Interaction Between Visual Acuity and Peripheral Vascular Disease with Balance

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OBJECTIVES: To determine whether visual acuity is related to balance in older adults with peripheral vascular disease (PVD) or diabetes mellitus.
DESIGN: Cross-sectional analysis.
SETTING: Canada.
PARTICIPANTS: Community-dwelling adults aged 45 to 85 from the Canadian Longitudinal Study on Aging (N=30,097).
MEASUREMENTS: Visual acuity was measured wearing habitual distance correction using the Early Treatment of Diabetic Retinopathy Study chart at a 2-m distance. Poor balance was defined as being unable to stand on 1 leg for at least 60 seconds. PVD and diabetes mellitus were assessed according to self-report of a physician diagnosis. Multiple logistic regression was used.
RESULTS: People who reported PVD (n=1,295) were more likely to have worse balance than those who did not (odds ratio (OR)=1.50, 95% confidence interval (CI)=1.29–1.77). In those who did not report PVD (n=26,211), a 1-line worse score on the visual acuity test was associated with 23% higher odds of being unable to stand for at least 60 seconds after adjusting for age, sex, education, province, body mass index, and diabetes mellitus (OR=1.23, 95% CI=1.20–1.26). In those who reported PVD, the odds of being unable to stand was almost double (OR=1.41, 95% CI=1.22–1.62). The interaction between visual acuity and PVD was statistically significant (P=.02).
CONCLUSIONS: Visual acuity and PVD interact in their relationship with balance. People with poor vision and PVD may be at an especially high risk of mobility difficulties. **J Am Geriatr Soc 66:1934–1939, 2018.**

Key words: vision; peripheral arterial disease; proprioception; CLSA

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Mobility limitations are an important predictor of poor quality of life, institutionalization, and mortality in older adults[1–3]. A requirement for good mobility is the ability to maintain balance while performing various tasks. Balance control in older adults uses sensory input from the visual, vestibular, and proprioceptive systems and requires neural and musculoskeletal control to correct postural disturbances[4]. Diseases that impair any of those sensory or correction systems may affect balance. Impairments in more than 1 system may have a magnified effect on balance.

Vision loss is a known risk factor for poor balance, especially when performing complex balance tasks such as standing on a compliant surface or on 1 foot. For example, a previous study found that, on a compliant surface, several measures of visual function were related to postural sway, whereas on a firm surface, no measures of visual function were related to postural sway[5]. A population-based study found that visual acuity (per 0.1 logMAR) was not related to simple standing balance positions such as side-by-side or semi-tandem but was related to more complicated standing balance positions such as tandem (OR=1.13, 95% CI=1.03–1.25) and on 1 foot (OR=1.29, 95% CI=1.03–1.62) after adjustment for age, sex, race, body mass index (BMI), and number of comorbidities[6].

Given that balance control is so multifactorial, it is important to consider the interactions between vision and other factors. Interaction is when the observed joint effect of 2 variables differs from that expected on the basis of the independent effects. Studies rarely have adequate sample size to investigate interactions between vision loss and

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chronic diseases that affect other regulators of balance. Interactions are important to investigate because people who have compromises in multiple balance control systems may have a much higher risk of poor balance and may require more urgent intervention. We used data from the 30,097 Canadian Longitudinal Study on Aging (CLSA) participants to investigate whether vision loss interacts with chronic diseases that might affect other sensory or correction systems such as peripheral vascular disease (PVD; also called peripheral arterial disease) and diabetes[7–9]. PVD and diabetes may affect balance by impairing proprioception and lower body strength[10,11], and they are common enough in older adults to have adequate statistical power to investigate interactions. We hypothesized that vision loss would be more strongly related to standing balance in individuals with PVD or diabetes than in those without.

