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Visual Impairment and Incident Mobility Limitations: The Health ABC Study

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Abstract

Objectives—To examine the association between multiple measures of visual impairment and incident mobility limitations in older adults.

Design—Prospective observational cohort study

Setting—Memphis, Tennessee and Pittsburgh, Pennsylvania

Participants—1,862 Health, Aging and Body Composition study participants aged 70 to 79 years without mobility limitations at the Year 3 visit.

Measurements—Vision was measured at the Year 3 visit and visual impairment was defined as:

1) distance visual acuity worse than 20/40, 2) contrast sensitivity <1.55 logContrast, and 3) stereoacuity >85 seconds of arc. Incident persistent walking and stair climbing limitation was

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defined as two consecutive 6-month reports of any difficulty walking ¼ mile or walking up 10 steps after 1, 3, and 5 years of follow-up.

Results—At Year 3 (baseline for these analyses), 7.4%, 27.2% and 29.2% had impaired visual acuity, contrast sensitivity, and stereoacuity, respectively. At all follow-up times, the incidence of walking and stair climbing limitations was higher in participants with visual acuity, contrast sensitivity, or stereoacuity impairment. After 5 years, impaired contrast sensitivity and stereoacuity were independently associated with a greater risk of walking limitation ($HR_{\text{contrast sensitivity}}=1.3$; 95% CI: 1.1–1.7; $HR_{\text{stereoacuity}}=1.3$; 95% CI: 1.1–1.6), and stair climbing limitation ($HR_{\text{contrast sensitivity}}=1.4$; 95% CI: 1.1–1.8; $HR_{\text{stereoacuity}}=1.3$; 95% CI: 1.1–1.7). Having both impaired contrast sensitivity and stereoacuity was associated with an increased risk of mobility limitations ($HR_{\text{walking limitations}}=2.0$; 95% CI: 1.6–2.5; $HR_{\text{stair limitations}}=2.1$; 95% CI: 1.6–2.8).

Conclusion—Findings suggest that multiple aspects of visual impairment may contribute to mobility limitations in older adults. Addressing more than one component of vision may be needed to reduce the impact of vision impairment on functional decline.

Keywords

Visual impairment; mobility; physical functioning

INTRODUCTION

Vision is required for completing most tasks of daily living. When vision is impaired, the ability to carry out these tasks is also affected. Visual impairment (VI) is of particular concern among older adults, as the prevalence increases from 0.3% in adults 40 to 49 years to 23.7% in adults 80 years and older.¹ A primary consequence of vision loss is impaired physical functioning, as VI is estimated to cause physical disability among 3.3% of US adults.²

Prior research has investigated the association between VI and physical functioning, with the majority of this research investigating how age-related eye disease and combinations of VI impairments affect mobility.^{3–12} While these studies show that VI is associated with mobility difficulties it is unclear which aspect of vision is driving this association. In clinical settings, assessment of visual impairment is typically determined by visual acuity (VA) alone, defined as the ability to see detail of an object at a distance. But, VA describes only one aspect of vision. Other measures include contrast sensitivity (CS), the ability to discriminate between an object and its background, and stereoacuity (SA), or depth perception.

Dysfunction in each of these aspects of vision has been found to be associated with mobility limitations in older adults. VA impairment is associated with slower walking speeds⁷, a greater likelihood of reporting mobility difficulty⁶, and an increased risk of developing mobility disability.¹³ Older adults with reduced CS also have slower walking speeds⁷, are more likely to report mobility disability⁶, and have a greater risk of incident mobility disability than those without this impairment.¹⁴ Additionally, individuals with SA deficits

exhibit more cautious obstacle-crossing behavior than those with normal stereo vision, suggesting that SA impairment may increase the risk of tripping or falling.¹⁵

Prior research has primarily considered the association between either a single aspect of visual functioning or a specific ophthalmic condition and physical function in older adults. By simultaneously examining multiple dimensions of visual functioning and incident mobility limitations we can evaluate the independent role of each aspect of vision on mobility decline and improve understanding of possible intervention strategies.

This study examined the relationship between three measures of visual functioning, VA, CS, and SA, and incident mobility limitation in a population of older adults participating in the Health, Aging and Body Composition (Health ABC) study. We hypothesized that older adults with either impaired VA, CS or SA would have a greater likelihood of developing walking and stair-climbing limitations. We further hypothesized each type of VI would contribute independently to the risk of mobility limitation.

