Motion-Detection Threshold and Measures of Balance in Older Adults: The SEE Project

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Purpose. The aim of this study was to identify the visual factors associated with various levels of balance ability in a population-based study of older adults.

Methods. Data for this analysis came from the third round of the Salisbury Eye Evaluation population-based cohort study (1505 individuals). Measures of visual function including acuity, contrast sensitivity, visual fields, and motion detection were obtained. Balance was assessed by determining if participants could complete a series of timed stands designed to increase in difficulty. The outcome was an unsuccessful stand. Analyses were performed using logistic regression with generalized estimating equations with stand type as an indicator variable.

Results. In a model containing all vision variables, those with worse motion-detection threshold were more likely to have an unsuccessful tandem stand (odds ratio [OR] = 1.56, 95% CI: 1.13–2.15) and soleo stand (on one foot of choice with eyes open and arms out; OR = 3.08, 95% CI: 1.57–6.06) while those with worse visual field were more likely to have an unsuccessful tandem stand (OR = 1.22, 95% CI: 1.08–1.38) after adjustment. Furthermore, the relationship between motion-detection threshold and an unsuccessful stand was stronger for the most difficult stand on one foot (the soleo stand) ($P = 0.02$).

Conclusions. Problems with balance in older adults may be due, in part, to decreased ability to detect small movements and/or visual field reduction. (*Invest Ophthalmol Vis Sci.* 2008; 49:5257–5263) DOI:10.1167/iovs.07-1106

The visual system, acting together with the somatosensory and vestibular systems, is important in the maintenance of balance. Studies have demonstrated the importance of vision to balance by finding that the ability to maintain steady posture is worse with eyes closed compared to eyes open.[1-3] As adults age, the visual system is thought to play a greater role in the maintenance of balance.[2] However, the onset of age-related eye disease may leave some older adults more vulnerable to balance problems. Poor balance is associated with the risk of falling in older adults.[4-6] Older adults who fall are at greater risk of hospitalization,[7] nursing home admission,[7,8] and death.[7,9,10] Thus, maintenance of balance is important, and factors that are associated with poor balance need to be identified so intervention strategies can be appropriately targeted.

Studies with small sample sizes have identified visual function measures that are associated with balance. Visual acuity was found to be associated with balance in two studies,[11,12] and contrast sensitivity and stereopsis were found to be important in maintaining postural stability on compliant surfaces in another study.[13] In one study of 13 elderly subjects, simulated cataract and refractive blur resulted in worse postural stability, which the researchers interpreted as the effect of reduced contrast sensitivity on balance.[14] In two other small-sample studies, Paulus et al.[15] and Turano et al.[16] showed that balance (measured by a reduction in the anterior-posterior sway) was strongly associated with the ability to detect small movements (motion-detection thresholds).

Balance-associated vision variables were also identified in a population-based study of 782 older adults. West and colleagues[17] identified the vision variables that were associated with the ability to maintain a full tandem stance (one foot behind the other) for at least 10 seconds. Binocularity, visual field integrity, and adaptation were associated with success on the tandem stance test. When analyzed within a multivariate model, visual field integrity was the only vision variable significantly associated with the tandem stance.

In the West et al. study,[17] balance was assessed solely on the basis of whether or not a tandem stance could be maintained for 10 seconds. The association between vision and balance in less-difficult stances heretofore had not been examined in large-scale studies with older adults. Moreover, motion detection, which was strongly associated with balance in the small-sample studies and which declines with age[18] and many ophthalmological diseases,[16,19–21] was not tested in the West et al. study.

The aim of this study was to identify the visual function predictors of balance across a range of test difficulty and to determine the strength of association in a population-based study of older adults. Predictors of balance may be different, depending on whether or not the stand is difficult. Evidence for this hypothesis comes from a study by Lord et al.[13] that found that vision variables were only associated with postural sway on a compliant surface whereas they were not associated with sway on a firm surface. Therefore, we hypothesized that as the difficulty of the balance test increased, so would the strength of association between vision and balance.

Methods

Study Population

Data for this analysis came from the Salisbury Eye Evaluation project (SEE), a prospective cohort study of 2520 adults begun in 1993 to study the impact of visual function on physical function. Eligibility criteria at baseline included age between 65 to 84 years, residence near Salisbury, non-institutionalization, ability to communicate, and a score greater than 17 on the Mini Mental State examination. Further description of the study can be found elsewhere.[22,23] The Johns Hopkins University Joint Committee on Clinical Investigation approved the study. The tenets of the Declaration of Helsinki were followed. Informed consent was obtained for all participants.

