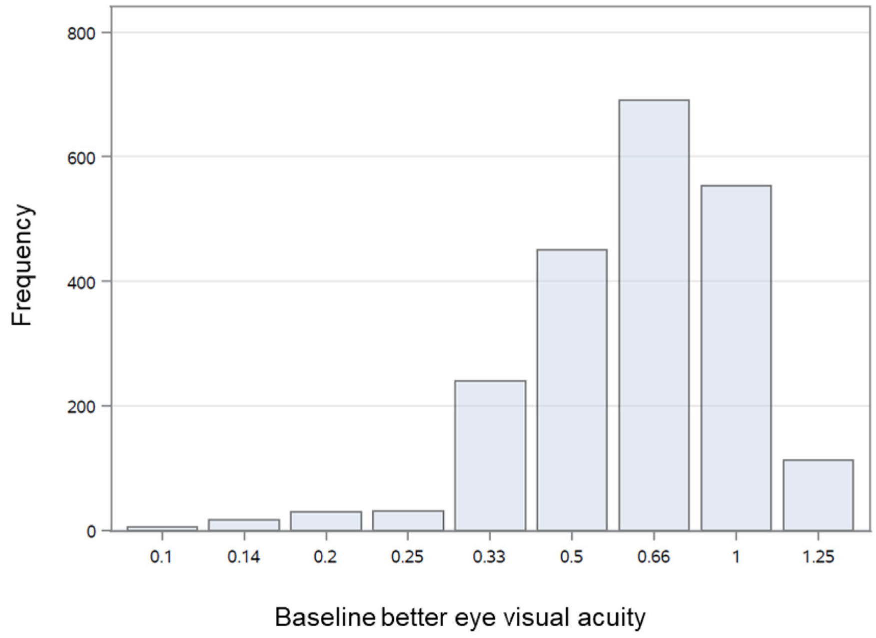
Acknowledgments

We thank all the members of the DO-HEALTH Research Group, and we are grateful to the highly engaged participants of the study in all 5 countries.

References

1. Eurostat. *Ageing Europe - Looking at the lives of older people in the EU European Union*, Eurostat; 2019. p. 162.
2. Nowakowski K. There are now more people over age 65 than under five—what that means. 2019. Accessed April 24, 2024. https://www.nationalgeographic.co.uk/history-and-civilisation/2019/07/there-are-now-more-people-over-age-65-than-under-five-what-that-means
3. Morrison A, Fan T, Sen SS, et al. Epidemiology of falls and osteoporotic fractures: a systematic review. *Clin Outcomes Res*. 2013;5:9–18.
4. Florence CS, Bergen G, Atherly A, et al. Medical costs of fatal and nonfatal falls in older adults. *J Am Geriatr Soc*. 2018;66:693–698.
5. Sterling DA, O'Connor JA, Bonadies J. Geriatric falls: injury severity is high and disproportionate to mechanism. *J Trauma*. 2001;50:116–119.
6. Alexander BH, Rivara FP, Wolf ME. The cost and frequency of hospitalization for fall-related injuries in older adults. *Am J Public Health*. 1992;82:1020–1023.
7. Vellas BJ, Wayne SJ, Romero LJ, et al. Fear of falling and restriction of mobility in elderly fallers. *Age Ageing*. 1997;26:189–193.
8. Tinetti ME, Williams CS. Falls, injuries due to falls, and the risk of admission to a nursing home. *N Engl J Med*. 1997;337:1279–1284.
9. Saftari LN, Kwon OS. Ageing vision and falls: a review. *J Physiol Anthropol*. 2018;37:11.
10. Pan CW, Ramamurthy D, Saw SM. Worldwide prevalence and risk factors for myopia. *Ophthalmic Physiol Opt*. 2012;32:3–16.
11. Harwood RH. Visual problems and falls. *Age Ageing*. 2001;30(Suppl 4):13–18.
12. Yeh TT, Cluff T, Balasubramaniam R. Visual reliance for balance control in older adults persists when visual information is disrupted by artificial feedback delays. *PLoS One*. 2014;9:e91554.
13. Black A, Wood J. Vision and falls. *Clin Exp Optom*. 2005;88:212–222.
14. Deandrea S, Lucenteforte E, Bravi F, et al. Risk factors for falls in community-dwelling older people: a systematic review and meta-analysis. *Epidemiology*. 2010;21:658–668.
15. Kulmala J, Viljanen A, Sipilä S, et al. Poor vision accompanied with other sensory impairments as a predictor of falls in older women. *Age Ageing*. 2009;38:162–167.
16. Lamoureux E, Gadgil S, Pesudovs K, et al. The relationship between visual function, duration and main causes of vision loss and falls in older people with low vision. *Graefes Arch Clin Exp Ophthalmol*. 2010;248:527–533.
17. Kwan MM, Lin SI, Close JC, et al. Depressive symptoms in addition to visual impairment, reduced strength and poor balance predict falls in older Taiwanese people. *Age Ageing*. 2012;41:606–612.
18. Stalenhoef PA, Diederiks JP, Knottnerus JA, et al. A risk model for the prediction of recurrent falls in community-dwelling elderly: a prospective cohort study. *J Clin Epidemiol*. 2002;55:1088–1094.
19. Lord SR, Dayhew J. Visual risk factors for falls in older people. *J Am Geriatr Soc*. 2001;49:508–515.
20. Skalska A, Wizner B, Piotrowicz K, et al. The prevalence of falls and their relation to visual and hearing impairments among a nation-wide cohort of older Poles. *Exp Gerontol*. 2013;48:140–146.

