Dual Tasking and Balance in Those With Central and Peripheral Vision Loss

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Submitted: March 14, 2013
Accepted: July 2, 2013
Citation: Kotecha A, Chopra R, Fahy RTA, Rubin GS. Dual tasking and balance in those with central and peripheral vision loss. Invest Ophthalmol Vis Sci. 2015;54:5408–5415. DOI:10.1167/iovs.13-12026

Purpose. To investigate the effects of a secondary task on standing balance in patients with glaucoma or AMD compared with age-similar control subjects.

Methods. Twelve AMD, 12 glaucoma, and 12 control participants underwent posturography under two standing conditions (eyes open on a firm or foam-rubber surface) and two tasks: quiet standing and undertaking a mental arithmetic task. Center of foot-pressure average displacement (root mean square [RMS]; in millimeters) was calculated.

Results. The mean (SD) age of the participants in each group was as follows: controls 66.2 (6.4) years, glaucoma 69.2 (4.3) years, and AMD 72.2 (5.3) years. There were significant differences in RMS between controls and AMD patients when undertaking the mental arithmetic task standing on the firm surface (mean difference [SE]: control versus AMD = 2.8 [0.8] mm, P = 0.005). There were significant differences between controls and AMD patients when undertaking the mental arithmetic task on the foam surface, with the difference between controls and glaucoma patients approaching significance (mean difference [SE]: control versus AMD = 3.1 [0.9] mm, P = 0.005; control versus glaucoma = 2.2 [0.9] mm, P = 0.06).

Conclusions. Postural instability increases with the addition of a secondary task in older persons, which may put them at greater risk of falls. Patients with central losses exhibit greater instability with the addition of a secondary task, particularly during somatosensory perturbations. The negative effects of secondary tasks on balance control in those with peripheral visual losses become more apparent under somatosensory perturbations.

Keywords: balance, glaucoma, age-related macular degeneration, secondary task

Balance control is not a completely automatic process but rather an attention-demanding perceptual-motor task.1–3 Information from the sensory systems needs to be integrated and processed efficiently to ensure that there are appropriate motor responses to stabilize the body in the environment.

Dual-tasking is the ability to do two things at once and represents the ability of the brain to coordinate and prioritize tasks that have different attention demands.

It has been suggested that there is an increased risk of falling when attentional resources are divided between maintaining postural stability and carrying out daily tasks simultaneously; for example, whilst walking and talking.4,5 With increasing age, there is a decline in attentional capacity, which makes it more difficult to perform two tasks concurrently,6 and it has been shown that balance7 and recovery8 may be compromised in the elderly with the introduction of a secondary task.

Visual impairment is known to adversely affect balance,9–13 and thus the addition of a secondary task may have an additional negative effect on balance control in these individuals. Geruschat and Turano found that patients with peripheral visual-field defects displayed slower reaction times to a secondary task as they navigated through an obstacle course.14 In a study of healthy elderly subjects, with no ocular pathology, in whom refractive blur was induced, Anand and coworkers15 found that the addition of a cognitive and physical secondary task had a cumulative detrimental effect on standing balance. These studies suggest that the attentional demands of mobility and standing balance are greater when visual input is compromised.

Two of the most common causes of irreversible blindness worldwide are AMD and glaucoma, which account for the majority of cases of blind and partial-sight registrations in the United Kingdom.16 These conditions have very different effects on vision: AMD primarily reduces central vision, whilst glaucoma causes a reduction in the peripheral field of view, often leaving central vision unaffected until the very advanced stages of the disease. The contributions of central and peripheral vision to balance control have been studied in normal subjects with artificially reduced vision.17–19 It is thought that central vision is required to stabilize lateral sway,17,20 and that peripheral vision better stabilizes fore-aft oscillations.18