This analysis used data from the third round to benefit from additional visual function tests that were performed. The round was completed by 1505 individuals (86% of those still alive), which was on

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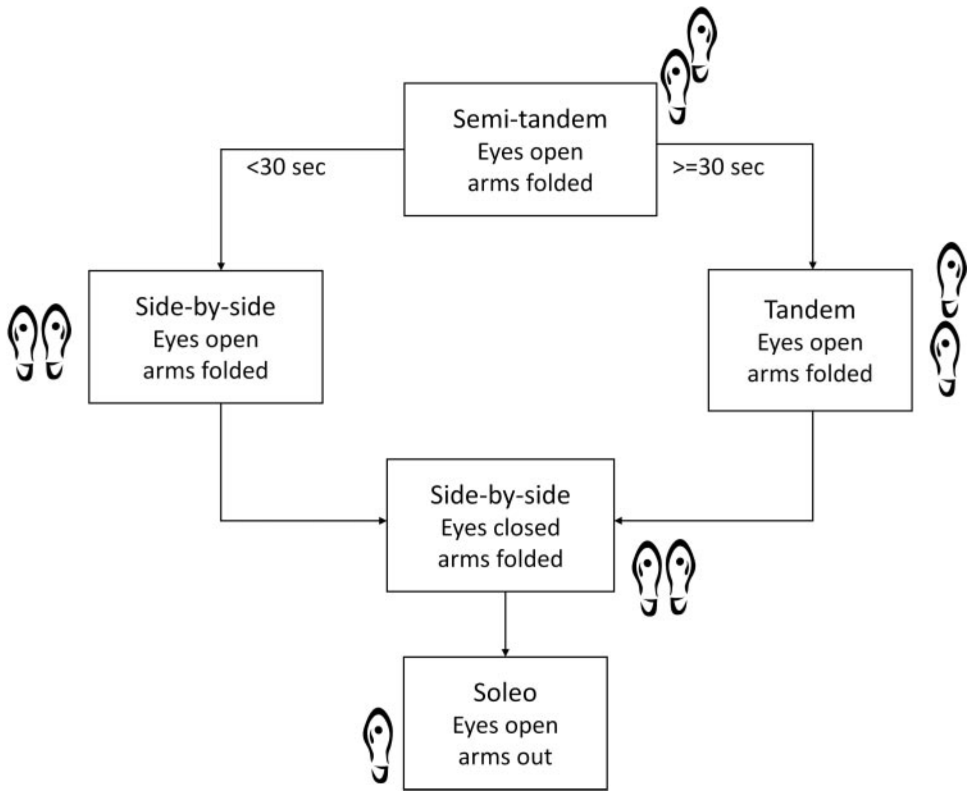

FIGURE 1. Progression of timed stand positions in Salisbury Eye Evaluation.

average six years after the baseline examination. This cohort ranged in age from 72 to 92 years old.

Visual Function

Visual function was tested at a SEE clinic using standardized procedures. Presenting (habitual) binocular visual acuity was measured using the Early Treatment of Diabetic Retinopathy Study (ETDRS) chart and was then converted to logMAR (log minimum angle resolution) units.[24] Contrast sensitivity was measured using a Pelli-Robson chart for each eye with measures for the better eye used in analyses. Visual field was measured monocularly using a Humphrey 81-point single threshold (24dB) full-field (60°) screen for each eye, as has been described previously.[25] Binocular visual fields were estimated from a composite of the more sensitive of the two visual field locations for each eye.[26] A total of 96 visual field locations composed the binocular visual field. Motion-detection thresholds were measured in a manner similar to that described previously in Turano et al.[20] Briefly, the participant viewed a short movie (1.5 seconds composed of 3 frames) of 50 dots moving in toto across the screen in one of four directions (left, right, up, or down). The dots were displayed on a high-resolution monitor (IKEGAMI, 19-inch diagonal, P104 phosphor, 60 Hz non-interlaced; Ikegami Electronics, Inc., Maywood, NJ, USA) generated by an IMAGRAPH 1280 × 1024 × 8 bits graphics board (IMAgraph Corp., Woburn, MA, USA). A 10°-diameter circular mask attached to the face of the monitor restricted the area of retinal stimulation. The participant's task was to view the movie and move the joystick in the same direction that the dots moved. The distance the dots moved (displacement magnitude) was constant across all dots but varied from trial-to-trial depending on the participant's previous response according to a three-down, one-up staircase procedure; displacement magnitude decreased after three consecutive correct responses and increased after a single incorrect response. Testing was terminated after 8 reversals, wherein a reversal is defined as when the displacement changes from increasing to decreasing or vice versa. Motion threshold, defined as the smallest displacement required for the participant to correctly determine the motion direction, was calculated as the mean of the displacements at the reversal points, stated in units of visual angle (arcminute). The scores were converted to log threshold to achieve greater spread in the scores.