METHODS

The Health ABC study is a prospective cohort of 3,075 community-dwelling older adults between 70 and 79 years of age at enrollment who resided in Pittsburgh, Pennsylvania or Memphis, Tennessee. Participants were selected from a random sample of white Medicare beneficiaries and all age-eligible black community residents. Baseline study visits occurred between 1997 and 1998. Enrollment and eligibility criteria have been previously described¹⁶, and required: 1) no reported difficulty walking ¼ mile, walking up 10 steps, or performing activities of daily living, 2) no known life-threatening cancers, and 3) no plans to move out of the study area for 3 years. All participants provided informed consent and the institutional review boards at each study site approved all protocols.

Visual Function

Three measures of visual function: VA, CS, and SA, were assessed binocularly with usual corrective lenses during the Year 3 study visit. Distance VA was measured using high contrast Bailey-Lovie charts at a 10 or 5 feet testing distance.^{17, 18} The number of letters read correctly was recorded and used to calculate acuity in logMAR ($\log_{10}$ minimum angle of resolution) units after accounting for the viewing distance ($1.2 - 0.2 \times \text{number of letters read correctly}$). These values were then converted to Snellen equivalents, such as 20/60, for ease of interpretation.

CS was measured using Pelli-Robson charts at a 10 or 5 feet testing distance.^{19, 20} Participants were asked to read the letters from highest contrast to lowest. The total number of letters read correctly was recorded, and used to determine logContrast ($\log_{10}$ Contrast) units ($\log_{10}(0.05 \times [\text{\# letters read}]) - 0.15$) indicating the lowest contrast threshold the participant could discern. Scores range from 0.00 to 2.25 logContrast with higher values indicating better CS.

SA was measured using a Frisby stereo test.^{21, 22} Participants were presented with stereo images on a sequence of three transparent plates. Each plate had a depth cue, with a central

circular area where the pattern is printed on the front of the plate, rather than the back, so that this circular area appears closer than the rest of the image. Participants were asked to identify which square has the depth cue. The plate with the largest depth differential was presented first (340 seconds of arc). If able to correctly see the depth cue on the preceding plate, participants were then presented with the middle plate (170 seconds of arc) followed by the plate with the smallest depth differential (85 seconds of arc). The SA (in seconds of arc) of the thinnest plate correctly seen was recorded.

In the Health ABC study, alert values were defined *a priori* as VA worse than 20/50, or CS 1.30 log units (no alert value was used for SA). All participants were informed of their distance visual acuity (in Snellen fraction). If either VA or CS were worse than alert levels, it was suggested that the participant see an eye care provider to check their vision.

Mobility Limitations

Walking and stair climbing limitations were assessed every 6 months based on interviewer-administered questionnaires administered during annual study visits or over the telephone in-between these visits. The lead in question was “Because of a health or physical problem, do you have any difficulty ...”. If yes, difficulty was determined to be: a little, some, a lot, or unable to complete the task. These questions were adapted from Rosow-Breslau²³ and have been shown to be valid assessments of mobility limitations.²⁴ Persistent walking and stair climbing limitation was defined as two consecutive reports of having any difficulty walking ¼ mile or walking up 10 steps, respectively. This requirement of two consecutive instances of limitation removed transient reports of difficulty. In the case of death, an event was recorded if difficulty was reported at the last interview and there was a proxy report of difficulty for more than 6 months. Missed contacts or refusals were imputed to the lesser response. For example, if over three interview periods a participant’s responses were “no difficulty”, missing, and “a little/some difficulty”, then the missing response was coded as “no difficulty”.

Other covariates

Covariate values from the Year 3 study visit were used for analyses. Age, sex, race (white or black), study site (Memphis or Pittsburgh) were recorded. Body mass index (BMI) was calculated as kg/m². Depression was defined as scoring higher than 10 on the Center for Epidemiologic Study Depression Scale short form.²⁵ Diabetes was determined based on self-report. Smoking status was bifurcated as current smokers and smokers who quit after age 50, or never and smokers who quit before age 50.

Participants were also asked about the presence of comorbidities that may affect mobility and include: hypertension, heart attack/angina/chest pain, stroke, coronary heart disease, cancer, arthritis, or knee pain. The lead in question was “Since we last spoke, about 6 months ago, has a doctor ever told you that you have...”. The number of comorbid conditions was classified as 0, 1, 2, or 3 conditions.

Statistical Analyses

Since visual impairment was measured in Year 3, analyses were limited to participants who attended the Year 3 study visit (occurring between 1999 and 2000) and who had not been classified as having persistent walking and stair climbing limitation prior to or at the Year 3 visit. Of the 2,595 participants at the 3 Year visit, 1,862 (71%) are included in these analyses.

Distance VA and CS were approximately normally distributed. Categories of VI were calculated based on the following cut points for each measure: VA worse than 20/40, CS < 1.55 logContrast, and SA > 85 seconds of arc (arcsec). The VA cut point was chosen to correspond to the American Academy of Ophthalmology definition of VI, defined as best-corrected VA worse than 20/40 in the better-seeing eye.²⁶ There are no clinical standards for defining CS and SA. Therefore, cut points previously determined were used to define impaired CS as 2 standard deviations below average, binocular CS in adults 60 years and older²⁷, and SA impairment was conservatively categorized as the inability to determine the smallest depth differential presented.