Our group recently showed that, during quiet upright standing, glaucoma patients have a reduced visual contribution and an increased somatosensory contribution to their balance control.21 Other studies observing postural stability during “quiet stance” have shown balance impairments in patients with glaucoma and AMD, and it has been suggested that those with either disease have a greater somatosensory contribution to balance control.9,22
TABLE 1. Study Group Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Control Mean (SD)</th>
<th>Glaucoma Mean (SD)</th>
<th>AMD Mean (SD)</th>
<th>Pearson $\chi^2$ Statistic (P Value)</th>
<th>1-Way ANOVA F Statistic (P Value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of males</td>
<td>4 (35%)</td>
<td>6 (50%)</td>
<td>6 (50%)</td>
<td>0.9 (0.6)</td>
<td></td>
</tr>
<tr>
<td>No. of patients reporting systemic/topical beta-blocker use</td>
<td>2 (17%)</td>
<td>4 (33%)</td>
<td>1 (8%)</td>
<td>2.5 (0.3)</td>
<td></td>
</tr>
<tr>
<td>No. of patients reporting 1 or more falls in previous year</td>
<td>5 (42%)</td>
<td>3 (25%)</td>
<td>3 (25%)</td>
<td>1.0 (0.6)</td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td>66.2 (6.4)</td>
<td>69.2 (4.3)</td>
<td>72.2 (5.3)</td>
<td>3.7 (0.04)</td>
<td></td>
</tr>
<tr>
<td>Binocular VA, logMAR</td>
<td>-0.02 (0.11)</td>
<td>0.06 (0.13)</td>
<td>0.46 (0.45)</td>
<td>10.2 (&lt;0.0001)</td>
<td>20.2 (&lt;0.0001)</td>
</tr>
<tr>
<td>Binocular CS</td>
<td>1.7 (0.08)</td>
<td>1.46 (0.18)</td>
<td>1.27 (0.21)</td>
<td>3.2 (0.07)</td>
<td></td>
</tr>
<tr>
<td>Better eye MD, dB</td>
<td>0.44 (1.10)</td>
<td>-10.76 (0.50)</td>
<td>-7.81 (2.60)</td>
<td>21.1 (&lt;0.0001)</td>
<td></td>
</tr>
<tr>
<td>Physical activity, MET h/wk</td>
<td>106.6 (66.2)</td>
<td>113.8 (59.7)</td>
<td>83.9 (37.8)</td>
<td>0.9 (0.44)</td>
<td></td>
</tr>
</tbody>
</table>

logMAR, logarithm of the minimum angle of resolution; CS, contrast sensitivity; MD, mean deviation (control and glaucoma participants) or mean defect (AMD participants) score.

The purpose of this study was to evaluate the effects of a secondary task on balance in older adults with glaucoma or AMD. It was hypothesized that (1) the addition of the secondary task would adversely affect the balance of those with visual impairment, and (2) the detrimental effects of the secondary task on balance would be further exacerbated in visually impaired patients during disruption to their somatosensory system.

METHODS

The study had the approval of the local research ethical committee; approval and informed consent, according to the tenets of the Declaration of Helsinki, were obtained from each participant prior to examination.

Patients were recruited from the clinics at Moorfields Eye Hospital, London, and control subjects were recruited from the local community. Participants who had a history of coexisting ocular pathologies (other than their primary diagnosis, if relevant) were ineligible for the study. Participants were also excluded if they had a history of diabetes, or reported a history of comorbidities affecting their lower limbs, such as arthritis, hip or knee replacements, Parkinsonian-type disorders, or any pathology that affected the vestibular or auditory systems, including the use of a hearing aid. All participants were administered the mini-mental state examination (MMSE) and required a score of better than 25 to be included in the study.25

Postural Balance Measures

Postural stability was measured using a force balance platform (Bertec Corp., Columbus, OH), which measured the coordinates of the center of foot pressure (CoP) during upright stance in both anteroposterior (AP) and mediolateral (ML) directions. The platform was connected to a personal computer and set at a sampling frequency of 1000 Hz.

Participants were asked to remove their shoes and stand still with their arms by their sides, feet parallel and 15 to 20 cm apart, on the center of the platform. Study participants wore their habitual distance spectacle prescription (if required) rather than a best corrected refraction to avoid any potential limitations a trial frame might have on the peripheral field of view. As the fixation target was adjusted to participant eye level, multifocal spectacle wear was permitted; there was no head flexion or downward eye gaze that might otherwise impair balance.25 Stability was examined under two visual test conditions, which were presented in a randomized order: both eyes open, on the firm surface of the platform (Fi); or both eyes open, on a foam-rubber surface (Fo) placed on top of the platform. The purpose of standing on the foam-rubber surface was to disrupt the somatosensory contribution to balance control. During upright standing, mechanoreceptors on the soles of the feet detect displacements of skin indentation, providing afferent information that facilitates appropriate corrective changes in lower limb muscle activity to maintain balance.26 The use of a foam surface disperses foot pressure, thus affecting the reliability of information received from these cutaneous receptors. Foam has been used extensively as a method of disrupting the somatosensory contribution to balance, and it correlates well with dynamic (i.e., moving platform) posturography methods in isolating the vestibular input to postural control.26–28 Postural stability was measured under two situations: (1) quiet stance, and (2) whilst performing a mental arithmetic task. Details are described below. Participants were instructed to rest on a chair for at least 3 minutes between tasks to minimize fatigue. Each participant had a 30-second familiarization period under each test condition and situation (i.e., Fi, Fo, quiet stance, mental arithmetic) prior to the start of the test procedure.

