Longitudinal Relationships among Visual Acuity and Tasks of Everyday Life: The Salisbury Eye Evaluation Study

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Purpose. To study the relationships among visual and physical function trajectories of aging adults.

Methods. The community-based random sample consists of 2520 adults who were aged 65 to 84 years in 1993 to 1995 and reassessed 2, 6, and 8 years later. Presenting and best-corrected Early Treatment Diabetic Retinopathy Study visual acuity were obtained. Activities of daily living (ADLs) and instrumental ADLs (IADLs) were evaluated through survey instruments. Growth curve models were used to simultaneously estimate health trajectories and obtain associations among the trajectories while controlling for relevant covariates.

Results. Best-corrected acuity (logMAR) worsened by an average of 0.013 (~1 letter) annually. ADL difficulties increased by 0.22 standard deviations (SD) and IADL difficulties increased by 0.28 SD annually. Controlling for demographic and health covariates, visual acuity rates of decline correlated with rates of increase in ADL difficulties ($r = 0.15$, $P = 0.05$) and IADL difficulties ($r = 0.41$, $P < 0.001$). Acuity loss was significantly related to increases in ADLs for men ($b = 0.039$, $P < 0.01$), but not for women ($b = 0.001$, $P > 0.9$). The direct effects of acuity loss were strongest for IADLs where a 1-unit decline in acuity (logMAR) was associated with a 0.067 SD increase in IADL difficulties ($P < 0.001$) at baseline, and a 1-unit acuity decline (logMAR) per year resulted in a 0.10 SD unit increase in the rate of change in IADL difficulties ($P < 0.001$) per year.

Conclusions. Over time, increases in visual acuity loss were related to increased IADL difficulties in men and women and increases in ADL difficulties for men only. The findings support the importance of maintaining vision in older adults. (*Invest Ophthalmol Vis Sci.* 2013;54:193–200) DOI:10.1167/iovs.12-10542

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The relationship between visual impairment and self-report of decreased performance—or observed poorer performance—on tasks of everyday life has been documented by a number of studies.[1–8] Decremental loss of vision is associated with corresponding decreases in performance of tasks of everyday life.[7,8] Musculoskeletal and visual impairment are strongly related to physical disability.[8] In the elderly, limitations in mobility, activities of daily living (ADL), and physical performance are associated with worsening visual function.[7] Methods of assessing performance of tasks of everyday life include self-reported questionnaires and performance-based tests.[9] Standardized questionnaires include ADLs[10] and instrumental ADLs (IADLs).[11] The ADLs are necessary in fundamental daily function (e.g., bathing, dressing, eating) while the IADLs are not essential for basic functioning but allow an individual to live independently in the community (e.g., telephone use, shopping, housework). Standardized performance-based testing simulates tasks of daily life and is carried out in the research setting.

Using longitudinal data over a period of 5 years from the Beaver Dam Eye Study, Klein et al.[3] examined the association between visual functioning (binocular visual acuity, best-corrected visual acuity (BCVA), near acuity, log contrast sensitivity, and visual perimetry sensitivity threshold) and history of physical limitations, falls, fractures, and change in time to walk a measured course in a population aged 43 to 86 years. Visual function is associated with some physical outcomes and limitations 5 years later and these associations are likely to be related, in part, to the presence of other medical conditions. Rubin el al.[4] utilized self-reported ADLs and IADLs as well as measured mobility activities and found reduced acuity and contrast sensitivity were significant risk factors for self-reported disability in a community-dwelling population of older women. In the Salisbury Eye Evaluation (SEE) project, Rubin et al.[2] reported from cross-sectional analyses that a factor of two reduction in visual acuity or contrast sensitivity was associated with a 3- to 5-fold odds of reporting difficulty with daily tasks, while West et al.[1] found both contrast sensitivity and visual acuity loss contributed independently to deficits in observed performance on everyday tasks.

However, there are scant data over time on trajectories of vision loss and trajectories of change in functional status and how the two are related. Using longitudinal data from the SEE study, the purpose of this study is to describe the visual and physical function trajectories occurring over time among aging adults and to estimate the relationships among the trajectories. To our knowledge, no other population-based studies have examined this longitudinally. This analysis extends prior work on the relationship between visual impairment and difficulty with daily tasks because it evaluates the association of within-person changes. Such an analytic design controls for unobserved characteristics of individuals that are not changing substantially within the timeframe of the study, including static contextual factors. For example, a person's genetic heritage, sex, and race are implicitly controlled. Social and environmen-