In this study population, 7 participants had missing data for the VA, 6 were missing CS, and 51 were missing SA data. Of these participants, 4 were classified as having VA impairment and 4 were classified as CS impaired because they could not see the testing chart. Of the 51 missing SA data 8 were re-coded as having SA impairment because they were unable to see the first testing plate.

The distributions of potential confounders were compared by VI categories at the Year 3 visit. Age- and sex-adjusted p values comparing the visually impaired to the non-visually impaired were determined. The mean VA (in logMAR) and mean CS (logContrast) by VI categories were also compared.

We examined walking and stair climbing limitation incidence at 1-year, 3-years, and 5-years after the Year 3 study visit. Time to incident limitation was defined as time (in days) from the analytical baseline (Year 3 visit) to the first of two consecutive reports of difficulty with the same activity. Cox proportional hazard regression models were used to determine relative hazard rates (HR) and 95% confidence intervals (CI) for the association between the three VI categories and risk of incident persistent walking and stair climbing limitation. The proportionality assumption was tested with models including time dependent covariates, but these covariates were not significant indicating this assumption was not violated. Similar results were observed between Poisson and Cox regression models, therefore only results from the Cox regression analyses are presented.

In these analyses, measures of visual impairment and all other covariates were treated as time-fixed predictor variables of walking and stair climbing limitations. Covariates included in the final models were chosen based on prior knowledge of the association between VI and physical function, and included age, sex, race, study site, BMI, depression, diabetes, smoking status, and number of comorbid conditions.

To determine the independent association between each VI measure and incidence of mobility limitations, Cox proportional hazard models adjusting for the same set of covariates and all three visual impairment measures were also constructed. We also investigated potentially synergistic relationships between the three types of VI, by creating categories for each pairwise combination. For example, for SA and CS we created the following categories: 1) neither impairment, 2) both CS and SA impairment, 3) CS impairment only, and 4) SA impairment only. Similar categories were created for CS and VA, as well as SA and VA, however due to the small number with VA impairment, we only present results from models that included combinations of CS and SA.

To assess if results were affected by the VI cut points used, analyses were run using the following categories: 1) VA: 20/20 or better, worse than 20/20 to 20/40, worse than 20/40 to 20/80, and worse than 20/80; 2) CS: 1.7, <1.7 to 1.6, <1.6 to 1.5, and <1.5 logContrast; and 3) SA: 85, 170, 340, and >340 seconds of arc. The categories for distance VA were based on clinically meaningful cut points, as normal vision is 20/20, low vision is considered distance acuity worse than 20/40, and moderate impairment is 20/80. As there are no consistent guidelines to determine impairment of CS, categories were based on quartiles of the study population. For SA, categories were determined by the depth differential (arcsec) of the testing plates used. Cox proportional hazard models (adjusted for the same covariates in primary models) were used to obtain HR and 95% CI, and determine the association between the categories of VI and the risk of incident persistent walking and stair climbing limitation.

All data were analyzed using SAS v 9.3 (SAS Inc., Cary, NC).

RESULTS

Population characteristics

In this cohort of 1,862 Health ABC participants, 7.4% were classified as having VA impairment (worse than 20/40), 27.2% had CS impairment (<1.55 logContrast), and 29.2% had SA impairment (>85 seconds of arc) (Table 1). A total of 500 (27%) participants had one of these VIs, 230 (12%) had two types, and 71 (4%) had all three.

Those with VA impairment were older and more likely black than those without this impairment (Table 1). Individuals with CS impairment were older and more likely to be black, reside in Memphis, and be current or recent smokers. Similarly, participants with SA impairment were older and more likely to be black, be male and reside in Memphis.

Incidence of persistent walking & stair climbing limitation

In the total study population, 164 individuals reported incident persistent walking and 119 persistent stair climbing limitation (Table 2), yielding unadjusted one year incidence rates of 9.1 and 6.5 per 100 person-years, respectively. After 3 years of follow-up, these incidence rates were 6.2 and 4.7 per 100 person-years, and increased to 6.3 and 4.9 per 100 person-years after 5 years. For all three time points, each a higher incidence of walking and stair climbing limitations was observed for each type of VI.

