Journal of Aging and Physical Activity, 2020, 28, 756-764
https://doi.org/10.1123/japa.2019-0057

Human Kinetics
ORIGINAL RESEARCH

Poorer Visual Acuity is Independently Associated With Impaired Balance and Step Length But Not Overall Physical Performance in Older Adults

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This study examined the association between varying levels of visual acuity (VA) and physical performance (Short Physical Performance Battery) in older adults. A cross-sectional analysis of participants aged ≥50 years with a clinical diagnosis of vision loss across two studies was undertaken. Of 434 (96%) participants with available VA data, 74% (320/434) had nil, 7% (32/434) had mild, 8% (33/434) had moderate, and 11% (49/434) had severe visual impairment. Poorer VA of both better and worse eye was found to be significantly associated with poorer standing balance ($p = .006$ and $p = .004$, respectively); worse VA of the better eye was significantly associated with increased number of steps per meter ($p = .005$). Mean total Short Physical Performance Battery score of this study population was lower than published normative data for this age group. Physical activity programs for older people with reduced VA should be targeted at improving balance and gait skills to reduce falls risk.

Keywords: Australia, falls risk, low vision, physical function

Reduced physical ability (Shumway-Cook, Baldwin, Polissar, & Gruber, 1997; Veronese et al., 2014) and vision impairment (de Boer et al., 2004; Freeman, Munoz, Rubin, & West, 2007; Klein, Klein, Lee, & Cruickshanks, 1998; Lamoureux et al., 2010; Patino et al., 2010) are independently associated with a heightened risk of falls and morbidity in people aged 60 years and older. This poses a problem, as falls are a major cause of injury and mortality in older adults (Australian Bureau of Statistics, 2006; World Health Organization, 2007). Physical ability in older adults is commonly compromised by loss of muscle mass and function (Dam et al., 2014; Rizzoli et al., 2013). Maintaining physical activity has been shown in an older population to improve walking speed and lower limb function, and reduce the risk of disability (Santanasto et al., 2017). Unfortunately, older adults with reduced vision are less likely to engage in regular physical activity than those with normal vision (Donoghue et al., 2014; Ramulu et al., 2012) and, as a consequence, have even poorer physical ability (Lamoureux et al., 2010).

Links between poor visual acuity (VA) or reduced contrast sensitivity (CS), and falls in older adults are well-documented (de Boer et al., 2004; Ivers, Cumming, Mitchell, & Attebo, 1998; Klein, Moss, Klein, Lee, & Cruickshanks, 2003; Kuang et al., 2008). Visual field defects, particularly those in the inferior field, have also been shown to increase the odds of falls in older adults (Black, Wood, & Lovie-Kitchin, 2011; Freeman et al., 2007; Ivers et al., 1998; Patino et al., 2010). However, the mechanism by which reduced vision mediates falls remains unclear (Lamoureux et al., 2010; Lord & Menz, 2000). The Short Physical Performance Battery (SPPB) is an assessment of physical function shown to be predictive of falls risk (Veronese et al., 2014), disability in activities of daily living, and nursing home admission (Guralnik et al., 1994). Investigating the relationship between SPPB scores and vision impairment may aid in understanding the role vision plays in the burden of falls and other negative consequences of vision loss.

Visual impairment may reduce an older person's ability to identify hazards within the environment, leading to greater risk of slips and trips. Evidence also suggests that reduced vision may affect a person's balance (Lee & Scudds, 2003; Lord & Menz, 2000; Tomomitsu, Alonso, Morimoto, Bobbio, & Greve, 2013). Lee and Scudds (2003) assessed potential differences in balance of persons aged 65 years and older with normal vision, mild, and moderate visual impairment. Those with mild vision impairment had balance scores that were significantly lower than those with normal vision, and higher than those with moderate vision impairment. A similar relationship has been reported between visual impairment and increased sway, with studies showing that the impact of reduced vision on balance is more profound when performing dynamic tasks such as standing on a compliant surface (Lord & Menz, 2000; Tomomitsu et al., 2013).