Table 1. Characteristics of Participants in the SEE, Round 1

	Number, *N*	Percent, %
Total	2520	100.0
Age		
65–69	780	31.0
70–74	835	33.1
75–79	554	22.0
80+	351	13.9
Sex		
Male	1062	42.1
Female	1458	57.9
Race		
White	1854	73.6
Black	666	26.4
BMI		
Underweight (BMI <18.5)	112	4.4
Normal weight (BMI 18.5–25)	707	28.1
Overweight (BMI 25–30)	957	38.0
Obese (BMI 30–35)	508	20.2
Very Obese (BMI >35)	236	9.4
Education		
Less than high school	1299	51.6
High school graduate	514	20.4
Above high school	707	28.1
Alcohol usage		
Never used	674	26.8
Past use	614	24.4
Current use	1227	48.9
Smoking status		
Never used	997	39.7
Past smoker	1146	45.6
Current smoker	368	14.7
	Mean	SD
Average ADL score	6.03	2.29
Average IADL score	8.25	3.76
Average severe depression score	1.18	0.34
Average presenting Bilateral visual acuity	0.035	0.21
Average BCVA	0.009	0.19

tal contextual factors such as socioeconomic status, family social supports, and environmental pollutants that are not changing during the 8 years of the study are also held constant without having to explicitly control for these in the model. Further controls on numerous health conditions are explicitly included in the model to strengthen the tests of association.

Methods

Study Population and Design

The SEE is a population-based study of age-related eye diseases, visual impairment, and functional status of noninstitutionalized residents aged 65 to 84 years.[12] The Johns Hopkins Institutional Review Board approved all protocols. The University of Miami Institutional Review Board also approved the current analysis. All participants gave written informed consent, and the study followed the tenets of the Declaration of Helsinki. Detailed description of the sampling procedure has been published.[12,13] Briefly, the sample was selected from the Health Care Financing Administration Medicare eligibility list and included individuals, between age 65 and 84 years as of July 1, 1993, living in the metropolitan area of Salisbury, Maryland. The sample included 100% of identified black residents and a random age-stratified sample of 58% of identified white residents. Eligible participants had to be able to travel to the clinic for vision tests and to score more than 17 on the Mini-Mental Status Examination.[14] Eligible participants participated in a 2-hour in-home interview followed by a 4- to 5-hour clinic examination. Of those who were eligible, 65% participated. The current analysis includes follow-up data over 8 years from 2520 participants of the initial cohort (1993–1995); 2240 second-round participants (1995–1997); 1504 third-round participants (1999–2001); and 1250 fourth-round participants (2001–2003). Smaller numbers of participants were available in the follow-up rounds with over half of the loss between rounds being due to death.

Outcome Measures and Covariates

Presenting (habitual) visual acuity was assessed using the Early Treatment Diabetic Retinopathy Study (ETDRS) chart, and ETDRS refraction was performed on participants worse than 20/30.[15] Visual acuity was obtained under normal luminance with illuminated ETDRS chart (Lighthouse-illuminated box; Lighthouse International, New York, NY). Presenting and best-corrected binocular distance visual acuity was converted to logarithm of the minimum angle of resolution (logMAR). Functional status of ADLs and IADLs were measured using the standardized validated questionnaires.[10,11] ADL assessments included five items: difficulty getting out of bed or a chair; difficulty dressing yourself; difficulty bathing or showering; difficulty using toilet; and difficulty feeding yourself (e.g., cutting your food or drinking from a glass). IADL assessments included six items: difficulty using the phone; difficulty doing light housework (sweeping, doing dishes) or light yard work (watering); difficulty doing heavy housework (scrubbing floors, washing windows) or heavy yard work (raking, gardening); difficulty preparing your own meals; difficulty managing your own money; difficulty shopping for personal items, such as medicines. Each question always started with: "By yourself, that is without help of another person or special equipment, do you have any difficulty . . . ?" Each question had one of the following possible answers: "no difficulty," "a little difficulty," "some difficulty," "a lot of difficulty," "unable to do this for health or physical reasons." We used confirmatory factor analysis (CFA) and associated model fit statistics to validate the items in the IADL and ADL scales. Both global model fit tests and indices (χ^2 test of model fit, root mean square of approximation [RMSEA], etc.) and component fit such as factor loadings and their statistical significance were used. To facilitate analysis, disability scores of ADLs and IADLs were constructed by summing the five and six items, respectively, at each time point. The sum scores were subsequently used in the trajectory models. Means and standard deviations of these scores for the sample are provided in Table 1. Because the scales are outcomes in the trajectory models, the random measurement error is part of the regression error and therefore does not impact the association parameters.