METHODS

Participants

A random sample of 30,097 community-dwelling adults aged 45 to 85 within a 25- to 50-km radius of 1 of the 11 data collection sites in 7 Canadian provinces (Victoria, Vancouver, Surrey, Calgary, Winnipeg, Hamilton, Ottawa, Montreal, Sherbrooke, Halifax, St. John's) participated in the Comprehensive Cohort of the CLSA[12]. Exclusion criteria included living in an institution or on a First Nations reserve or settlement, being a full-time member of the Canadian Armed Forces, being unable to speak French or English, and having overt cognitive impairment (unable to understand the study or answer basic questions about themselves). Research ethics boards in 7 provinces approved the project. Research followed the tenets of the Declaration of Helsinki. Written informed consent was obtained from all participants.

Sampling Strategy

Two sampling strategies were used to recruit people for the Comprehensive Cohort of the CLSA[12,13]. Participants were recruited from provincial health registries (14%) and using random digit dialing (86%). Each randomly chosen eligible person recruited from a provincial health registry was sent a consent form to sign and return. For those recruited through random digit dialing, a random sample of landline telephone numbers was selected for a given geographic area. Once a call was answered, eligibility was established, and consent was obtained. Stratified sampling was used to ensure adequate representation of various demographic groups. Strata within a province were defined according to age group, sex, and distance from the data collection site.

Data Collection

An interviewer administered various questionnaires at home or a data collection site. Physical examinations were conducted at the data collection site. Data were collected between 2010 and 2015. All CLSA personnel underwent extensive training to ensure standardized data collection.

Visual Acuity

Visual acuity was measured at the data collection site with both eyes open wearing the usual prescription for distance correction, if any, using the Early Treatment of Diabetic Retinopathy Study (ETDRS) chart at 2 m. Acuity was scored as the total number of letters read correctly and then converted to the log of the minimum angle of resolution (logMAR). A logMAR of 0.0 is normal (20/20) and of 1.0 indicates blindness (20/200).

Balance Assessment

The 1-leg standing test was used to assess balance[14]. This test has shown good reliability and is predictive of adverse events such as falls and incident disability[15,16]. Only those who could stand unassisted were asked to perform the balance test. Participants were positioned without shoes approximately 1 m from a wall and instructed to stand on 1 foot while lifting the other leg to calf level with hands on hips. The interviewer briefly demonstrated. Participants were allowed to practice the procedure before the timed test. The time the person stood without putting the raised leg down, touching the wall, or losing balance was recorded for up to 60 seconds. The test was performed first on the right leg and then repeated on the left leg. The better time of the 2 legs was used for analysis. Given the truncated distribution of this variable (the test was stopped at 60 seconds), this score was dichotomized such that the person could or could not stand for at least 60 seconds on the better leg.[13]

Sociodemographic Data

Information was collected on age, sex, and education. Education was measured by asking about the highest degree attained and categorized into 3 groups: more than a bachelor's degree (or equivalent), bachelor's degree, and less than a bachelor's degree.

Health Behavior and Health Status

Participants were grouped into 3 smoking status groups: current, former, and never. Former smokers were people who had smoked at least 100 cigarettes in their lifetimes but had not smoked in the last 30 days. Current smokers had smoked in the last 30 days.

Participants were asked about a physician diagnosis of diabetes. An affirmative response led to a follow-up question about the type of diabetes: type 1, type 2, or neither/diabetes suspect. Participants were asked about a physician diagnosis of PVD or poor circulation in the limbs. BMI was calculated by dividing measured weight (kg) by measured height squared (m^2).