Risk of persistent walking & stair climbing limitation

After adjustment for all covariates, there was an increased risk of incident persistent walking limitation among those with VA, CS, and SA impairment (Table 3) at all three follow-up points. Similar results were observed for persistent stair climbing limitation. To assess the independent association of each measure of visual impairment, models including all three VI categories were also explored (Table 3). After 1 year of follow-up, only VA impairment was associated with incident persistent walking limitation (HR=1.8; 95% CI : 1.1–3.0) and stair climbing limitation (HR=2.0; 95% CI: 1.1–3.6); however, this association was not observed at the 3- and 5-year follow-up points. Inversely, risk for developing persistent walking and stair climbing limitations was significantly greater for those with CS and SA impairment at 3 years and 5 years of follow-up.

Investigation of the combined effect between CS and SA revealed that a third of participants had impairments in both measures of visual impairment (250 had both impairments /767 with either impairment) (Table 4). We also found that the risk of developing incident walking and stair climbing limitation after 1, 3 and 5 years of follow-up was greater when these VI coexisted.

Sensitivity analyses

To assess the sensitivity of the findings to the cut points used to define VI, we further categorized each measure of visual impairment and examined the risk of walking and stair climbing limitation by these categories (Table 5). The findings were consistent with those using the dichotomous definitions examined in separate models (Table 3). After 5-years of follow-up, individuals with VA in the two worse categories (worse than 20/40 to 20/80 and worse than 20/80) had a greater risk of persistent walking and stair climbing limitation than those with VA 20/20. Those with the most severely CS deficit (1.5 logContrast) had a significantly greater risk of persistent walking and stair climbing limitation at all time points than those with CS of 1.7 logContrast. Lastly, those with SA in the worst two categories (340 and >340 seconds of arc) had a greater risk of persistent walking limitation, and those with SA >340 seconds of arc had a greater risk of persistent stair climbing limitation than those with 85 seconds of arc after 5 years of follow-up.

DISCUSSION

In this population of well-functioning, community-dwelling older adults, a high percentage (43%) had one or more type of VI. We found a higher incidence of persistent walking and stair climbing limitation among participants with these VI after 1, 3, and 5 years of follow-up. In multivariate analyses, a consistent elevated risk of developing mobility limitations was observed among participants with impaired VA, CS and SA beginning as early as 1 year of follow-up. Additionally, CS and SA impairments were independently associated with an increased risk of developing mobility limitations after 3 years. Investigation of the combined effect between CS and SA categories suggests that there is a synergistic relationship between these two measures of visual functioning, putting those with impairments in both types of vision at greatest risk of developing mobility limitations. These results highlight the

need to include measures of CS and SA, in addition to distance VA, as core elements of vision research and vision exams.

Sensitivity analyses further categorizing VI revealed that those with the worst level of impairment were at greatest risk of developing these mobility limitations after 5 years of follow-up, suggesting an increased risk of mobility limitations with increasing severity of VI. This suggests that the inferences from our primary results are robust to the cut point of VI used.

In the Health ABC study vision was measured at Year 3 only. Since the prevalence VI increases with age¹, it is likely that the prevalence of VI would have increased over 5 years of follow-up. This would result in misclassification of those who developed CS and SA impairment as non-visually impaired, since these impairments rarely improve (except from treatment of specific eye diseases, such as cataract). This misclassification would attenuate the observed HR making our estimates conservative. For VA impairment, only presenting distance VA (as opposed to best-corrected VA) was assessed in Health ABC. As a result, we are unable to determine if VA impairment is due to uncorrected refractive error, the need for corrective lenses, or ocular disease. For those with VA impairment due to refractive error, it is possible that participants could have received the proper lens correction over the follow-up period. If this was the case, then we may have overestimated the association between VA impairment and mobility limitation risk. But, even if the majority of Health ABC participants with VA impairment had refractive error, it is unlikely that many of these individuals sought out the proper corrective lenses. Data from the National Health and Nutrition Examination Survey indicate that 60% of VA impairment among US adults 60 years and older is due to refractive error that is not corrected²⁸, suggesting that the majority of older adults with uncorrected refractive error do not obtain proper correction.

We investigated the incidence of mobility limitations at three time points, as the etiologically relevant period from different types of VI to mobility limitation is unknown. Previous research is limited to the use of self-reported VI^{29,30}, examination of only VA¹³, or inclusion of only CS¹⁴. We are unaware of any previous longitudinal studies examining incidence of mobility limitation in those with SA impairment. Our results suggest that by 5 years of follow-up impaired VA, CS, and SA contributed to mobility limitations in a cohort of well-functioning older adults. This result may be helpful for further research efforts in determining the length of follow-up necessary to observe mobility deficits in older adults with vision impairments. However, it is unknown how long Health ABC participants had VI, and further research investigating the time from incident VI to mobility limitation will better estimate the critical period between vision loss and disability.