Control variables include demographics, physical health conditions, severe depression, and health behavior–related variables. A standardized form was used to query all participants about demographics (e.g., age, sex, race, formal education) and medical history of physical health conditions. All control variables, except age, used in models were measured at the baseline assessment. Age was allowed to be time-varying in order to assess health trajectories with respect to age. Education was measured as highest grade completed and ranged from 0 to 17. Medical history included 15 medical conditions that were self-reported responses to the question "Has a doctor ever told you that you have. . .?" The 15 medical conditions included diabetes, stroke, heart disease, high blood pressure, cancer, asthma, arthritis, angina, back problem, broken hip, congestive heart failure, claudication, emphysema, Meniere's disease, and Parkinson's disease. Severe depression was assessed using the Severe Depression subscale of General Health Questionnaire (GHQ)-28. The questions included phrasing such as: (1) "thought that you might do away with yourself"; (2) "felt that life is entirely hopeless"; (3) "felt that life isn't worth

Table 2. Model Fit Statistics for Linear Trajectory Models and the Full Model

	χ^2	*df*	*P* Value	CFI	TLI	RMSEA	90% RMSEA
BCVA trajectory*	25.523	13	0.020	0.995	0.992	0.02	[0.008, 0.031]
Presenting bilateral acuity trajectory*	27.452	13	0.011	0.995	0.991	0.021	[0.010, 0.032]
ADL trajectory*	49.809	13	0.000	0.975	0.957	0.034	[0.024, 0.044]
IADL trajectory*	22.086	13	0.054	0.995	0.992	0.017	[0.000, 0.028]
Trajectory correlation, best corrected model*	409.146	86	0.000	0.957	0.943	0.039	[0.035, 0.042]
Trajectory correlation, bilateral model*	415.212	86	0.000	0.957	0.943	0.039	[0.035, 0.043]
Full model with controls, best corrected	770.715	324	0.000	0.954	0.943	0.023	[0.021, 0.026]
Full model with controls, presenting bilateral	782.735	324	0.000	0.958	0.941	0.024	[0.022, 0.026]
Full model sex moderation, best corrected	1223.566	658	0.000	0.950	0.935	0.026	[0.024, 0.028]

* Trajectory models and correlation models control for age only.

living"; (4) "felt at times you couldn't do anything because nerves were too bad"; (5) "found that the idea of taking your own life kept coming to your mind"; (6) "found yourself wishing you were dead and away from it all"; (7) "been thinking of yourself as a worthless person." Each question had four possible answers: "not at all," "no more than usual," "rather more than usual," or "much more than usual." An overall indicator that we call a severe depression scale was created by taking the average value of the seven questions. Health behavior–related variables include questions on smoking measured as current smoker, past smoker, or nonsmoker (reference); alcohol use measured as current user, past user, or nonuser (reference). We measured height and weight and categorized the body mass index (BMI) as normal (reference BMI 18.5 to <25); underweight (BMI <18.5); overweight (BMI 25 to <30); obese (BMI 30–35); or very obese (BMI >35). All of these measures were performed at the baseline assessment.

Analysis

Table 1 displays descriptive statistics for participants in the first round of the study. Trajectory models were estimated separately for visual acuity and for each of the health outcomes, ADLs and IADLs. These models were mixed- or random-effects models estimated in the latent growth curve framework.[16] Models provide an average level at baseline and average annual change between baseline and the last assessment as well as interindividual variation in starting value and changes over time in the outcomes. The models were estimated controlling for age of the respondents at each wave of assessment. The model is specified as follows:

$$y_{it} = \mu_\alpha + \mu_\beta T + \beta age_{it} + \delta_{\alpha i} + \delta_{\beta i} T + \varepsilon_{it}$$

where y_{it} is the outcome for person i at time t; μ_α is the estimated average of the outcome at baseline (the trajectory intercept); μ_β is the estimated average annual change in the outcome with T measuring time (the trajectory slope); β is the effect of age for person i at time t on the outcome; $\delta_{\alpha i}$ is the random effect (interperson variance) in the outcome at baseline; and $\delta_{\beta i} T$ is the random effect (interperson variance) of the change in the outcome over time. Therefore, average change in visual acuity, ADLs and IADLs as well as the degree of heterogeneity in changes among individuals were estimated for this population. We tested for nonlinear trajectories of change, but found that linear trajectories fit the data best for visual acuity, ADL, and IADL outcomes.

Next, all three linear trajectory models were combined into one model to assess the association of visual acuity trajectories with the ADL trajectories. The three trajectories are estimated simultaneously in these models. Two separate models were evaluated. One model used the BCVA trajectory and the other used presenting bilateral acuity trajectory. The models were estimated first with only time-varying age as a control (unconditional models) and second with all covariate controls (conditional models). The parameters of interest include the correlations between the baseline values [e.g., the correlation between best corrected acuity and ADLS at baseline $corr(\delta_{BEST\alpha i}, \delta_{ADL\alpha i})$] and the correlations between the slopes [e.g., the correlation between change in best-corrected acuity and change in ADLs, $corr(\delta_{BEST\beta i}, \delta_{ADL\beta i})$]. These are partial correlations in the presence of covariates.

The final models include all covariates and specify visual acuity trajectories as predictors of ADL and IADL health trajectories. For all of the models with simultaneous estimation of trajectories, intercepts and slopes both within trajectories and across trajectories were allowed to correlate unless a direct effect was specified between trajectory components. Therefore, in the final models, IADL and ADL trajectories outcomes were allowed to correlate.