Balance Assessment

Balance was assessed by timing the participants' ability to maintain balance with their feet in one of four stand positions (see Fig. 1). Two of the positions (semi-tandem and side-by-side) were ones used in the Frailty and Injuries Cooperative Studies of Intervention Techniques (FICSIT) trials[27] and the soleo position was similar to the one-legged stance used in FICSIT-4.[28] These stand positions have been validated as measures of balance in the FICSIT trials.[28] A study by Vellas et al.[5] found that a one-legged stance test of balance predicted injurious falls.

The participants were asked to hold their balance for 30 seconds in the series of stand positions which were designed to increase in the level of difficulty. First, participants were asked to stand in a *semi-tandem* position. The semi-tandem position involved standing with the big toe of one foot placed at the side of the heel of the other foot with eyes open and arms folded across the chest. If the participant could hold the semi-tandem stand for 30 seconds, they were then asked to stand in a *tandem* position. If they did not hold the semi-tandem for 30 seconds, they were asked to stand in a *side-by-side stand* with eyes open. Participants were then asked to stand with feet side-by-side, eyes closed, and arms folded (this stand was not used in this analysis since the aim of the study was to identify the vision factors associated with balance ability). Finally, participants were asked to stand in the *soleo* position (on one foot of their choice with eyes open and arms out). The participants performed the stands in a small, carpeted room that contained a desk, bookcase, table, chairs, and a carpeted false stairwell. A study coordinator stood near them in case they lost their balance. They were not given specific instructions on where to look.

Outcomes

The outcome for this analysis was whether an individual was unsuccessful on a stand (yes or no). The outcome was measured in four stand positions that varied in their degree of difficulty. A stand was defined as unsuccessful if the participant was unable to hold it for 30 seconds without moving the feet from position or holding on to a support. A stand was also defined as unsuccessful if the participant or technician did not feel the stand was safe to attempt. A stand was defined as successful if it was held for 30 seconds. A stand was defined as a missing value if the participant could not understand the instructions or if the participant refused for reasons unrelated to safety concerns. If the semi-tandem stand was held for 30 seconds (successful), we considered the side-by-side with eyes open stand to be successful, even though the participant was not asked to hold this stand. If the participant could not hold the semi-tandem stand for 30 seconds (unsuccessful), we considered the tandem stand to be unsuccessful as well, even though the participant was not asked to hold this stand.

Questionnaire and Clinic Examination

An interviewer-administered questionnaire was given to participants. Information was obtained on demographic information and medical history. Participants were asked a detailed health questionnaire that included questions on whether a physician had diagnosed them with any of 15 medical conditions. In addition, weight and height were measured by trained observers in the clinic. Body mass index was calculated by dividing weight (kg) by the square of height (m^2).

Statistical Analysis

To determine the association between vision and an unsuccessful stand, we used a logistic regression model with repeated measures. For each subject, there were 4 outcomes: unsuccessful (=1) or successful (=0) on the side-by-side stand, on the semi-tandem stand, on the tandem stand, and on the soleo stand. Each outcome was modeled against the type of stand being held, vision measures, and demographic and physical factors. Generalized estimating equations[29] were used to account for the repeated measures. The demographic and physical factors that were included in the regression models included age, sex, race, body mass index, and number of comorbidities. These factors were chosen because of our a priori assumption that they would be associated with both vision and balance. Age, body mass index, and number of comorbidities were modeled as continuous variables. Squared terms and splines were added to the models to check for non-linearity. Body mass index (BMI) was best modeled using a spline term at 30 kg/m^2 to account for non-linearity.