Statistical Analysis

Individuals who did not attempt the balance test were compared with those who did. The sociodemographic and health variables of those who could and stand at least 60

Table 1. Participant Characteristics According to Ability to Stand for 60 Seconds (N = 28,330)

Variable	60 Seconds, n = 13,577	<60 Seconds, n = 14,753[b]
Visual acuity, logMAR, mean ± SE (n = 28,102)	–0.02 ± 0.00	0.05 ± 0.00
Age, mean ± SE (n = 28,330)	55.14 ± 0.06	64.2 ± 0.10
Sex, %		
Female (n = 14,326)	48	54
Male (n = 14,004)	52	46
Education, %		
> Bachelor's degree (n = 6,211)	41	53
Bachelor's degree (n = 6,797)	31	25
< Bachelor's degree (n = 15,272)	28	22
Smoker, %		
Current (n = 2,374)	8	10
Former (n = 12,325)	38	45
Never (n = 13,535)	54	45
Diabetes mellitus, %		
No (n = 23,467)	90	80
Type 1 (n = 147)	0	1
Type 2 (n = 2,446)	4	12
Neither or suspect (n = 1,991)	6	8
BMI, kg/m^2, mean ± SE (n = 28,308)	26.77 ± 0.04	29.36 ± 0.06
PVD (n = 28,207)	3	6

Categories not adding to 28,330 had missing data for that variable: visual acuity (n = 228), smoking (n = 96), diabetes mellitus (n = 279), body mass index (BMI) (n = 22), peripheral vascular disease (PVD) (n = 123)
[b]All variables were statistically significantly different between the two groups using chi-square tests or t-tests.

seconds were compared with the variable of those who could not. The 60-second cut-point gave maximum statistical power. Differences between the two groups were tested using chi-square tests for categorical variables and t-tests for continuous variables. Logistic regression was used to adjust simultaneously for variables that might confound the relationship between visual acuity and standing balance. Potential confounders included variables found in previous research to be associated with visual acuity or balance and included age, sex, education, smoking, BMI, diabetes, and PVD[6,10,11,17,18]. Diabetes and PVD were also investigated as effect modifiers in their relationship with vision. Multiplicative interaction was assessed by creating interaction terms which were tested for statistical significance in the regression model. All analyses were adjusted for the complex study design using strata and weight variables with Stata IC version 11 (Stata Corp., College Station, TX). Sensitivity analyses were conducted to determine the effect of assuming that those who did not attempt the standing balance test because they could not stand unassisted were unable to stand 60 seconds.

RESULTS

People who were unable to stand unassisted did not perform the standing balance test (n=1,767, 5.9%). This group was much older (67.5) than those who performed the test (59.1) and had worse visual acuity (mean logMAR

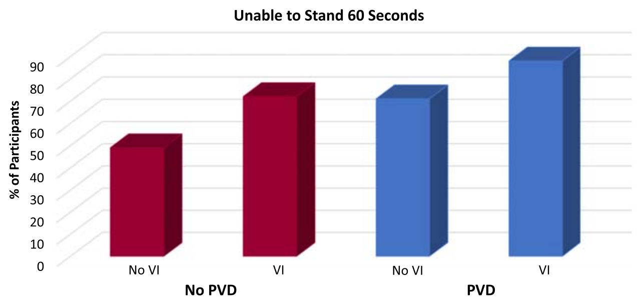

Figure 1. Percentages of participants who were unable to stand at least 60 seconds according to visual impairment (VI) and peripheral vascular disease (PVD).

0.12 vs 0.01). The Spearman correlation between logMAR visual acuity and standing balance time was –0.3 (P<.001). Of those who attempted the standing balance test, 44% were able to stand for at least 60 seconds on one leg.

A description of those who could and could not stand for at least 60 seconds on one leg can be found in Table 1. People who could not stand for at least 60 seconds had worse visual acuity; were older; and were more likely to be female and to have less education, to have smoked, to have diabetes, to have PVD, and to have a higher BMI (P<.05). In Figure 1, the percentages of those who could not stand for 60 seconds are shown according to whether they had impaired visual acuity (<20/40) or PVD.