Visual impairment can negatively impact aspects of physical strength and performance. Poorer VA, CS, and visual field restrictions have been linked to slower gait time (Klein et al., 1998). In a small ($n = 33$) cross-sectional study, assessing the relationship between vision impairment, balance, and lower limb strength in adults aged ≥70 years, Chen, Fu, Chan, and Tsang (2012) found that sighted subjects had greater stability during walking tasks compared with blind subjects and increased knee muscle strength compared with participants with low vision. However, there was no difference between the groups in lower limb strength, as measured by the sit to stand test. Salive et al. (1994) also found a significant association between reduced binocular VA and poorer physical performance and mobility in a large ($n = 3{,}133$) longitudinal study of older adults in the United States. Although visual function in this study was graded by severity, participants reporting functional blindness did not undertake confirmatory vision screening and

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were automatically categorized as severely vision impaired (Salive et al., 1994). A population-based study of adults aged ≥55 years reported by West et al. (2002) found that restricted visual field (horizontal diameter less than 40°) was significantly associated with poor performance on all measures of physical function. Here, reduced high-contrast VA (20/70 [0.54 logarithm of the minimum angle of resolution (logMAR)] or worse) was found to have significant associations with the walking test and chair stand test, but not with the tandem stand test. Other studies have not been able to offer insight into how varying levels of visual impairment impact overall physical ability (Friedman, Freeman, Munoz, Jampel, & West, 2007; West et al., 2002).

Research to date is yet to establish a consensus regarding the relationship between visual function and physical performance in a population of older adults across the full range of vision impairment. This study aims to contribute to this evidence base by objectively assessing this relationship using the SPPB within a community-dwelling population of older adults with varying levels of VA.

Methods

Baseline data from the FOCUS (Falls in Older people with Cataract: a longitudinal evalUation of impact and riSk; Keay et al., 2014) and VISIBILITY (Vision Impairment Balance and Mobility; Gleeson, Sherrington, Borkowski, & Keay, 2014) studies were combined for analysis to ensure the study population included the full range of vision. The VISIBILITY population included participants with mainly severe to moderate vision impairment, whereas FOCUS included those with nil to moderate impairment according to the World Health Organization International Classification of Diseases 11th Revision. Participants of both studies were clinically diagnosed with some form of vision impairment, although no objective measure of vision was imposed as inclusion criteria (see Table 1). Each study included the same standardized measure of physical performance for all participants and followed the same protocol for administering this. Ethical approval for the FOCUS study was granted by the New South Wales Population and Health Services Research Ethics Committee (HREC/13/CIPHS/25) and the institutional ethics committees of each clinical site. Ethical approval for the VISIBILITY study was granted by the human research ethics committees at the University of Sydney (Protocol No 12985) and the University of New South Wales (HREC10277). VISIBILITY was registered with the Australian New Zealand Clinical Trials Registry (ACTRN12610000634077).

VISIBILITY

The VISIBILITY study was a two-armed randomized control trial with 120 participants aged >50 years, who were receiving orientation and mobility services for vision impairment from a community organization (Guide Dogs NSW/ACT). The study investigated whether lessons in the Alexander Technique can prevent falls in older people with low vision. Inclusion and exclusion criteria for this study are outlined in Table 1, and further details on participant recruitment and consent have been outlined previously (Gleeson et al., 2014). The self-reported visual diagnosis of participants included macular disease (39%), glaucoma (12%), cerebral injury (5%), diabetic retinopathy (5%), retinitis pigmentosa (12%), and other conditions (27%). Baseline measurements (prior to randomization) were obtained between September 2010 and December 2011.

FOCUS

FOCUS is a longitudinal cohort study of 329 participants aged ≥65 years recommended for first-eye cataract surgery in eight public hospital eye clinics within the Australian cities of Sydney, Melbourne, and Perth. The study investigated epidemiology of falls in older people with cataract before and after the first and second eye surgery. Participant inclusion and exclusion criteria are outlined in Table 1, and further details on sampling and recruitment within this study have been described previously (Keay et al., 2014). Baseline measurements (prior to first-eye cataract surgery) were obtained between October 2013 and August 2015.

Data Collection

Demographic and health data for all participants included age, sex, total medications, self-reported comorbidities (scored using