All models were evaluated using model fit statistics including the χ^2 test of model fit, which indicates a good fit if the *P* value is not statistically significant. However, with larger sample sizes, the χ^2 value is often statistically significant even with small deviations in replication of the data. Other fit statistics were included that overcome this problem, including the Comparative Fit Index and Tucker-Lewis Index for which values above 0.90 show a good fit and values above 0.95 show an excellent fit. A final measure, the RMSEA, was used for which values less than 0.10 indicate a good fit and less than 0.05 indicate an excellent fit.

We include all individuals from the study in the analysis whether or not they have missing items during the study. Maximum likelihood for missing data (full information ML) estimation was used to arrive at estimates in the presence of missing data.[17] This method assumes that missing items—due to attrition or some other mechanism—are missing at random, conditioned on all of the covariates in the model. Therefore, the conditional distributions of visual acuity, IADL, and ADLs at each time point are assumed to be unbiased representations of the conditional distributions in the population. These assumptions are less restrictive than assuming that items are unconditionally missing at random, which is the assumption operating under list-wise deletion methods for dealing with missing data.

Results

There were 2520 study participants in the first round of study, 42% men, 74% white, and 26% African American (Table 1). In this population, 52% had less than high school and 28% had above high school education, 4% were underweight, 38% were over-weight, and 29% were obese. At the time of interview, 49% were alcohol users, 24% were past alcohol users, 15% of participants were smokers, and 46% were past smokers.

All four separate trajectory models fitted the data well as shown in Table 2 (rows 1 through 4). There was little difference in model fit for the two measures of visual acuity, best-corrected and presenting bilateral (rows 1 and 2, Table 2). Figure 1 portrays the linear trajectories for models with no controls and pooling across age. Intercept and slope means were divided by their standard deviations for the purposes of comparing across health outcomes. Increasing values of visual acuity loss, ADLs, and IADLs indicate worsening visual function and worsening daily activity functionality. Visual acuity loss, ADLs, and IADLs difficulties were all increasing as this population aged. The best-corrected acuity loss increases were

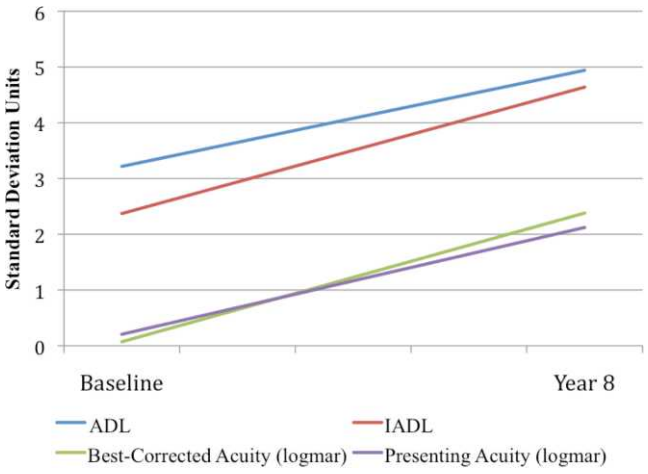

Figure 1. Linear trajectories of acuity loss, ADL difficulties, and IADL difficulties.

slightly higher than the bilateral presenting acuity loss increases. The annual decline in visual acuity was 0.011 and 0.013 logMAR for bilateral presenting acuity and best-corrected acuity, respectively, which is an annual loss of less than one letter on the ETDRS acuity chart or close to one line over 8 years. On average, difficulties with ADLs and IADLs showed an increase of 0.22 and 0.29 SD units every year, and increases in visual acuity loss, measured on the same scale, were 0.24 and 0.9 SD units per year for bilateral presenting acuity and best-corrected acuity, respectively.

Models that combined the three health trajectories also fit the data well (Table 2, rows 5 and 6). After accounting for age only (Table 3), best-corrected visual acuity at baseline was correlated with IADL levels at baseline ($r = 0.37$, $P < 0.001$) as well as with increases in disability of ADL ($r = 0.14$, $P < 0.01$) and IADL ($r = 0.10$, $P < 0.05$) over time. Increased loss in best-corrected acuity over time is strongly correlated with IADL declines ($r = 0.39$, $P < 0.001$) over time. Results using bilateral presenting visual acuity were similar for this model (Table 3). After adding all control variables, the results were also similar except baseline levels of bilateral presenting and best-corrected acuity no longer correlated significantly with changes in IADL over time (Table 4).