Interactions between type of stand and vision measures were included in the models to determine whether vision was acting differently depending on the type of stand being held. Eq. 1 describes the model for visual acuity.

Equation 1: Example Using Visual Acuity

log (odds of an unsuccessful stand)

$$= \beta_0 + \beta_{sem}x_{sem} + \beta_{tan}x_{tan} + \beta_{sol}x_{sol} + \beta_{va}y_{va} + \beta_{va\times sem}x_{sem}y_{va} + \beta_{va\times tan}x_{tan}y_{va} + \beta_{va\times sol}x_{sol}y_{va} + \ \ldots \quad (1)$$

where x_{sem} is the indicator variable for semi-tandem stand, x_{tan} is the indicator variable for tandem stand, x_{sol} is the indicator variable for soleo stand, y_{va} is the visual acuity, and where an unsuccessful stand was defined as 1 if the stand was not attempted for safety reasons or was not held for 30 seconds, or 0 if it was held for 30 seconds. The y variables were the vision measures, as continuous measures. The ellipses indicate other demographic and physical factors included in the model (e.g., age, sex, BMI). High positive estimates of β indicate a strong relationship of the variable with an unsuccessful stand; high negative estimates of β indicate a strong relationship with a successful stand. The example shown includes interaction terms.

Besides the interactions included between vision and stand type, interactions were also examined between other covariates and stand positions, although these interaction terms were excluded from the model if not statistically significant since they were not part of our hypothesis.

We examined results from models with each vision measure separately, and then created a model with all four vision measures to determine whether one type of vision was more important than the others.

Results

There were 1505 participants in round three of SEE; of these, 1460 (96.3%) participated in the stand procedure. Forty-five individuals did not perform the first stand for reasons unrelated to safety concerns. These reasons included physical limitations or pain, or problems in comprehension. Seventy-two percent (1055/1460) of participants were able to successfully hold the semi-tandem stand for 30 seconds. Individuals who did not attempt the semi-tandem stand because of safety concerns ($n = 237$) were older, more likely to be women, African-American, to have a higher body mass index, more comorbid conditions, worse acuity, contrast sensitivity, visual field, and motion-detection threshold than those who passed the semi-tandem stand ($P < 0.05$; Table 1). The soleo stand was the most difficult stand for participants to complete with 5.6% (81/1445) of participants able to hold it for 30 seconds.

Of the 1460 participants who participated in the stand procedure, 1188 (81.4%) had complete vision (visual acuity, contrast, visual field, and motion threshold scores) and physical measures (BMI, number of comorbid conditions). Of the 272 who were missing vision or physical measures, 205 (75.4%) were missing either the visual field test or the motion threshold test. The logistic model results presented below only included the 1188 subjects with complete data.

In a multiple logistic regression model that included indicator variables for stand position, the following variables were associated with an unsuccessful completion of a stand (Table 2): older age (OR = 1.16, 95% CI: 1.13–1.19); female sex (OR = 2.38, 95% CI: 1.90–2.97); African-American race compared to Caucasian race (OR = 1.30, 95% CI: 1.00–1.68); greater BMI (only for those with BMI >30 kg/m^2; OR = 1.14, 95% CI: 1.09–1.19); and more comorbidities (OR = 1.24, 95% CI: 1.17–1.31 per 1 additional comorbid condition). By far the most important predictor of an unsuccessful stand was the type of stand being held: the semi-tandem, tandem, and soleo stands were significantly more difficult than the side-by-side stand.

Each vision variable was first examined in separate regression models in Table 3. Those with worse acuity were more likely to unsuccessfully complete the tandem (OR = 1.13, 95% CI: 1.03–1.25) and soleo stands (OR = 1.29, 95% CI: 1.03–1.62) after adjusting for age, sex, race, BMI, and number of comorbidities (Table 3). Worse acuity appeared to have greater effect on the stand the more difficult it became since the odds ratios get progressively further from one. However, none of the odds ratios were statistically significantly different from the odds ratio for the side-by-side stand (*P*-values for difference from side-by-side stand >0.05).