In this population, approximately 7% were classified as having VA. This percentage observed in a sample of well-functioning older adults is only slightly lower than estimates from a nationally representative population sample, which indicates 9% of adults 60 years and older have VA impairment.²⁸ While VI is most often classified based on VA alone, in this study population the percentage with CS (27.2%) and SA (29.2%) impairment was over 3-times higher than the percentage with VA deficits. Additionally, a third of these participants had both CS and SA impairment. The high prevalence of CS and SA

impairment without mobility limitation at baseline first suggests that these aspects of vision may not affect mobility. However, our results indicate that CS and SA are independent predictors of mobility limitations and may synergistically affect mobility difficulty. This result may reflect the largely uncorrectable nature of CS and SA impairment. Further research examining how changes in these vision measures affect mobility disability may be warranted.

This study is among the first to examine risk of incident mobility limitation for multiple aspects of visual functioning in older adults. Overall, our results suggest that VA, CS, and SA impairment predict mobility limitation in older adults, and in this population those with both CS and SA impairment are at greatest risk of mobility limitations. The results from this study highlight the need to expand on previous research that has largely focused on the association between distance VA and functioning in older adults. If the goal is to reduce disability associated with VI among the elderly, then the impact of multiple aspects of visual functioning may need to be considered.

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Table 1
Characteristics of participants without mobility limitations at Year 3 visit by visual impairment status: The Health ABC Study 1999

	Visual Acuity Impairment			Contrast Sensitivity Impairment			Stereovacuity Impairment			Total*
	Yes (Worse than 20/40) 137 (7.4%)	No (20/40 or better) 1722 (92.6%)	P Value ^a	Yes (< 1.55 log Contrast) 505 (27.2%)	No (1.55 log Contrast) 1,355 (72.9%)	P Value ^a	Yes (>85 arcsec) 531 (29.2%)	No (≤ 85 arcsec) 1,288 (70.8%)	P Value ^a	
Demographics										
Age, N (%)										
71–74 years	39 (28.5)	750 (43.6)		161 (31.9)	628 (46.4)		202 (38.0)	570 (44.3)		789 (42.4)
75–79 years	78 (56.9)	791 (45.9)		259 (50.1)	617 (45.5)		242 (45.6)	610 (47.4)		871 (46.8)
80+ years	20 (14.6)	181 (10.5)	<0.001	91 (18.0)	110 (8.1)	<0.001	84 (16.4)	108 (8.4)	<0.001	202 (10.9)
Sex, N (%)										
Male	84 (61.3)	896 (52.0)		267 (52.9)	713 (62.6)		317 (59.7)	642 (49.8)		982 (52.7)
Female	53 (38.7)	826 (48.0)	0.054	238 (47.1)	642 (47.4)	0.891	214 (40.3)	646 (50.2)	<0.001	880 (47.3)
Race, N (%)										
White	71 (51.8)	1152 (66.9)		284 (56.2)	939 (69.3)		319 (60.1)	872 (67.7)		1223 (65.7)
Black	66 (48.2)	570 (33.1)	<0.001	221 (43.8)	416 (30.7)	<0.001	212 (39.9)	416 (32.3)	<0.001	639 (34.3)
Study Site										
Pittsburgh	68 (49.6)	878 (51.0)		219 (43.4)	727 (53.7)		251 (47.3)	679 (52.7)		947 (50.9)
Memphis	69 (50.4)	844 (49.0)	0.667	286 (56.6)	628 (46.3)	<0.001	280 (52.7)	609 (47.3)	0.020	915 (49.1)
Health Measures										
Body Mass Index, N (%)										
Normal (<25)	64 (46.7)	627 (36.4)		200 (39.6)	491 (36.2)		202 (38.1)	472 (36.7)		693 (37.2)
Overweight (25–<30)	47 (34.3)	762 (44.3)		208 (41.2)	602 (44.5)		219 (41.3)	575 (44.6)		810 (43.5)
Obese (30+)	26 (19.0)	332 (19.3)	0.375	97 (19.2)	261 (19.3)	0.746	109 (20.6)	241 (18.7)	0.949	358 (19.2)
CES-D10 Score, N (%)										
10 (not depressed)	124 (90.5)	1578 (91.7)		454 (89.9)	1248 (92.2)		481 (90.8)	1183 (91.9)		1704 (92.6)
>10 (depressed)	13 (9.5)	143 (8.3)	0.681	51 (10.1)	106 (7.8)	0.200	49 (9.3)	105 (8.2)	0.519	157 (8.4)
Diabetes, N (%)										
No	132 (96.4)	1661 (96.6)		484 (95.8)	1310 (96.9)		508 (96.0)	1245 (96.7)		1796 (96.6)
Yes	5 (3.6)	58 (3.4)	0.827	21 (4.2)	42 (3.1)	0.137	21 (4.0)	42 (3.3)	0.382	63 (3.4)