Table 1 Inclusion and Exclusion Criteria for FOCUS and VISIBILITY Studies

Criteria	FOCUS	VISIBILITY
Inclusion criteria	• Aged 65 years or older • Living in the community or self-care unit of retirement village • Recommended for first-eye cataract surgery and joining public hospital waiting list[a]	• Aged 50 years or older • With visual impairments that affect their mobility • Have received mobility training from orientation and mobility instructors at Guide Dogs NSW/ACT within the past 5 years to maintain independent mobility • Mobility aids may include identification canes, long white canes, support canes, walking frames, and guide dogs • Live in greater metropolitan Sydney and have conversational English
Exclusion criteria	• A diagnosis of dementia, Parkinson's disease, or stroke • Wheelchair bound • Presence of significant ocular comorbidities (advanced glaucoma, retinopathy, or amblyopia) • Undergoing combined ocular surgery (e.g., cataract and glaucoma) or cataract surgery for the second time on the same eye • Residing outside the metropolitan area or unable to participate in the follow-up assessments	• Clinically diagnosed dementia or a short mental status questionnaire score of <8 • Not independently mobile with aids already mentioned • Planning cataract surgery in the next 12 months[b] • Unable to understand and speak conversational English

Note. FOCUS = Falls in Older people with Cataract: a longitudinal evalUation of impact and riSk; VISIBILITY = Vision Impairment Balance and Mobility.
[a]Only baseline measures from the FOCUS study were used in the present analysis; therefore, vision measures reported are before first-eye cataract surgery. [b]Participants with planned cataract surgery were excluded from the VISIBILITY study because this could dramatically improve their vision impairment during the randomized control trial.

the Functional Comorbidity Index, score of 0–18; Groll, To, Bombardier, & Wright, 2005), and presence of depressive symptoms (evaluated by the 5-item Geriatric Depression Scale). In the FOCUS study, VA was recorded separately for each eye as a letter count score based on assessment with the Early Treatment Diabetic Retinopathy Study high-contrast VA chart at 3 m using presenting (habitual) spectacle correction. The VISIBILITY study recorded habitual VA in Snellen notation as found in participant's medical records. For the purposes of this study, bilateral VA data from both datasets were converted to logMAR, and participants stratified into groups according to the World Health Organization categories of vision impairment (World Health Organization, 2018). Mild visual impairment was defined as presenting (with habitual correction) VA in the better eye of logMAR 0.5 (20/60) or better, moderate visual impairment as presenting better eye VA poorer than logMAR 0.5 but better than or equal to logMAR 1.00 (20/200), and severe visual impairment and blindness as presenting better eye VA poorer than logMAR 1.00. Due to different visual field methodologies between the two studies and significant missing data, visual field assessment was not included. Explanation and rationale for each of the included variables are presented in Table 2.

Measure of Physical Performance

The SPPB was used as an objective measure of basic physical performance. First described by Guralnik et al. (1994), the SPPB comprises three physical ability measures designed to assess lower extremity function: standing balance, gait speed, and five times sit to stand test (5TSTS). Performance in each of the three physical ability measures of the SPPB is evaluated by a component score ranging from 0 (*worse performance*) to 4 (*best performance*). A composite (total) score of 0–12 is used to indicate an overall level of physical performance, with a score of 12 being best.

The standing balance component consists of standing for 10 s with feet positioned in six variations: feet apart with assistance, feet apart without assistance, feet together, semitandem stance, tandem stance, and single-leg stance. The variations are assessed in a hierarchical manner of increasing difficulty. If the participant is unable to complete 10 s of standing assisted with feet apart, the balance assessment does not continue, and they are awarded a score of 0. To create the component score for the SPPB, participants are awarded a score of 4 for being able to hold the single-leg stance for a full 10 s without assistance. A standing balance time of 60 s indicates best performance in this component.

The gait speed component is a timed 4-m walk during which the participant is scored based on their ability to complete the walk within a given time. A score of 0 indicates inability to complete the task. A score of 1–4 indicates the time category in which the participant completed the 4-m walk, with four being the fastest (<3.1 s). In this study, gate speed is reported in meters per second (m/s) with the number of steps taken per meter (steps/m).

The final component of the SPPB is the 5TSTS. The participant must rise from a hard chair with arms folded across their chest for five repetitions, as quickly as possible. Quartiles for length of time required to complete the five repetitions are used for scoring: a score of 0 being inability to perform the task and a score of 4 assigned to those who are able to complete the five repetitions in <11.1 s.

Statistical Analysis

The distribution of total SPPB score and the separate component scores was described and compared with normative values for total SPPB score (Vasunilashorn et al., 2009). Multivariate linear regression was used to investigate the relationship between VA (both worse eye and better eye) and physical performance. A series of five multivariate models were developed to include total SPPB score and each of its subscales: SPPB overall score, standing balance, gait speed (m/s), number of steps per meter, and the 5TSTS score. Additional explanatory variables included in each model were age, gender, Functional Comorbidity Index score, and number of medications. These factors are known to be associated with falls risk and physical function (see Table 2). A significance level of .05 was applied.