Final models were estimated where ADL and IADL baseline disability levels were regressed on baseline levels of visual acuity, and changes in ADL and IADL disabilities over time are regressed on baseline levels and changes in visual acuity (Figure 2 depicts the model). These models had very good fit to the data (Table 2, rows 7 and 8). Results for the full models including all covariate controls were included in Table 5 for best-corrected acuity. A 1 logMAR unit greater level of best-corrected acuity loss at baseline was associated with a 0.067 unit higher level of IADL disability at baseline ($P < 0.001$) and a small (0.002 unit) increase in average annual increases in ADL disability ($P < 0.01$; or 0.017 over the 8-year study). A 1 logMAR unit increase in best-corrected acuity loss on average every year resulted in a 0.05 ($1.02 / 2 \times 10$) unit increase on average every year in IADL disability ($P < 0.001$). Very similar results and effect sizes were observed in the model using presenting bilateral measure of acuity (data not shown). The strongest results from these analyses were the relationships between changes in visual acuity and changes in IADL disabilities during the aging process ($r = 0.40$, $P < 0.001$). Note that it is the effects of changes in visual acuity with changes in ADL and IADLs that are the strongest tests of association since these are the effects that control for all unobserved, static characteristics.

We tested our full model using best-corrected visual acuity for race and sex moderation. There were no differences in the trajectories by race after controlling for covariates, except that blacks had less ADL on average at baseline ($P < 0.01$). None of the relationships between the trajectories differed by race. After controlling for covariates, there were no differences in the trajectories by sex. However, the relationship between

Table 3. Correlation Matrix for Visual Acuity, ADL, and IADL Trajectories Controlling for Age

Visual Acuity	ADL Baseline	ADL Change	IADL Baseline	IADL Change
Model 1				
Best-corrected baseline	0.087	0.141*	0.370†	0.100‡
Best-corrected change	0.152*	0.122	0.165*	0.393†
Model 2				
Presenting bilateral baseline	0.074	0.109‡	0.386†	0.109‡
Presenting bilateral change	0.124*	0.154‡	0.159*	0.387†

* $P < 0.01$.
† $P < 0.001$.
‡ $P < 0.05$.

Table 4. Correlation Matrix for Visual Acuity, ADL, and IADL Trajectories with All Controls

Visual Acuity	ADL Baseline	ADL Change	IADL Baseline	IADL Change
Model 1				
Best-corrected baseline	0.019	0.165†	0.365‡	0.086
Best-corrected change	0.111*	0.147	0.136*	0.413‡
Model 2				
Presenting bilateral baseline	0.001	0.132*	0.380‡	0.084
Presenting bilateral change	0.075	0.158*	0.108	0.395‡

* $P < 0.05$.
† $P < 0.01$.
‡ $P < 0.001$.