	Visual Acuity Impairment		Contrast Sensitivity Impairment		Stereoaquity Impairment		Total*
	Yes (Worse than 20/40) 137 (7.4%)	No (20/40 or better) 1722 (92.6%)	Yes (< 1.55 log Contrast) 505 (27.2%)	No (≥ 1.55 log Contrast) 1,355 (72.9%)	Yes (> 85 arcsec) 531 (29.2%)	No (≤ 85 arcsec) 1,288 (70.8%)	
Smoking, N (%)							
Never/Quit before age 50	94 (68.6)	1265 (73.9)	349 (69.9)	1011 (74.8)	371 (70.4)	958 (74.7)	1361 (73.5)
Current/Quit after age 50	43 (31.4)	448 (26.1)	150 (30.1)	341 (25.2)	156 (29.6)	325 (25.3)	492 (26.6)
Number of comorbid conditions, N (%)							
0	80 (60.2)	881 (52.1)	273 (55.5)	689 (51.7)	279 (53.1)	663 (52.7)	963 (52.7)
1	41 (30.8)	662 (39.2)	184 (37.4)	519 (39.0)	200 (38.1)	486 (38.6)	704 (38.6)
2	9 (6.8)	125 (7.4)	25 (5.1)	109 (8.2)	39 (7.4)	91 (7.2)	134 (7.3)
3	3 (2.3)	22 (1.3)	10 (2.0)	15 (1.1)	7 (1.3)	18 (1.4)	25 (1.4)

^a Age and sex adjusted p-values

Table 2
Incidence of mobility limitations by visual functioning categories: The Health ABC Study 1999–2004

	Persistent Walking Limitation ^a			Persistent Stair Climbing Limitation ^b		
	Number of Person-Years	Number of Events	Incidence (per 100 person-years)	Number of Person-Years	Number of Events	Incidence (per 100 person-years)
1-Year						
<i>Total population</i>	1812.4	164	9.1	1821.6	119	6.5
Visual acuity						
Worse than 20/40	132.5	24	18.1	131.7	20	15.2
20/40 or better	1676.9	139	8.3	1686.9	98	5.8
Contrast sensitivity (logContrast)						
<1.55	486.9	62	12.7	488.3	49	10.0
1.55	1323.6	102	7.7	1331.3	70	5.3
Stereoacuity (arcsec)						
>85	513.2	64	12.5	515.2	50	9.7
85	1257.8	97	7.7	1264.9	66	5.2
3-Year						
<i>Total population</i>	4929.5	303	6.2	5089.9	241	4.7
Visual acuity						
Worse than 20/40	345.8	34	9.8	356.4	29	8.1
20/40 or better	4578.0	296	5.9	4726.7	212	4.5
Contrast sensitivity (logContrast)						
<1.55	1286.0	124	9.6	1344.0	105	7.8
1.55	3638.9	179	4.9	3741.3	136	3.6
Stereoacuity (arcsec)						
>85	1342.4	121	9.0	1402.1	101	7.2
85	3470.6	174	5.0	3571.6	134	3.8
5-Year						
<i>Total population</i>	7797.5	495	6.3	8243.6	400	4.9
Visual acuity						
Worse than 20/40	510.8	54	10.6	551.4	45	8.2
20/40 or better	7280.1	440	6.0	7686.5	354	4.6

	Persistent Walking Limitation ^a			Persistent Stair Climbing Limitation ^b		
	Number of Person-Years	Number of Events	Incidence (per 100 person-years)	Number of Person-Years	Number of Events	Incidence (per 100 person-years)
Contrast sensitivity (logContrast)						
<1.55	1958.4	179	9.1	2123.5	153	7.2
1.55	5833.6	316	5.4	6116.5	247	4.0
Stereoacuity (arcsec)						
>85	2071.2	178	8.6	2230.7	153	6.9
85	5544.2	305	5.5	5826.4	238	4.0

^a Persistent walking limitation defined as two consecutive reports of having any difficulty walking ¼ mile;

^b Persistent stair climbing limitation defined as two consecutive reports of having any difficulty walking up 10 steps

Table 3

Association between visual functioning and incident mobility limitations: The Health ABC Study 1999–2004