Table 2 Justification of Variables Included in Multivariate Analysis

Variable	Rationale	Type of variable	Scale
VA	VA has been shown to be predicative of gait time, mobility limitation (Lord & Menz, 2000; Marigold & Patla, 2008), falls (Hallemans et al., 2011; Ivers et al., 1998; Keay et al., 2014), and sway (Chen et al., 2012; Klein et al., 2003; Lee & Scudds, 2003). When described as a logMAR value, VA of 0 is considered normal vision and values >0 indicate increasingly worse vision.	Continuous Categorical	0–2.5 logMAR Mild ≤ 0.5 Moderate > 0.5–≤1.00 Severe > 1.00
Age Gender	Age and gender can influence physical performance in older adults (Steffen, Hacker, & Mollinger, 2002), while age specifically has also been proven to influence postural control (Hageman, Leibowitz, & Blanke, 1995). Age is used in analysis as both a continuous and discrete variable.	Continuous Discrete Categorical	≥50 years Male Female Unknown
FCI Total number of medications	Comorbidities and the number of medications taken give an indication of participant's overall general health, which can affect strength and mobility. FCI was used instead of total number of comorbidities, as it designed specifically to explain variance in physical function (Penninx et al., 2000). The FCI also takes depression into consideration, which has been linked to slower gait time and worse overall physical performance (Bruce, Seeman, Merrill, & Blazer, 1994; Penninx et al., 1998).	Discrete Discrete	0–18 Count data

Note. FCI = Functional Comorbidity Index (a high score indicates a high number of comorbidities); logMAR = logarithm of the minimum angle of resolution; VA = visual acuity; logMAR = logarithm of the minimum angle of resolution.

Results

A total of 450 participants (41% male; mean ± *SD* age 79 ± 7 years) were included for analysis after combining baseline measurements from the two studies. Over half (56%, 251/450) of all participants were born in Australia and the majority of participants lived at home (62%, 279/450). Almost half (43%, 194/450) of all participants had fallen in the year prior to their study assessment. The mean Functional Comorbidity Index score was 4.9 ± 2.5, and the mean number of medications taken by each participant was 4.8 ± 3.5. Complete VA data were available from 434/450 (96%) participants. Applying International Classification of

Table 3 Categorization of Visual Impairment of Study Participants, Applying ICD11