The variables associated with being unable to stand at least 60 seconds after adjustment for each other in a multiple logistic regression model are shown in Table 2. People with worse visual acuity were more likely to have balance problems such that, for each 0.1 logMAR higher score (1 less line of letters read on the acuity chart), there was 23% higher odds of being unable to stand at least 60 seconds (OR=1.23, 95% CI=1.20–1.27) after adjustment

Table 2. Variables Related to Poor Balance Using Multiple Logistic Regression

Variable	Odds Ratio (95% Confidence Interval)
Visual acuity, per line	1.23 (1.20–1.27)
Age, per year	1.13 (1.12–1.13)
Female	1.45 (1.35–1.55)
Education (reference >bachelor's degree)	
Bachelor's degree	1.02 (0.93–1.13)
< Bachelor's degree	1.45 (1.32–1.57)
Smoking (reference never)	
Past	0.99 (0.92–1.07)
Current	2.24 (1.97–2.55)
Diabetes mellitus	
Type 1	3.41 (2.04–5.70)
Type 2	1.67 (1.46–1.90)
Neither or suspect	1.05 (0.92–1.19)
Body mass index, per kg/m^2	1.13 (1.12–1.14)
Peripheral vascular disease	1.50 (1.29–1.77)

Adjusted for province.

for demographic and health variables. PVD was also related to being unable to stand at least 60 seconds (OR=1.50, 95% CI=1.29–1.77), as were female sex, low education, current smoking, BMI, and Type 1 and 2 diabetes (P<.05).

Visual acuity and PVD interacted such that the odds of being unable to stand were almost double in those who reported PVD (OR=1.41, 95% CI=1.22–1.62) as in those who did not (OR=1.23, 95% CI=1.20–1.26) (interaction P=.02) (Table 3). There was not a statistically significant multiplicative interaction between visual acuity and diabetes because the interaction term was not statistically significant (stratified data not shown) (interaction term P=.11).

Sensitivity analyses were conducted to determine whether the results in Tables 2 and 3 changed if we assumed that all 1,767 people who did not attempt the standing balance test were unable to stand for 60 seconds. The results did not change.

Table 3. Results of Multiple Logistic Regression Models Showing Relationships Between Visual Acuity and Poor Balance Stratified According to Report of Peripheral Vascular Disease (PVD)

Strata	Variable	Balance<60 Seconds Odds Ratio	95% Confidence Interval
No PVD	Visual Acuity, Per 1 Line	1.23	1.20, 1.26
PVD	Visual Acuity, Per 1 Line	1.41	1.22, 1.62

Models were adjusted for age, sex, education, smoking, body mass index, diabetes mellitus, and province.

DISCUSSION

Good balance requires the integration of input from multiple physiological systems, yet to our knowledge, no previous population-based studies have reported an interaction between vision and chronic diseases affecting other balance control systems. Consistent with our hypothesis, we found for the first time that the relationship between visual acuity and standing balance was much stronger in those with a report of PVD, indicating an interaction. Conversely, although diabetes was independently associated with balance problems, it did not interact with vision because the OR for vision was the same regardless of the presence of diabetes.

Visual acuity and other measures of visual function have previously been found to be associated with standing balance[5,6,19–21]. When standing, the body undergoes small oscillatory movements that result in small retinal image movements that indicate the need for the body to compensate to maintain postural control. Although we found that visual acuity was related to standing balance, we did not have data on other measures of visual function. Studies have reported that other measures of visual function such as visual field and motion detection are even more strongly related to balance than visual acuity[6,21].

A narrowing or blockage of the blood vessels in the arms and legs causes PVD. There is some prior evidence of a relationship between PVD and balance. One study found that people with PVD had greater sway velocity during the semitandem stand than those without, after adjustment for age, sex, smoking, diabetes, chronic obstructive pulmonary disorder, and congestive heart failure[8]. Another study found that people with PVD were able to stand on 1 leg for 28% less long than those without it[9]. PVD is thought to affect balance through its effect on leg strength and ischemic neuropathy in severe cases[10].