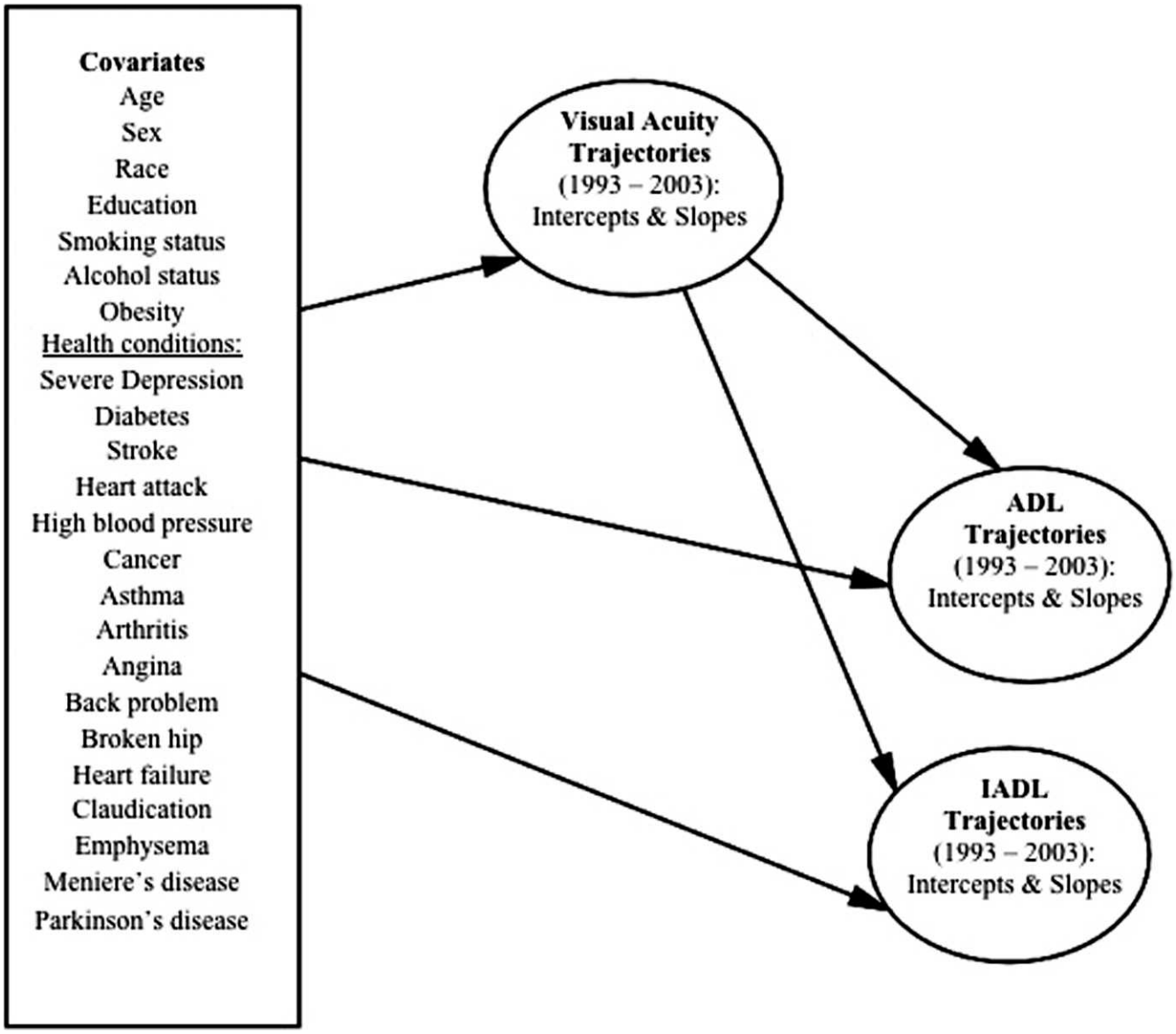

Figure 2. Model relationships in the full model.

changes in visual acuity and changes in ADLs did differ for men and women where there was no statistically significant relationship for women ($b = 0.001$, $P > 0.9$) and there is a statistically significant relationship for men ($b = 0.039$, $P < 0.01$; Table 6). This means that in addition to visual acuity changes having large effects on changes in IADLs across race and sex, there seems to be a substantial effect of changes in vision on ADLs for men but not women. To compare effects, the fully standardized coefficient for the effect of changes in best-corrected visual acuity on changes in IADL for all participants is 0.46 and the fully standardized coefficient for the effect of changes in best-corrected visual acuity on changes in ADL for men only is 0.36.

Discussion

We found a significant relationship between visual acuity decline and IADL decline over time in the elderly population-based participants of the SEE. A similar significant relationship between visual acuity decline and ADL decline over time among elderly men was also found. These relationships persisted even after controlling for demographic and health condition covariates at baseline and unobserved, within-person characteristics that did not change during the 8-year study. The mean change in best-corrected visual acuity over the 8-year study period was equivalent to a change from near 20/20 to near 20/25, and this change was coupled with a corresponding mean change equivalent to one-unit of increasing difficulty in two to three items of the IADLs. For instance, a participant with no difficulties with IADLs at baseline is likely to have developed a little difficulty in performing housework, preparing meals, and shopping for personal items.

Verbrugge and Jette proposed a Disablement Process model in 1994 that still serves as a useful framework for the maintenance of independence and the prevention or forestalling of disability.[18] The presence of worsening pathology (e.g., progression of AMD) leads to impairment (e.g., declining visual acuity). Without vision-restoring treatment or adaptive accommodations to address this impairment, disability in the form of increasingly impaired ADL and IADL ensues. Left unchecked, disability levels increase, leading to reductions in quality of life,

Table 5. Effects of BCVA Trajectories and Controls on Visual Acuity, ADL, IADL Trajectories ($n = 2518$)

	ADL* Baseline	ADL* Change	IADL* Baseline	IADL* Change	Acuity Baseline	Acuity Change
Visual acuity						
Best-corrected baseline	0.003	0.004†	0.067‡	0.005		
Best-corrected Change		0.013		0.102‡		
Demographics						
Age at baseline	−0.014	0.007	0.353‡	0.02	0.016†	0.004‡
Female	0.337†	−0.026	0.481†	0.066	0.020	−0.004
Black	0.067	−0.093§	0.564†	−0.177§	0.029†	−0.003
Education	−0.008	−0.009	0.051	−0.02	−0.005†	0
Health behavior						
Past smoker	−0.009	−0.01	−0.059	0.102	0.012	−0.002
Current smoker	−0.199	0.049	0.379	0.215§	0.025	0.004
Past alcohol use	−0.118	0.067	−0.061	0.094	0.018	0
Current alcohol use	−0.208	0.045	−0.155	0.119	0.002	0.001
Underweight	1.882‡	0.082	2.48‡	0.14	0.052§	0.004
Overweight	0.053	−0.005	−0.008	−0.026	−0.008	0.002
Obese	0.124	0.015	0.453	0.026	−0.010	0.002
Very obese	0.614§	0.058	1.562‡	0.135	−0.004	0
Health Conditions						
Severe depression scale	1.153‡	0.093	1.836‡	0.09	0.028	0.016§
Diabetes	0.133	0.283‡	0.26	0.445‡	0.037†	0.012†
Stroke	1.317‡	0.209§	1.892‡	0.148	0.018	0.07
Heart attack	0.138	−0.076	0.319	−0.138	−0.014	0.009
High blood pressure	−0.032	−0.02	−0.096	0.048	−0.005	0
Cancer	0.201	−0.068	0.335	−0.013	0.002	−0.008§
Asthma	0.338	0.02	1.241†	−0.245	0.005	0.010
Arthritis	0.583‡	0.018	0.73‡	0.011	−0.018§	−0.003
Angina	0.045	0.031	0.468§	0.118	0.003	−0.008§
Back problem	0.39‡	−0.014	0.735‡	−0.027	0.002	−0.002
Broken hip	1.269†	0.154	1.357§	0.009	0.023	0.014
Congestive heart failure	0.669§	−0.087	1.187†	−0.339	0.007	0.024§
Claudication	0.224	−0.09	0.367	−0.036	0.001	0.005
Emphysema	0.117	0.018	0.39	0.109	0.024	−0.006
Meniere's	0.011	−0.049	−0.1	−0.05	0.017	−0.006
Parkinson's	1.688†	0.535	1.497	1.527†	0.011	0.007