Impairment	Participants (*N* = 434)[a]	VISIBILITY (*n* = 104)	FOCUS (*n* = 330)
Visual impairment as per better eye			
No visual impairment, *n* (%)	320 (73.7)	20 (19.2)	300 (90.9)
Mean VA (logMAR)	0.09	0.14	0.09
Median (range) logMAR VA	0.08 (–0.09 to 0.30)	0.18 (–0.08 to 0.30)	0.08 (–0.09 to 0.30)
Age, years (mean ± *SD*)	79.2 ± 5.9	82.7 ± 10.4	80.0 ± 5.4
Female, *n* (%)	174 (54.4)	12 (60.0)	162 (54.0)
Mild visual impairment, *n* (%)	32 (7.4)	9 (8.7)	23 (7.0)
Mean VA (logMAR)	0.38	0.41	0.37
Median (range) logMAR VA	0.36 (0.32 to 0.50)	0.40 (0.32 to 0.50)	0.35 (0.32 to 0.49)
Age, years (mean ± *SD*)	81.1 ± 6.9	85.3 ± 8.2	79.4 ± 6.0
Female, *n* (%)	21 (65.6)	7 (77.8)	12 (52.2)
Moderate visual impairment, *n* (%)	33 (7.6)	26 (25.0)	7 (2.1)
Mean VA (logMAR)	0.81	0.83	0.73
Median (range) logMAR VA	0.78 (0.52 to 1.00)	0.84 (0.60 to 1.00)	0.62 (0.52 to 1.00)
Age, years (mean ± *SD*)	82.7 ± 10.2	82.4 ± 10.7	78.6 ± 4.2
Female, *n* (%)	23 (69.7)	14 (53.8)	6 (85.7)
Severe visual impairment, *n* (%)	49 (11.3)	49 (47.1)	0
Mean VA (logMAR)	1.92	1.92	
Median (range) logMAR VA	2.00 (1.08 to 2.30)	2.00 (1.08 to 2.30)	
Age, years (mean ± *SD*)	81.0 ± 11.7	82.2 ± 11.3	
Female, *n* (%)	35 (71.4)	36 (73.5)	
Visual impairment as per worse eye			
No visual impairment, *n* (%)	213 (49.1)	8 (7.7)	205 (62.1)
Mean VA (logMAR)	0.15	0.07	0.15
Median (range) logMAR VA	0.17 (–0.04 to 0.30)	0.01 (0.00 to 0.30)	0.17 (–0.04 to 0.30)
Age, years (mean ± *SD*)	78.7 ± 5.5	77.3 ± 10.5	78.8 ± 5.3
Female, *n* (%)	117 (54.9)	5 (62.5)	112 (54.6)
Mild visual impairment, *n* (%)	54 (12.4)	1 (1.0)	53 (16.0)
Mean VA (logMAR)	0.38	0.44	0.38
Median (range) logMAR VA	0.36 (0.32 to 0.49)	.	0.36 (0.32 to 0.49)
Age, years (mean ± *SD*)	80.2 ± 6.3	74	80.0 ± 6.7
Female, *n* (%)	31 (57.4)	1	25 (47.2)
Moderate visual impairment, *n* (%)	50 (11.5)	13 (12.5)	37 (11.2)
Mean VA (logMAR)	0.73	0.84	0.69
Median (range) logMAR VA	0.70 (0.52 to 1.00)	0.80 (0.60 to 1.00)	0.66 (0.52 to 1.00)
Age, years (mean ± *SD*)	80.9 ± 7.6	79.1 ± 11.7	78.6 ± 5.0
Female, *n* (%)	30 (60.0)	6 (46.2)	21 (56.8)
Severe visual impairment, *n* (%)	117 (27.0)	82 (78.8)	35 (10.6)
Mean VA (logMAR)	1.82	1.91	1.36
Median (range) logMAR VA	1.70 (1.08 to 2.30)	2.00 (1.08 to 2.30)	1.40 (1.10 to 1.70)
Age, years (mean ± *SD*)	81.0 ± 9.8	82.1 ± 11.2	78.5 ± 4.8
Female, *n* (%)	75 (64.1)	59 (72.0)	19 (54.3)

Note. ICD11 = International Classification of Diseases 11th Revision; logMAR = logarithm of the minimum angle of resolution; VA = visual acuity; FOCUS = Falls in Older people with Cataract: a longitudinal evalUation of impact and riSk; VISIBILITY = Vision Impairment Balance and Mobility.
[a]Complete VA data available from 434 participants.

Diseases 11th Revision and when classified by VA of the better eye, 74% of these participants (320/434) had no visual impairment, 7% (32/434) had mild, 8% (33/434) had moderate, and 11% (49/434) had severe visual impairment or blindness (Table 3). Participant demographic and clinical characteristics are presented in Table 4.

Participants' average SPPB total score was 8.19 ± 2.66. Figure 1a shows the mean total SPPB score for the nil (8.32 ± 2.63), mild (7.66 ± 2.95), moderate (8.85 ± 2.25), and severe (7.82 ± 2.59) visual impairment groups. The average total score for age-matched normative data (Vasunilashorn et al., 2009) was higher at 9.89 ± 3.22. Participants' average performance for each of the three SPPB components was 49.4 ± 12.04 s for standing balance, 0.86 ± 0.33 m/s for gait speed, and 0.32 ± 0.15 sit to stands per second for the 5TSTS test.

Multivariate Linear Regression Analysis

Three of the five multivariate models required transformation to normalize the distribution of data. The 5TSTS scores and number of steps per meter were log transformed, and the standing balance scores were squared. Both worse eye and better eye VA were found to be significantly associated with standing balance score (Table 5; Figure 1b); for every 0.1 increase in logMAR VA of the better eye (i.e., VA worsening by one logMAR line of letters), there was a reduction of 1.43 s of standing balance time. VA of the better eye was significantly associated with number of steps taken per meter (Table 5; Figure 1c). An increase of 0.11 steps taken per meter was seen for every 0.1 increase in logMAR VA of the better eye. No other significant associations between VA and physical performance were found (Table 5).