Worse contrast sensitivity was also associated with an unsuccessful stand after adjustment (Table 3). Those with worse contrast sensitivity were more likely to be unable to complete the side-by-side stand (OR = 1.06, 95% CI: 1.01–1.12), the tandem stand (OR = 1.10, 95% CI: 1.04–1.16), and soleo stand (OR = 1.22, 95% CI: 1.09–1.35). The relationship between

Table 1. Characteristics of Individuals by Performance on Semi-Tandem Stand

Variable	Category	Did Not Attempt Semi-Tandem† $n = 237$	Failed Semi-Tandem (<30 seconds) $n = 168$	Passed Semi-Tandem (30 seconds) $n = 1055$	Chi-square P*
Age	70–74	38 (16.0)	36 (21.4)	380 (36.0)	<0.0001
	75–79	75 (31.7)	56 (33.3)	418 (39.6)	
	80–84	74 (31.2)	49 (29.2)	181 (17.2)	
	85+	50 (21.1)	27 (16.1)	76 (7.2)	
Gender	Men	70 (29.5)	47 (28.0)	489 (46.4)	<0.0001
	Women	167 (70.5)	121 (72.0)	566 (53.6)	
Ethnicity	Caucasian	160 (67.5)	131 (78.0)	818 (77.5)	0.004
	African-American	77 (32.5)	37 (22.0)	237 (22.5)	
BMI	Missing	32 (13.5)	4 (2.4)	12 (1.1)	
	14–24	56 (23.6)	63 (37.5)	330 (31.3)	0.002
	25–29	66 (27.8)	58 (34.5)	422 (40.0)	
	30+	83 (35.0)	43 (25.6)	291 (27.6)	
Comorbid conditions	Missing	3 (1.3)	1 (0.6)	7 (0.7)	
	0–1	19 (8.0)	16 (9.5)	209 (19.8)	<0.0001
	2–3	80 (33.8)	78 (46.4)	488 (46.3)	
	4–12	135 (57.0)	73 (43.4)	351 (33.3)	
Visual acuity	Missing	1 (0.4)	1 (0.6)	3 (0.3)	
	20/20 or better	54 (22.8)	61 (36.3)	530 (50.2)	<0.0001
	>20/20 to 20/40	147 (62.0)	85 (50.6)	453 (42.9)	
	Worse than 20/40	35 (14.8)	21 (12.5)	69 (6.5)	
Contrast sensitivity (letters correct)	Missing	6 (2.5)	0 (0.0)	7 (0.7)	
	0–29	50 (21.1)	19 (11.3)	80 (7.6)	<0.0001
	30–34	116 (49.0)	85 (50.6)	392 (37.2)	
	35+	65 (27.4)	64 (38.1)	576 (54.6)	
Visual fields (points missed)	Missing	81 (34.2)	21 (12.5)	66 (6.3)	
	0–19	47 (19.8)	37 (22.0)	435 (41.2)	<0.0001
	20–39	66 (27.8)	87 (51.8)	433 (41.0)	
	40–59	23 (9.7)	17 (10.1)	82 (7.8)	
	60+	20 (8.4)	6 (3.6)	39 (3.7)	
Motion threshold‡ (arcmin)	Missing	80 (33.8)	20 (11.9)	81 (7.7)	
	0.5–1.9	23 (9.7)	28 (16.7)	297 (28.2)	<0.0001
	2–2.9	47 (19.8)	41 (24.4)	346 (32.8)	
	3+	87 (36.7)	79 (47.0)	331 (31.4)	

* Chi-square test done on non-missing categories.
† Did not complete semi-tandem stand for safety reasons; we coded these individuals as having failed the stand in regression analyses.
‡ Motion threshold presented in Table 1 but log (motion threshold) used in regression analyses.

contrast sensitivity and an unsuccessful stand was greater for the soleo stand ($P = 0.04$, compared to side-by-side stand).

Worse visual field was associated with an unsuccessful stand after adjustment for age, sex, race, BMI, and number of comorbidities (Table 3). Those with worse visual field were more likely to be unsuccessful on the side-by-side stand (OR = 1.21, 95% CI: 1.06–1.37, per 10 points missed), tandem stand (OR = 1.31, 95% CI: 1.17–1.47), and soleo stand (OR = 1.41, 95% CI: 1.10–1.82). The relationship between visual field and an unsuccessful stand was less for the semi-tandem stand compared to the side-by-side stand ($P = 0.05$ compared to side-by-side stand).