* ADL and IADL scales are in original units. See Table 1 for means and standard deviations.
† $P < 0.01$.
‡ $P < 0.001$.
§ $P < 0.05$.

increased risk of transition to nursing home admission, and increased risk of death.[19]

The stronger associations found for visual acuity decline and IADL decline over time, which were consistent across categories of race and gender, also reflect the life-course perspective of the Disablement Process model, which posits that increasing levels of visual impairment will first impact IADLs.[18] Previous research has also documented that visual impairment does impact IADLs more so than ADLs.[20] However, as impairment increases, ADLs will also become impacted. Without intervention and with increasing visual impairment, these impacts worsen, increasing the likelihood that a person will need to move into a nursing home or will die.[19]

Table 6. Effects of BCVA Trajectories and Controls on Visual Acuity, ADL, IADL Trajectories (1062 men, 1456 women)

BCVA	ADL Baseline	ADL Change	IADL Baseline	IADL Change
Visual acuity (men)				
Baseline Acuity	0.006	0.003	0.077†	0.003
Acuity Change		0.039*		0.132†
Visual acuity (women)				
Baseline Acuity	0.003	0.004‡	0.052†	0.006
Acuity Change		0.001		0.090†

Parameter estimates for covariate controls not shown.
* $P < 0.01$.
† $P < 0.001$.
‡ $P < 0.05$.

In addition, the strength of the association between loss in best-corrected acuity over time and IADL declines in our analysis was surprising ($r = 0.39$ controlled for age, Table 3); according to Jacob Cohen, this correlation corresponds to the midpoint between cutpoints for a large (0.5) and a moderate (0.3) effect size.[21] By way of comparison, the 2-year development of new or worsening IADLs in Medicare beneficiaries based on baseline obesity levels found an increased risk among those in the extreme obesity category relative to individuals maintaining a healthy weight level (BMI >35 kg/m^2 versus 22.0–24.9 kg/m^2).[22] The odds ratio for men and women was 1.37 and 1.41, respectively, indicating effect sizes of less than 0.2.[23] In our study, the association between best visual acuity loss and IADL decline (0.102, $P < 0.001$,

Table 5) is stronger than that of obesity and IADLs (0.026, $P > 0.05$, Table 5).

Also surprising was our finding that the association between visual acuity decline and ADL decline over time was present only for men. Furthermore, the strength of the association for men was similar to that found for IADLs in all SEE participants, irrespective of race and gender ($b = 0.40$, $P < .01$). We could find no report in the literature that examined gender-specific comparisons of visual impairment trajectories and associations with change in any disability indicators. However, reports examining other gender-specific predictors of disability generally report greater impact on women versus men. For example, in a 2000 to 2006 study of 1634 elderly residents of Sao Paulo, Brazil, initially with no ADL difficulties, women with chronic diseases and social vulnerability experienced a greater incidence of disability than men after adjusting for socioeconomic status and health conditions on follow-up 6 years later.[24] In the Swedish Panel Study of Living Conditions among the Oldest Old (SWEOLD), a nationally representative interview survey of persons aged 77 years and over, compared with men, women had significantly higher prevalence rates for most health indicators in both survey years, but there were no significant gender differences in ADL/IADL limitations. Prevalence rates increased significantly between 1992 and 2002 for all health indicators, but not for ADL/IADL.[25]