Discussion

In this cohort of older adults with compromised vision, VA was not found to be associated with overall physical performance but was independently associated with balance and the number of steps taken per meter walked. The average SPPB total score of our cohort was lower than that of age-matched norms (Vasunilashorn et al., 2009), in concordance with associations between vision impairment and poor physical performance reported elsewhere (Salive et al., 1994; West et al., 2002). The population-based studies by West et al. (2002) and Salive et al. (1994) that reported this association included all community-dwelling older adults. In the study by West et al. (2002), participants overall had a good level of vision (mean VA 20/40; 0.3 logMAR), whereas Salive et al. (1994) used self-reported functional blindness to categorize participants with severe vision impairment. The mean total SPPB score of age-matched community-dwelling adults were also higher than our "no visual impairment"

Table 4 Sociodemographic and Health Characteristics of Study Participants

Characteristic	Participants (*N* = 450)	VISIBILITY (*n* = 120)	FOCUS (*n* = 330)
Age (mean ± *SD*)	79 ± 7.4	82.4 ± 11	79 ± 5.4
Gender, *n* (%)			
Male	183 (40.7)	35 (29.2)	147 (44.8)
Female	267 (59.3)	85 (70.8)	182 (55.2)
Country of birth, *n* (%)			
Australia	251 (55.8)	89 (74.2)	161 (48.8)
Other	199 (44.2)	31 (25.8)	169 (51.2)
Language, *n* (%)			
English	387 (86.0)	109 (90.8)	277 (83.9)
Other	63 (14.0)	11 (9.2)	53 (16.1)
Residence type, *n* (%)			
Home	277 (61.6)	52 (43.3)	225 (68.2)
Granny flat	4 (0.9)	1 (0.8)	3 (0.9)
Unit	119 (26.4)	49 (40.8)	70 (21.2)
Independent living unit	22 (4.9)	13 (10.8)	9 (2.7)
Serviced apartment	3 (0.7)	3 (2.5)	0
Other	25 (5.6)	2 (1.7)	23 (7.0)
Living arrangement, *n* (%)			
Alone	169 (37.6)	71 (59.2)	98 (29.7)
Spouse only	168 (37.3)	27 (22.5)	141 (42.7)
Spouse and children	47 (10.4)	7 (5.8)	40 (12.1)
Child/children	32 (7.1)	5 (4.2)	27 (8.2)
Relatives/friends	29 (6.4)	6 (5.0)	23 (7.0)
Other	5 (1.1)	4 (3.3)	1 (0.3)
FCI score (mean ± *SD*)	4.9 ± 2.5	3.9 ± 2.0	3.5 ± 1.8
Total number of medications (mean ± *SD*)	4.8 ± 3.5	5.4 ± 3.3	4.6 ± 3.6
Fallen in past year, *n* (%)	195 (43.3)	66 (55.0)	129 (39.1)

Note. FCI = Functional comorbidity index; FOCUS = Falls in Older people with Cataract: a longitudinal evalUation of impact and riSk; VISIBILITY = Vision Impairment Balance and Mobility.