21. Källstrand-Eriksson J, Hildingh C, Bengtsson B. History of falling and visual ability among independently living elderly in Sweden. *Clin Ophthalmol*. 2016; 10:1265–1273.
22. 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;50:1329–1335.
23. Gupta P, Man REK, Fenwick EK, et al. Associations between visual impairment, incident falls and fall frequency among older asians: longitudinal findings from the Singapore epidemiology of eye diseases study. *Br J Ophthalmol*. 2023;107: 1590–1596.
24. Teister CJ, Chocano-Bedoya PO, Orav EJ, et al. Which method of fall ascertainment Captures the most falls in Prefrail and frail seniors? *Am J Epidemiol*. 2018;187:2243–2251.
25. Bischoff-Ferrari HA. DO-HEALTH/Vitamin D3 - Omega3 - home exercise - healthy ageing and longevity trial. *DO-HEALTH)*. 2021;100:106124.
26. Bischoff-Ferrari HA, Vellas B, Rizzoli R, et al. Effect of Vitamin D Supplementation, Omega-3 fatty Acid Supplementation, or a strength-Training exercise Program on clinical outcomes in older adults: the DO-HEALTH randomized clinical trial. *JAMA*. 2020;324:1855–1868.
27. Bischoff-Ferrari HA, de Godoi Rezende Costa Molino C, Rival S, et al. DO-HEALTH: Vitamin D3 - Omega-3 - home exercise - healthy aging and longevity trial - design of a multinational clinical trial on healthy aging among European seniors. *Contemp Clin Trials*. 2020;100:106124.
28. Buchner DM, Hornbrook MC, Kutner NG, et al. Development of the common data base for the FICSIT trials. *J Am Geriatr Soc*. 1993;41:297–308.
29. Marsden J, Stevens S, Ebri A. How to measure distance visual acuity. Community. *Eye Health*. 2019;32:46.
30. Dietze H. [Measuring visual acuity]. *Klin Monbl Augenheilkd*. 2018;235:1057–1075.
31. Rohrschneider K, Spittler AR, Bach M. [Comparison of visual acuity measurement with Landolt rings versus numbers]. *Ophthalmologe*. 2019;116:1058–1063.
32. World Health Organization. World report on vision. 2019. Accessed April 24, 2024. https://www.who.int/publications/i/item/9789241516570
33. Sangha O, Stucki G, Liang MH, et al. The Self-Administered Comorbidity Questionnaire: a new method to assess comorbidity for clinical and health services research. *Arthritis Rheum*. 2003;49:156–163.
34. Fried LP, Tangen CM, Walston J, et al. Frailty in older adults: evidence for a phenotype. *J Gerontol A Biol Sci Med Sci*. 2001;56:146–156.
35. de Godoi Rezende Costa Molino C, Chocano-Bedoya PO, Sadlon A, et al. Prevalence of polypharmacy in community-dwelling older adults from seven centres in five European countries: a cross-sectional study of DO-HEALTH. *BMJ Open*. 2022;12:e051881.
36. Wolf AM, Hunter DJ, Colditz GA, et al. Reproducibility and validity of a self-administered physical activity questionnaire. *Int J Epidemiol*. 1994;23: 991–999.
37. Palagyi A, Morlet N, McCluskey P, et al. Visual and refractive associations with falls after first-eye cataract surgery. *J Cataract Refract Surg*. 2017;43:1313–1321.
38. Foss A. Prompt access to cataract surgery is vital for preventing falls in older people. *Med J Aust*. 2022;217:84–85.
39. 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;50:1760–1766.
40. Bongue B, Dupré C, Beauchet O, et al. A screening tool with five risk factors was developed for fall-risk prediction in community-dwelling elderly. *J Clin Epidemiol*. 2011;64:1152–1160.
41. Hong T, Mitchell P, Burlutsky G, et al. Visual impairment and the incidence of falls and fractures among older people: longitudinal findings from the Blue Mountains Eye Study. *Invest Ophthalmol Vis Sci*. 2014;55: 7589–7593.
42. Lord SR, Clark RD, Webster IW. Postural stability and associated physiological factors in a population of aged persons. *J Gerontol*. 1991;46:69–76.
43. World Health Organization. *Integrated care for older people (ICOPE) Guidelines on community-level interventions to manage declines in intrinsic capacity Evidence profile: visual impairment*. World Health Organization. 2017.
44. Montero-Odasso MM, Kamkar N, Pieruccini-Faria F, et al. Evaluation of clinical Practice Guidelines on fall prevention and management for older adults: a systematic review. *JAMA Netw Open*. 2021;4:e2138911.
45. Colenbrander A. The Historical Evolution of visual acuity measurement. *Vis Impair Res*. 2008;10:57–66.
46. Dhital A, Pey T, Stanford MR. Visual loss and falls: a review. *Eye*. 2010;24: 1437–1446.