Table 2. Non-vision Factors Associated with an Unsuccessful Stand in Logistic Regression Model

Variables	Odds Ratio	95% CI	P
Age, per 1 year	1.16	[1.13–1.19]	<0.0001
Gender			
Female	2.38	[1.90–2.97]	<0.0001
Race			
African-American	1.30	[1.00–1.68]	0.05
Stand type			
Side-by-Side	1.00	—	—
Semi-tandem	4.95	[3.98–6.17]	<0.0001
Tandem	62.2	[47.2–81.9]	<0.0001
Soleo	449.8	[321.6–629.1]	<0.0001
BMI			
<30 kg/m²	1.00	[0.97–1.04]	0.93
≥30 kg/m²	1.14	[1.09–1.19]	<0.0001
Comorbid conditions	1.24	[1.17–1.31]	<0.0001

Table 3. Univariate Relationship between Visual Acuity, Contrast Sensitivity, Visual Fields, and Motion-Detection Threshold and the Odds of an Unsuccessful Stand Adjusting for Age, Sex, Race, BMI, and Number of Comorbid Conditions

Vision Type	Stand	Odds Ratio	95% CI	*P*	*P* for Difference from Side-by-side
Visual acuity, per 0.1 logMAR	Side-by-side	1.08	[0.98–1.20]	0.12	—
	Semi-tandem	1.09	[1.00–1.19]	0.06	0.95
	Tandem	1.13	[1.03–1.25]	0.01	0.53
	Soleo	1.29	[1.03–1.62]	0.03	0.16
Contrast sensitivity, per 1 letter incorrect	Side-by-side	1.06	[1.01–1.12]	0.01	—
	Semi-tandem	1.04	[0.98–1.09]	0.17	0.19
	Tandem	1.10	[1.04–1.16]	0.0003	0.39
	Soleo	1.22	[1.09–1.35]	0.0005	0.04*
Visual field, per 10 points missed	Side-by-side	1.21	[1.06–1.37]	0.003	—
	Semi-tandem	1.08	[0.97–1.20]	0.15	0.05*
	Tandem	1.31	[1.17–1.47]	<.0001	0.30
	Soleo	1.41	[1.10–1.82]	0.007	0.26
Log motion threshold, per unit threshold increase	Side-by-side	1.47	[1.05–2.07]	0.03	—
	Semi-tandem	1.38	[1.03–1.85]	0.03	0.71
	Tandem	1.94	[1.45–2.60]	<.0001	0.20
	Soleo	4.15	[2.21–7.79]	<.0001	0.004*

* Relationship between unsuccessful stand and vision measure is different by type of stand ($P < 0.05$).

Finally, worse log motion-detection threshold scores were associated with an unsuccessful stand after adjustment (Table 3). Those with worse motion-detection threshold were more likely to be unsuccessful on the side-by-side stand (OR = 1.47, 95% CI: 1.05–2.07), the semi-tandem stand (OR = 1.38, 95% CI: 1.03–1.85), the tandem stand (OR = 1.94, 95% CI: 1.45–2.60), and the soleo stand (OR = 4.15, 95% CI: 2.21–7.79). The relationship between motion-detection threshold and an unsuccessful stand was stronger for the soleo stand compared to side-by-side stand (P = 0.004).

We then examined a model simultaneously including visual acuity, contrast sensitivity, visual field, and motion-detection threshold to determine the independent relationships of the vision variables (Table 4). Worse motion-detection threshold scores were associated with higher odds of an unsuccessful tandem stand (OR = 1.56, 95% CI: 1.13–2.15) and the soleo stand (OR = 3.08, 95% CI: 1.57–6.06). The relationship between motion-detection threshold and the soleo stand was stronger than that between motion-detection threshold and the side-by-side stand (P = 0.02). Visual field was associated with higher odds of an unsuccessful tandem stand (OR = 1.22, 95% CI: 1.08–1.38). Visual acuity and contrast sensitivity were no longer associated with being unsuccessful on any of the stands. Other covariates that were statistically significantly associated with unsuccessful stands were body mass index ≥ 30 kg/m^2 and a greater number of comorbidities (Table 4).