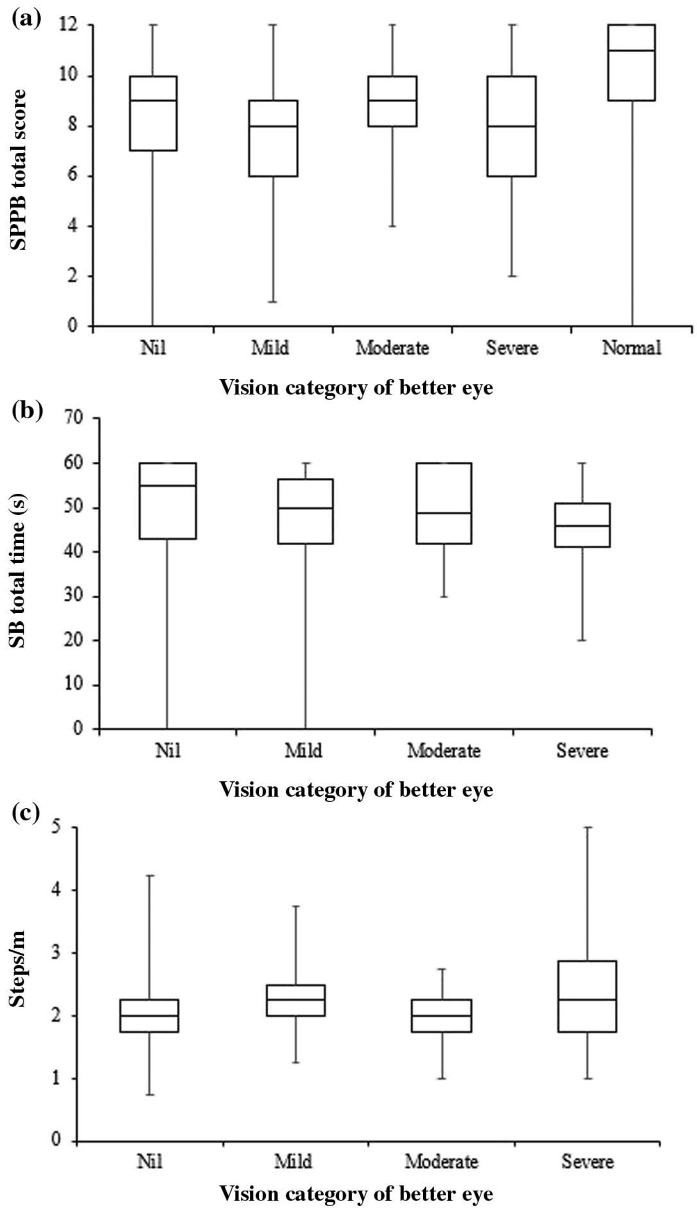

Figure 1 — (a) SPPB total score by vision category. Data have been compared with normative values of a community-dwelling population aged 65 years and older. VA levels of this population were not tested as this was not an inclusion criteria (Vasunilashorn et al., 2009). SPPB total scores range from 0 to 12 where a low score indicates poorer physical performance. (b) SB time by vision category. Lower scores (time in seconds) indicate worse balance. (c) Number of steps per meter by vision category. Higher scores (steps per meter) indicate shorter step length. All vision categories are according to better eye: nil (VA ≤ 0.3 logMAR), mild (0.3 < VA ≤ 0.5 logMAR), moderate (0.5 < VA ≤ 1.00), and severe (VA > 1.00 logMAR). Bars indicate Q3, median, and Q1 values, respectively; and whiskers indicate maximum/minimum values for each group. *Note.* SB = standing balance; SPPB = Short Physical Performance Battery; logMAR = logarithm of the minimum angle of resolution; VA = visual acuity.

group (Figure 1a; Vasunilashorn et al., 2009). This finding may be due to differences in populations whereby all our participants had some form of visual condition despite varying levels of VA, while the Vasunilashorn et al. (2009) population had no visual inclusion or exclusion criteria.

It has been proposed that poor physical performance in vision impaired older adults occurs due to reduced physical activity (Nguyen, Arora, Swenor, Friedman, & Ramulu, 2015). Fear of falling may cause activity restriction and has been linked with reduced physical activity in a low vision population (Donoghue et al., 2014). Several studies have found visual field defects, particularly in the periphery and lower field, to be associated with higher frequency of falls compared with central vision loss (Freeman et al., 2007; Patino et al., 2010). A notable limitation of the present study is that high-contrast VA was used as the measure of vision, resulting in assessment of central vision only. Other measures of functional vision, such as visual field and CS, have also been more consistently linked with aspects of physical performance (Lord & Menz, 2000) and falls risk (de Boer et al., 2004).

A significant relationship was found between VA of either eye and standing balance in our cohort, that is, the poorer the VA, the worse the standing balance performance. Impaired vision has been repeatedly shown to be predictive of balance, though most commonly in laboratory settings (Chen et al., 2012; Lee & Scudds, 2003; Lord & Menz, 2000). Various measures of balance, including the Berg balance test (Lee & Scudds, 2003), perturbed double-leg stance (Chen et al., 2012), and variations of the standing balance test (Salive et al., 1994), have all shown to be significantly impacted by vision. Lord et al., however, reported that vision was only predictive of balance on (often more challenging) compliant surfaces (e.g., foam; Lord & Menz, 2000). The consensus between our findings and those of previous studies, despite substantial differences in methodology, serves to strengthen the evidence base linking vision and balance in both familiar and unfamiliar environments. Balance is thought to be partly governed by visual cues, particularly when proprioceptive information from the lower limbs is reduced (Lord & Menz, 2000). This suggests that it may be more dependent on image clarity and steady fixation, potentially explaining why a significant association has been found between VA and balance but not overall physical performance.