We are not aware of any prior population-based studies that have reported an interaction between vision and chronic diseases affecting other balance control systems, although the Clinical Test for Sensory Interaction and Balance was developed in 1986 to detect sensory selection problems, such as when a person is highly dependent on input from only 1 balance control system[22]. This test uses artificial means to distort the sensory input from 1 or more systems by having a person stand with eyes closed or on a foam surface. Studies have used this and similar approaches to determine the effect of these balance control systems on postural sway and falls[23–26]. Simulation studies show that the central nervous system may continually reweight input from balance control systems in the face of altered environmental conditions that may affect the accuracy of that input for postural control[27]. Whether these temporary artificial disturbances generalize to the onset of permanent age-related diseases in their effect on balance is unclear. The interaction between diseases affecting multiple balance control systems deserves additional investigation.

Additional potentially modifiable variables were also related to poor balance, including current smoking, diabetes, and BMI. Current smokers were more likely to have poor balance, which has been shown previously[17,28]. It is not clear whether this relationship is because of confounding factors (e.g., smokers exercise less) or a direct effect of tobacco on the vestibular system, peripheral nervous system, leg muscles, peripheral circulation, or brain. People with Type 1 or Type 2 diabetes also had worse standing balance[29]. This is believed to be mainly because of the effect of diabetes on the peripheral nervous system, although it could also be partially because of confounding factors such as muscle weakness and BMI[29]. Finally, people with higher BMI had worse standing balance[30,31]. It has been hypothesized that mechanisms such as poor plantar sensitivity and high mechanical demand due to a large body mass lead to worse balance[31].

The strength of this work is that it uses a large population-based dataset of middle-aged and older adults from all over Canada. Large datasets are required to have adequate statistical power to search for biologically plausible interactions. A limitation of this work is that the data are cross-sectional, so we cannot assess whether vision loss and PVD preceded onset of balance difficulties. For example, someone with balance problems may have greater difficulty accessing eye care and therefore might be more likely to have avoidable vision loss. We also cannot determine the temporality of the vision loss and PVD. It is possible that worse visual acuity is due to worse PVD, although studies have not found a relationship between the ankle-brachial index, which can be used to assess PVD, and retinal microvascular abnormalities[32]. Longitudinal data are necessary to examine this temporality. In addition, PVD was assessed according to self-report of a physician diagnosis rather than ankle-brachial index. In prior research, investigators found that percentage agreement between self-reported PVD and PVD defined using the ankle brachial index was 0.79, which was lower than other chronic conditions that are more disruptive to function or require more frequent monitoring[33]. This may have led to nondifferential misclassification, which may have diluted the true relationship. We had data only on visual acuity and not on multiple measures of visual function such as visual field and contrast sensitivity. We did not have data on reports of vestibular disease or on proprioception testing. Finally, the CLSA Comprehensive Cohort sample was recruited from within 25 to 50 km of the 11 urban data collection sites in 7 provinces of Canada. Therefore, the generalizability of our results to other populations is unknown.

Our findings are important because poor balance when standing on 1 leg increases the risk of injurious falls and incident disability[16,34]. For example, a previous study found that inability to stand on 1 leg for at least 5 seconds was a predictor of an injurious fall in the next 3 years in adults aged 60 and older (relative risk (RR)=2.13, 95% CI=1.04–4.34)[34].

Clinicians treating people for PVD may want to encourage them to have an optometrist or ophthalmologist check their vision[35]. In addition, those with balance problems should have sensory testing for neuropathy and potentially have their ankle-brachial index determined to exclude PVD. Furthermore, it may be possible to design interventions to improve balance. Interventions that target lower leg strength have shown promise in being able to improve muscle strength[36], although targeting leg strength alone may not be enough. Interventions designed to improve balance could target not only leg strength, but also the proprioceptive, vestibular, and visual systems. For example, refractive error is the leading cause of visual impairment, so an ocular assessment would be a wise addition to a multifactorial balance intervention[35]. Researchers hoping to improve balance have developed a tactile intervention[37] for people with diabetes and a vestibular intervention for people with vestibular disorders[38]. The more we understand about the interaction of the three balance control systems, the better we can develop interventions that target the relevant systems for each person.

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