Supplementary Figure 1. Distribution of baseline better-eye visual acuity in the study population.

Supplementary Table 1
Incidence Rates of All and Injurious Falls Among Participants With and Without Decreased Visual Acuity at Baseline When Further Adjusting for the Baseline Number of Comorbidities, Frailty Status, Polypharmacy, and Physical Activity Levels

	Decreased Visual Acuity (n = 1464; 68.7%)	Normal Visual Acuity (n = 667; 31.3%)
All falls		
Incidence rate of all falls (95% CI), per person-year	0.54 (0.50, 0.58)	0.45 (0.40, 0.50)
Incidence rate ratio (95% CI)	1.20 (1.06, 1.37)	
P value	.005	
Injurious falls		
Incidence rate of injurious falls (95% CI), per person-year	0.35 (0.33, 0.37)	0.29 (0.26, 0.33)
Incidence rate ratio (95% CI)	1.19 (1.04, 1.36)	
P value	.012	

The association between baseline visual acuity and all and injurious falls was assessed using separate negative binomial regression models with an offset of the log of person-years in the study. The adjusted models control for study site, sex, age, previous fall, baseline body mass index, baseline use of walking aids, baseline number of comorbidities, baseline frailty status, baseline polypharmacy, and baseline physical activity levels.

Supplementary Table 2
Adjusted Incidence Rates of All and Injurious Falls Among Participants With and Without Decreased Visual Acuity at Baseline When Excluding Participants Who Underwent Eye Surgery for Cataract Over the Follow-up

	Decreased Visual Acuity (n = 1178; 66.8%)	Normal Visual Acuity (n = 586; 33.2%)
All falls		
Incidence rate of all falls (95% CI), per person-year	0.53 (0.49, 0.57)	0.43 (0.38, 0.48)
Incidence rate ratio (95% CI)	1.22 (1.06, 1.41)	
P value	.006	
Injurious falls		
Incidence rate of injurious falls (95% CI), per person-year	0.34 (0.32, 0.37)	0.28 (0.25, 0.32)
Incidence rate ratio (95% CI)	1.22 (1.05, 1.41)	
P value	.012	

The association between baseline visual acuity and all and injurious falls was assessed using separate negative binomial regression models with an offset of the log of person-years in the study. The adjusted models control for study site, sex, age, previous fall, baseline body mass index, and baseline use of walking aids.

Supplementary Table 3
Adjusted Incidence Rates of All and Injurious Falls Among Participants With and Without Decreased Visual Acuity at Baseline When Excluding Participants Reporting the Use of Multifocal Glasses

	Decreased Visual Acuity (n = 1310; 68.4%)	Normal Visual Acuity (n = 605; 31.6%)
All falls		
Incidence rate of all falls (95% CI), per person-year	0.53 (0.50, 0.57)	0.44 (0.39, 0.49)
Incidence rate ratio (95% CI)	1.22 (1.06, 1.40)	
P value	.005	
Injurious falls		
Incidence rate of injurious falls (95% CI), per person-year	0.35 (0.32, 0.37)	0.29 (0.26, 0.33)
Incidence rate ratio (95% CI)	1.18 (1.03, 1.36)	
P value	.021	

The association between baseline visual acuity and all and injurious falls was assessed using separate negative binomial regression models with an offset of the log of person-years in the study. The adjusted models control for study site, sex, age, previous fall, baseline body mass index, and baseline use of walking aids.

Supplementary Table 4
Odds of Falling at Least Once Among Participants Without Decreased Visual Acuity at Baseline

	Decreased Visual Acuity	Normal Visual Acuity
No. of participants	1464	667
No. of participants who sustained at least 1 fall	906	386
Crude estimates		
Odds ratio (95% CI)	1.23 (1.01, 1.49)	
P value	.038	
Adjusted estimates		
Odds ratio (95% CI)	1.20 (0.96, 1.50)	
P value	.10	

The association between baseline visual acuity and falling at least once was assessed using logistic regression models with an offset of the log of person-years in the study. The crude model is unadjusted and the adjusted model controls for study site, sex, age, previous fall, baseline body mass index, and baseline use of walking aids.