Quiet Stance. The participant was instructed to look steadily at a cross-fixation target, which was displayed on an LCD monitor 90 cm away at eye level. Stability was measured over a 30-second period under each test condition and repeated three times with the participant instructed to step off the platform after each measurement. This generated a total of six (2 × 3) balance measures per participant.

Secondary Task: Mental Arithmetic Task. Postural stability measurements were repeated whilst the subject performed a mental arithmetic task. For each measurement, the participant was asked to correctly count backwards aloud in sevens starting from 100; the emphasis being on counting accuracy rather than speed. If they were particularly fast and reached the final number, they were asked to restart the counting at 100. Participants were asked to fixate on the same target as for the quiet-stance situation. Measurements were repeated as for the quiet-stance situation, generating a total of six measurements per participant.

The raw CoP data were filtered post hoc with a Butterworth filter to remove any noise from the measurements. The CoP displacement in the AP (fore–aft) and ML (lateral) directions were calculated, and the average magnitude of displacement (root mean square [RMS]) was calculated.

Visual Measures

Glaucoma and control participants underwent a Humphrey Visual Field Analyzer (HFA; Zeiss Humphrey Systems, Dublin, CA) SITA standard threshold 24–2 visual field test on both eyes. Mean deviation (MD) scores were recorded for each eye. AMD patients underwent microperimetry (Nidek microperimeter
MP1; Nidek Instruments, Padova, Italy) using the 10-2 program, and mean defect scores for each eye were recorded. LogMAR visual acuity (VA), measured using the EDTRS chart, and Pelli Robson contrast sensitivity was measured with the participant’s habitual refractive correction.

Physical Activity Measures

In view of the association between physical activity and balance, study participants were administered the EPIC physical activity questionnaire (EPAQ-2), a validated instrument that requires an individual to report the amount of time spent undertaking activities at work, home, and during recreation over the previous 12 months. Energy expenditure was determined by calculating the metabolic equivalent (MET) hours per week reported for each activity, using the MET scores listed in the Compendium of Physical Activities as reference. A MET score of 1 is considered a resting metabolic rate during quiet sitting; thus the higher the MET score, the greater the metabolic energy expenditure for the activity. The

**FIGURE 1.** Estimated means illustrating surface × group interactions for (a) AP and (b) ML directions. Clear bars indicate firm standing; shaded bars indicate foam standing; error bars are 95% confidence intervals for the estimated means. *Significantly different from control group at \( P < 0.01 \).
combined MET hours per week in all three domains are presented (Table 1).

A detailed medical history with special reference to systemic and topical medication and number of falls (defined as “unintentionally coming to rest on the ground or some other level”) in the preceding year was taken from each participant.

**Data Analysis**

Data were analyzed using a repeated measures analysis of covariance (ANCOVA), with age and physical activity scores as covariates, surface standing (Fi versus Fo) and task (quiet versus mental arithmetic) as within-subject factors, and group (control versus glaucoma versus AMD) as between subject factor.
Within subjects

<table>
<thead>
<tr>
<th>Effect</th>
<th>AP RMS F Statistic (P Value)</th>
<th>ML RMS F Statistic (P Value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface × task (2,31)</td>
<td>0.01 (0.9)</td>
<td>0.02 (0.9)</td>
</tr>
<tr>
<td>Task (1,31)</td>
<td>0.06 (0.9)</td>
<td>0.8 (0.4)</td>
</tr>
<tr>
<td>Surface × group (2,31)</td>
<td>5.4 (0.01)*</td>
<td>8.4 (0.001)*</td>
</tr>
<tr>
<td>Task × group (2,31)</td>
<td>3.6 (0.04)*</td>
<td>0.6 (0.5)</td>
</tr>
<tr>
<td>Surface × task × group (2,31)</td>
<td>0.08 (0.8)</td>
<td>1.7 (0.2)</td>
</tr>
</tbody>
</table>

Between subjects

| Group (2,31)              | 2.9 (0.07)*†                | 1.8 (0.2)                    |

“Surface” indicates firm or foam surface; “task” indicates quiet, mental arithmetic; and “group” indicates control, glaucoma, and AMD.

† Significant at P < 0.05.

Results

Twelve control participants, 12 glaucoma, and 12 AMD patients were recruited for the study. The mean (SD) spherical refraction for the participant groups was control –0.4 (3.1) diopters (D); glaucoma –1.0 (3.5) D, and AMD 0.5 (2.2) D. Characteristics of the study group are presented in Table 1.

Effects of Secondary Task on Balance

There was no significant effect of surface standing or task within groups; however, there were significant “surface × group” and “task × group” interactions (Figs. 1, 2; Table 2). The between-group differences in standing balance only approached significance in the anteroposterior (AP) direction.