	Persistent Walking Limitation ^a		Persistent Stair Climbing Limitation ^b	
	Hazard Ratio	95% Confidence Interval	Hazard Ratio	95% Confidence Interval
1 Year				
<i>Individual Models ^c</i>				
Visual acuity: worse than 20/40 vs. 20/40 or better	2.0	1.3 – 3.2	2.5	1.5 – 4.2
Contrast sensitivity: <1.55 vs. 1.55 logContrast	1.4	1.03 – 2.0	1.8	1.2 – 2.7
Stereoacuity: >85 vs. 85 arcsec	1.5	1.1 – 2.1	1.8	1.2 – 2.6
<i>Joint Model ^d</i>				
Visual acuity: worse than 20/40 vs. 20/40 or better	1.8	1.1 – 3.0	2.0	1.1 – 3.6
Contrast sensitivity: <1.55 vs. 1.55 logContrast	1.2	0.8 – 1.8	1.4	0.8 – 2.2
Stereoacuity: >85 vs. 85 arcsec	1.3	0.9 – 1.9	1.5	1.0 – 2.2
3 Year				
<i>Individual Models ^c</i>				
Visual acuity: worse than 20/40 vs. 20/40 or better	1.5	1.1 – 2.1	1.5	1.01 – 2.3
Contrast sensitivity: <1.55 vs. 1.55 logContrast	1.7	1.4 – 2.2	1.8	1.4 – 2.4
Stereoacuity: >85 vs. 85 arcsec	1.6	1.2 – 2.0	1.6	1.3 – 2.2
<i>Joint Model ^d</i>				
Visual acuity: worse than 20/40 vs. 20/40 or better	1.1	0.7 – 1.6	1.0	0.7 – 1.6
Contrast sensitivity: <1.55 vs. 1.55 logContrast	1.6	1.3 – 2.2	1.6	1.2 – 2.2
Stereoacuity: >85 vs. 85 arcsec	1.4	1.1 – 1.8	1.5	1.1 – 2.0
5 Year				
<i>Individual Models ^c</i>				
Visual acuity: worse than 20/40 vs. 20/40 or better	1.7	1.3 – 2.3	1.7	1.2 – 2.3
Contrast sensitivity: <1.55 vs. 1.55 logContrast	1.5	1.2 – 1.8	1.6	1.3 – 2.0
Stereoacuity: >85 vs. 85 arcsec	1.4	1.2 – 1.7	1.5	1.2 – 1.9
<i>Joint Model ^d</i>				
Visual acuity: worse than 20/40 vs. 20/40 or better	1.4	1.0 – 2.0	1.3	0.9 – 1.8
Contrast sensitivity: <1.55 vs. 1.55 logContrast	1.3	1.1 – 1.7	1.4	1.1 – 1.8
Stereoacuity: >85 vs. 85 arcsec	1.3	1.1 – 1.6	1.3	1.1 – 1.7

^aPersistent walking limitation defined as two consecutive reports of having any difficulty walking ¼ mile^bPersistent stair climbing limitation defined as two consecutive reports of having any difficulty walking up 10 steps

^cThree separate cox proportional hazard regression model was run for each visual function covariates (visual acuity, contrast sensitivity, and stereoacuity) and adjusted for age category, sex, race, study site, body mass index category, depression, diabetes, smoking status, and number of comorbid conditions.

^dCox proportional hazard regression joint models included all three visual function covariates (visual acuity, contrast sensitivity, and stereoacuity) and adjusted for age category, sex, race, study site, body mass index category, depression, diabetes, and smoking status.

Table 4

. Association between contrast sensitivity and stereoacuity impairment and incident mobility limitations: The Health ABC Study 1999–2004

	Persistent Walking Limitation ^a			Persistent Stair Climbing Limitation ^b		
	# with outcome / # in group ^c 161/1817	Hazard Ratio ^d	95% Confidence Interval	# with outcome / # in group ^c 116/1817	Hazard Ratio ^d	95% Confidence Interval
1 Year						
Neither impairment:	79/1050	Ref	Ref	54/1050	Ref	Ref
Both CS and SA impairment:	43/250	2.2	1.5 – 3.3	36/250	2.9	1.8 – 4.6
CS impairment only:	18/238	0.9	0.5 – 1.6	12/238	1.0	0.5 – 1.9
SA impairment only:	21/279	0.9	0.6 – 1.5	14/279	0.9	0.5 – 1.7
3 Years						
Neither impairment:	126/1050	Ref	Ref	95/1050	Ref	Ref
Both CS and SA impairment:	72/250	2.4	1.7 – 3.2	63/250	2.6	1.8 – 3.6
CS impairment only:	48/238	1.6	1.1 – 2.3	39/238	1.5	1.0 – 2.2
SA impairment only:	49/279	1.3	1.0 – 1.9	38/279	1.3	0.9 – 2.0
5 Years						
Neither impairment:	236/1050	Ref	Ref	181/1050	Ref	Ref
Both CS and SA impairment:	106/250	2.0	1.6 – 2.5	93/250	2.1	1.6 – 2.8
CS impairment only:	69/238	1.3	1.0 – 1.7	57/238	1.4	1.0 – 1.9
SA impairment only:	72/279	1.2	0.9 – 1.5	60/279	1.2	0.9 – 1.7

^a Persistent walking limitation defined as two consecutive reports of having any difficulty walking ¼ mile

^b Persistent stair climbing limitation defined as two consecutive reports of having any difficulty walking up 10 steps

^c Population subset (n=1817) is less than the 1862 in analytic sample, due to requiring both contrast sensitivity and stereoacuity values be nonmissing.