Discussion

We have found that older adults who had visual field loss or worse motion-detection threshold scores had a worse ability to successfully perform a stand. Although visual acuity and contrast sensitivity were associated with unsuccessful stands in separate models, estimates for these measures were greatly

Table 4. Multivariate Relationship between Vision Variables and the Adjusted Odds of an Unsuccessful Stand, Adjusted for Age, Sex, and Race

Vision Type	Stand	Odds Ratio	95% CI	*P*	*P* for Difference from Side-by-side
Visual Acuity, per 0.1 logMAR	Side-by-side	0.99	[0.83–1.17]	0.90	—
	Semi-tandem	1.05	[0.94–1.17]	0.38	0.43
	Tandem	1.01	[0.90–1.13]	0.87	0.84
	Soleo	1.07	[0.83–1.37]	0.60	0.61
Contrast sensitivity, per 1 letter incorrect	Side-by-side	1.02	[0.93–1.12]	0.60	—
	Semi-tandem	1.00	[0.93–1.08]	0.95	0.53
	Tandem	1.03	[0.96–1.10]	0.39	0.93
	Soleo	1.09	[0.96–1.23]	0.17	0.42
Visual field, per 10 points missed	Side-by-side	1.16	[0.99–1.37]	0.08	—
	Semi-tandem	1.04	[0.92–1.18]	0.53	0.12
	Tandem	1.22	[1.08–1.38]	0.002	0.64
	Soleo	1.16	[0.87–1.56]	0.31	0.99
Log motion threshold, per unit threshold increase	Side-by-side	1.21	[0.75–1.96]	0.43	—
	Semi-tandem	1.28	[0.91–1.79]	0.15	0.81
	Tandem	1.56	[1.13–2.15]	0.006	0.36
	Soleo	3.08	[1.57–6.06]	0.001	0.02
Body mass index, per 1 kg/m^2	<30 kg/m^2	1.01	[0.98–1.05]	0.51	—
	≥30 kg/m^2	1.14	[1.09–1.18]	<0.0001	0.0005*
Number of Comorbidities		1.21	[1.14–1.29]	<0.0001	

* P-value for difference from BMI < 30.

attenuated and no longer statistically significant with motion-detection threshold and visual field in the model. Our finding in a large population of older adults that visual field size was important for postural stability confirms previous research.[30–33] Past studies have shown that postural sway is larger in conditions of reduced visual fields. Not only older adults[33] but young adults[32] are less stable under conditions of restricted visual field and unreliable or limited somatosensory information.

Our population-based results also confirm previous research that showed that motion-detection threshold was important for postural stability.[15,16] When standing, the body undergoes small oscillatory movements which result in small retinal-image movements. Detection of the retinal-image movements cues postural compensation. Turano et al.[16] found that motion-detection threshold explained 45% of the variance in the contribution of vision to anterior-posterior sway in a group of people with central visual field loss while the addition of visual acuity and contrast sensitivity to the model did not explain additional variability. Furthermore, our data showed that the relationship between motion-detection threshold and an unsuccessful stand was stronger for the most difficult stand on one foot (the soleo stand). This implies that motion detection may be less important for easier stands but plays a greater role in postural stability in more difficult stands, such as when input from the somatosensory system is reduced by having only one foot on the ground instead of two. This confirmed our hypothesis that the visual predictors of an unsuccessful stand can differ depending on the difficulty of the stand and is consistent with similar findings by Lord et al.[13]

To our knowledge, this analysis is the first large-scale study using population-based data to examine how visual function including motion-detection threshold is related to the ability to maintain balance. Strengths of this analysis include the large number of older people, the use of population-based data, the evaluation of various stands that differed in degree of difficulty, and the simultaneous examination of multiple measures of visual function that were evaluated using standardized tests.

A limit of this analysis is the cross-sectional nature of the observational data, as opposed to an experimental study, which limits our ability to make causal inferences. However, we have accounted for variables that we thought would confound the relationship between vision and balance such as demographic factors, body mass index, and number of comorbidities. Another limit is that some individuals had missing data for the stands ($n = 45$). These individuals were older and had a greater number of comorbidities indicating they may have been more likely to have had balance problems compared to those who did not have missing data. Since they also had worse vision, our estimates of the relationship between vision and stand success may be conservative due to their exclusion.

In summary, we found that motion-detection threshold decrements are associated with poor balance Since poor balance is a risk factor for falling,[4–6,13] we suggest that motion-detection threshold decrements may increase risk of falls, and are worth further investigation.

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