Poorer VA of the better eye was also associated with a greater number of steps taken per meter in our participants. This is in keeping with findings that indicate that older people (Marigold & Patla, 2008) and people with low vision or blindness (Gazzellini et al., 2016; Hallemans, Ortibus, Truijen, & Meire, 2011; Nakamura, 1997) tend to take shorter steps. Some literature suggests that step length is impacted primarily by defects of the lower and peripheral visual field (Hallemans, Ortibus, Meire, & Aerts, 2010; Marigold & Patla, 2008). The proposed mechanism is a lack of anticipatory control mechanisms from reduced or absent sight (Gazzellini et al., 2016; Nakamura, 1997). Given heightened awareness of central vision loss, participants here may have been less confident and felt the need to be more cautious, therefore, adapting their gait accordingly. Similar gait adaptations have been shown in sighted people who were blindfolded while walking (Hallemans et al., 2009).

Other aspects of physical performance, including gait speed and lower limb strength, were not found to be associated with VA in this study. Existing literature on the impact of VA on gait speed shows mixed results (Klein et al., 1998; Klein et al., 2003; Salive et al., 1994; West et al., 2002) and indicates that it is more reliant on peripheral vision through identification of hazards in the environment (West et al., 2002). As we were unable to use visual field data in this study, a correlation of this kind could not be confirmed and this is a limitation of this study. In contrast, lower limb strength has been consistently shown to not have an association with VA (Chen et al., 2012; Donoghue et al., 2014; Lee & Scudds, 2003; West et al., 2002), nor has it been directly correlated

Table 5 Multivariate Analysis of Associations Between Monocular VA as a Continuous Variable and Performance in the SPPB

	Total SPPB score		Gait speed		Number of steps/m		Standing balance[c]		Sit to stand[b]	
Multivariate models[a]	**β**	***p* value**	**β**	***p* value**	**β**	***p* value**	**β**	***p* value**	**β**	***p* value**
VA better eye	–0.015	.45	–0.001	.51	.11	**.0048**	–1.43	**.0058**	1.14	.09
VA worse eye	0.004	.81	0.003	.11	.1	.43	–1.36	**.0035**	1.12	.08

Note. Bold values are those which show a significant *p*-value <.05. β = beta coefficient as parameter estimate, represents change per reduction in VA of one logarithm of the minimum angle of resolution line of letters; SPPB = Short Physical Performance Battery; steps/m = steps per meter; VA = visual acuity; analyzed as a continuous variable, *N* = 434.

[a]Multivariate models contained variables with <3% missing data. Covariates included in these models were age, gender, Functional Comorbidity Score, and number of medications. [b]The exponential of beta coefficients for number of steps/m and sit to stand was taken to reverse transformation. [c]The square root of beta coefficient for standing balance was taken to reverse transformation.

with any particular aspect of vision (Donoghue et al., 2014; West et al., 2002).

Secondary analysis of cross-sectional data can impose limitations. In this case, the available data contained a limited visual assessment. Peripheral vision has been shown to be predictive of falls risk (Freeman et al., 2007; Lamoureux et al., 2010; Patino et al., 2010), balance (Lord & Menz, 2000), mobility (West et al., 2002), and gait speed (Marigold & Patla, 2008); however, we were unable to use visual field data due to large amounts of missing data and inconsistencies in how visual fields were assessed in each study. Future studies should include more broad measures of functional vision, specifically visual field and CS. They should look to compare physical performance in varying types of visual impairment, such as central and peripheral vision loss, using a quantifiable and standardized measure such as the SPPB. The impact of long standing and acquired vision loss on physical performance should also be investigated as the period of adaptation may be of relevance.

While most participants had no or mild visual impairment, our study was able to assess physical performance in a large sample of older adults across the spectrum of VA. The SPPB is a standardized, objective measure of key components of physical performance that have been found to be predictive of increased falls risk (Veronese et al., 2014); loss of independence (Volpato et al., 2010); reported disability in activities of daily living (Guralink et al., 1994); and hospitalization (Penninx et al., 2000). These measures allow us to determine the potential physical implications of reduced VA within this high-risk population and therefore inform a more targeted management plan. We were able to show that overall SPPB score in this cohort, where all had some form of visual condition, was lower than that typical of aged-matched community-dwelling adults (Vasunilashorn et al., 2009). We also found that both balance and step length were reduced with worsening VA. Clinicians working with older adults should be mindful that vision loss may be accompanied by adaptations to physical activity and movement (Donoghue et al., 2014; Ramulu et al., 2012). A program that allows older adults with vision impairment to safely maintain a healthy level of physical activity and therefore mitigate their risks of falls should focus on balance and gait skills. While vision impairment as classified by VA only cannot be considered the sole determinant of physical limitations, the results of this study indicate that this measure is of significance for inclusion criteria in such programs.

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