Given this limited body of research, there are no clear explanations for finding an association between visual acuity decline and ADL decline over time only among men. However, a traditional cultural emphasis on male self-reliance embedded within concepts of masculinity may interact with the increasing need to rely on the assistance of others in the face of visual acuity declines, leading to reduced feelings of self-efficacy.[26,27] Lowered self-efficacy may, in turn, increase the likelihood that men are either more likely to report ADL declines or actually experience ADL reductions as they acquiesce to the increased challenges of functioning with declining vision.[27] Although highly speculative, indirect support for this process comes from one report from the MacArthur Studies of Successful Aging in which higher levels of instrumental support (typically thought to be beneficial), were predictive of the onset of ADL disability in older men.[27] Findings were strikingly different in men versus women. In multivariate models, instrumental support was typically protective for onset of ADL disability in women, although for most instrumental measures, these protective effects were not statistically significant. In men, there were several support indicators that were unexpectedly predictive of ADL onset. For example, odds of ADL disability onset was 6.86 in men reporting more than two episodes of instrumental support at baseline versus those reporting zero to two episodes. These findings suggest that future research on the longitudinal impacts of changes in visual acuity should incorporate vision-associated self-efficacy measures to determine if reductions in this domain may help to explain associations with changes in measures of disability and functioning.

Irrespective of the need for additional gender-specific research into associations between visual decline and ADL/IADL changes, other ocular research has documented that visual impairment is associated with quality of life indicators, including disability-free life expectancy,[20] a finding consistent with the Disablement Process model.[18] These findings point to the continuing need for research to identify strategies for primary prevention in order to avoid the development of potentially vision impairing ocular conditions such as AMD and glaucoma, as well as access to secondary prevention to limit the period of time persons are living with visual impairment from conditions amenable to vision restoring treatment (e.g., cataract surgery).[28] However, findings also suggest that those with irreversible vision loss should have access to available aids to help mitigate the effects of living with this condition.[29,30] There is increasing research showing that disabled elderly can regain functional ability so increased efforts at providing vision rehabilitation services may help to improve quality of life, but also to slow the disablement process.[31,32]

The mean best-corrected visual acuity in the SEE study decreased over an 8-year period from nearly 20/20 to nearly 20/25 with a decline of 2.9 letters. The visual acuity decline observed in the SEE is similar to the Blue Mountains Eye Study where the mean decline in best-corrected visual acuity over a 5-year period was 3.2 letters for participants aged 65 to 74 years at baseline and 6.3 letters for participants aged 75 years or older at baseline.[33] In the Beaver Dam Eye Study, the mean decline in best-corrected visual acuity over a 15-year period for participants 75 years of age or older at baseline was approximately 3 lines of ETDRS acuity (14.9 letters).[34] The greater decline in visual acuity loss in the Beaver Dam Eye Study compared with the SEE may be related in part to differences in race of participants, prevalence of ocular conditions, and follow-up rates.

The strength of our models assessing relationships in changes over time is that it provides a more rigorous test of causality than cross-sectional associations because it eliminates all potential confounders that are stable within the person. The method is a quasi-experimental design in that each individual is used as their own control.

Limitations of our study include the self-reported measures of ADLs and IADLs, which are influenced by an individual's assessment of his or her ability, the individual's expectation of that ability, and the individual's determination of the degree of difficulty in performing the task in the presence of limitations. However, we used standard questionnaires and in this way are no different from all other studies using self-reported data. While these models provide stronger tests of association by controlling for all static, within-person characteristics, they do not control for unobserved covariates that are changing significantly during the course of the study (except for age, ADL, IADL, and visual acuity). Unfortunately, we were unable to estimate the model using time-varying assessments of health conditions and controlled for baseline levels only. Therefore, changes in these health conditions since baseline were not accounted for in the models. Persons with severe cognitive impairment were not included in the SEE at baseline, to ensure that visual acuity could be measured on all participants in a standardized fashion. SEE retention efforts included offering abbreviated ocular examinations at participants' homes when participants were unable or unwilling to travel to the clinic site. However, some participants who dropped out because of entering a nursing home and those who died were likely to have greater increase in ADLs and IADLs, which may have caused an underestimation of the trajectories.

In summary, in this longitudinal study of older adults, visual acuity loss over time is related to increased difficulty with IADLs in women and men, and with increased difficulty in ADLs in men only. The findings indicate that reduced vision over time in the elderly is associated with significant functional decline, although it is important to note that unmeasured factors in our study may also play a role. Additional research is needed to identify ocular and nonocular factors that could help mitigate functional decline as visual impairment increases. This research will take on increasing importance as the demographic profile of the United States is undergoing a shift as the leading edge of the "baby boomer" generation started turning 65 in 2011.[35] By 2030, this older proportion of the US population is expected to double to 72 million—in comparison with the number of older Americans in the population in the year 2000—leading to more Americans living with vision

impairment.[35] The emerging diabetes epidemic, in combination with these demographic shifts, is expected to increase the number of Americans living with diabetic retinopathy from 5.5 million in 2005 to 12.3 million by 2030.[36,37] Finally, results suggest that additional efforts to prevent ocular conditions and complications that can lead to irreversible vision loss (e.g., glaucoma, diabetic retinopathy) are needed so that the proportion of future cohorts living with visual impairment is reduced over time.

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