^d Cox proportional hazard regression models included all three visual function covariates (visual acuity, contrast sensitivity, and stereoacuity) and adjusted for age category, sex, race, study site, body mass index category, depression, diabetes, smoking status, and number of comorbid conditions.

CS impairment = contrast sensitivity <1.55 logContrast; SA impairment = stereoacuity >85 arcsec

Table 5

Sensitivity analyses. Association between visual function categories and incident mobility limitations: The Health ABC Study 1999–2004

		1 Years		3 Years		5 Years	
	Number (%)	Hazard Ratio ^a	95% CI	Hazard Ratio	95% CI	Hazard Ratio	95% CI
Persistent Walking Limitation^b							
<i>Visual Acuity</i>							
20/20 or better	438 (24%)	REF	REF	REF	REF	REF	REF
Worse than 20/20–20/40	1284 (69%)	1.5	1.0–2.3	1.5	1.1–2.1	1.3	1.1–1.7
Worse than 20/40–20/80	116 (6%)	2.24	1.3–4.05	2.0	1.2–3.1	1.9	1.3–2.8
Worse than 20/80	21 (1%)	5.78	2.3–14.9	2.1	0.8–5.9	3.4	1.8–6.4
<i>Contrast sensitivity (logContrast)</i>							
1.7	726 (39%)	REF	REF	REF	REF	REF	REF
<1.7–1.6	422 (23%)	1.2	0.7–1.8	1.3	0.9–1.8	1.2	0.9–1.5
<1.6–1.5	348 (19%)	1.32	0.8–1.9	1.4	1.0–2.0	1.1	0.8–1.5
<1.5	364 (19%)	1.89	1.2–2.9	2.4	1.8–3.3	2.0	1.6–2.5
<i>Stereoacuity (arcsec)</i>							
85	1285 (71%)	REF	REF	REF	REF	REF	REF
180	215 (12%)	1.1	0.6–1.8	1.2	0.9–1.8	1.1	0.8–1.4
340	108 (6%)	1.7	0.9–3.0	1.7	1.1–2.6	1.6	1.1–2.2
>340	198 (11%)	1.9	1.2–2.9	1.8	1.3–2.5	1.8	1.4–2.4
Persistent Stair Climbing Limitation^c							
<i>Visual Acuity</i>							
20/20 or better	438 (24%)	REF	REF	REF	REF	REF	REF
Worse than 20/20–20/40	1284 (69%)	1.9	1.0–3.4	1.2	0.8–1.7	1.2	0.9–1.6
Worse than 20/40–20/80	116 (6%)	3.6	1.7–6.7	1.6	0.9–2.7	1.8	1.2–2.7
Worse than 20/80	21 (1%)	10.6	3.4–33.2	3.0	1.1–7.8	3.0	1.4–6.3
<i>Contrast sensitivity (logContrast)</i>							
1.7	726 (39%)	REF	REF	REF	REF	REF	REF
<1.7–1.6	422 (23%)	1.1	0.6–1.9	1.5	1.0–2.2	1.2	0.9–1.7
<1.6–1.5	348 (19%)	1.1	0.6–1.9	1.4	0.9–2.1	1.3	0.9–1.7
<1.5	364 (19%)	2.4	1.5–3.9	2.8	2.0–4.0	2.2	1.7–2.8

	Number (%)	1 Years		3 Years		5 Years	
		Hazard Ratio ^a	95% CI	Hazard Ratio	95% CI	Hazard Ratio	95% CI
Stereoacuity (arcsec)							
85	1285 (71%)	REF	REF	REF	REF	REF	REF
180	215 (12%)	1.2	0.7 – 2.2	1.2	0.8 – 1.8	1.1	0.8 – 1.6
340	108 (6%)	1.6	0.7 – 3.4	1.7	1.1 – 2.8	1.4	1.0 – 2.1
>340	198 (11%)	2.5	1.5 – 4.0	2.1	1.5 – 3.0	2.0	1.5 – 2.6

^aCox proportional hazard regression models adjusted for age category, sex, race, study site, body mass index category, depression, diabetes, smoking status, and number of comorbid conditions.

^bPersistent walking limitation defined as two consecutive reports of having any difficulty walking ¼ mile

^cPersistent stair climbing limitation defined as two consecutive reports of having any difficulty walking up 10 steps