As there was no significant difference in mediolateral (ML) RMS between groups, post hoc analyses were performed on AP RMS only. Bonferroni-corrected 1-way ANOVA revealed no significant group differences during quiet standing on either the firm or the foam surface. There were significant differences in AP RMS between controls and AMD patients when undertaking the mental arithmetic task standing on the firm surface, with the difference between glaucoma and AMD patients approaching significance (mean difference [SE]: control versus AMD = 2.8 [0.8] mm, P = 0.005; AMD versus glaucoma = 2.0 [0.8], P = 0.05). There were significant differences between controls and AMD patients when undertaking the mental arithmetic task on the foam surface, with the difference between controls and glaucoma patients approaching significance (mean difference [SE]: control versus AMD = 3.1 [0.9] mm, P = 0.005; control versus glaucoma = 2.2 [0.9], P = 0.06; Fig. 3).

Discussion

The results of this study show that performing a concurrent task whilst standing upright increases postural instability in older persons with and without eye disease. The effect of the secondary task was significantly more detrimental to AMD patients compared with control subjects during both firm and foam surface standing, whilst the detrimental effect to glaucoma patients only became apparent with disruption to their somatosensory system. This finding suggests that balance control whilst standing upright and undertaking a secondary task is attentionally demanding, particularly in the presence of a visual impairment.

The addition of the secondary task had a significant detrimental effect on the standing balance of AMD patients after adjusting for age and physical activity. It is known that balance control worsens with advancing age,32,33 and that the effects of a secondary task on standing balance are more detrimental to older persons.34 In this study, AMD participants showed an increased somatosensory contribution to balance control during quiet standing, which corresponds with the findings of others who have studied the effects of somatosensory disruption on the quiet standing balance of those with central vision losses.9,53,56 This study also demonstrated that the addition of a secondary cognitive task during somatosensory disruption had the greatest detrimental effect on balance control in this patient group. Poor vision is a predictor of balance instability,11,20 and poor central vision has been shown to be a risk factor for falls.10,37,38 This work adds to the evidence of the importance of central vision to balance control. Undertaking a secondary cognitive task during upright standing will have an adverse effect on standing balance control in those with central vision loss, and the negative effect will be further compounded under conditions where the somatosensory system is disrupted.

During firm surface standing, glaucoma and control subjects displayed similar levels of balance control during both quiet standing and with the addition of the mental arithmetic task. With disruption to the somatosensory system, however, the additional task appeared to exert a more negative effect on glaucoma patients compared with control subjects. It has previously been shown that, like those with AMD, glaucoma patients have an increased somatosensory contribution to balance control.21,22 This study corroborates those findings and adds further evidence to the importance of the somatosensory contribution to balance control in individuals with visual impairment. Balance control during somatosensory perturbations is attentionally demanding; particularly in older individuals.19 The glaucoma group showed significant balance instability with somatosensory disruption. Thus, it might be inferred that peripheral vision is important for balance control, particularly under somatosensory disruptions, which is consistent with others’ findings.19

During foam surface standing, the balance control of glaucoma patients did not worsen significantly when the secondary task was introduced, unlike the in AMD group. Previous work has shown that vision is important in balance recovery when the somatosensory system is perturbed,40 and that with advancing age, a reduction in sensory information (visual and/or somatosensory) increases the attentional demands of upright postural control.59,41 Our results may reflect the relative importance of central versus peripheral vision for balance control during the addition of a secondary task, but this should be further explored.

It had been expected that AMD patients with central visual losses would display worse lateral stability, whilst glaucoma...
patients with peripheral visual losses would have worse fore–aft stability, and that these differences would be exacerbated with the addition of the secondary task. This is because previous research has suggested that fovea vision predicts lateral sway, whilst fore–aft sway is predicted by peripheral vision.\textsuperscript{17,18} However, in this study, there were no significant group differences in lateral or fore–aft stability, and the “task × group” interaction was only significant for fore–aft (AP) stability. This may be related to the level of disease status, and future work should explore the differences in directional stability in a wider range of disease.

Limitations to this study include the laboratory setting and the relatively small sample size. There are many factors that influence balance control, including lower limb muscle

![Figure 3](http://tvst.arvojournals.org/)  
**Figure 3.** Estimated marginal means of AP RMS during (a) firm and (b) foam surface standing during “quiet” and “mental arithmetic” tasks, adjusted for age and physical activity. **Clear bars** indicate quiet standing; **filled bars** indicate mental arithmetic task; **error bars** are 95% confidence intervals for the estimated means; *significantly different from control group at \( P < 0.01 \); †difference from control group approaching significance \((P = 0.06)\).
strength,24,25 which was not measured. Physical activity, however, was measured using self-report,30 and the AMD group appeared to be the least physically active. This may have exerted an effect on balance measurements; more physically active and fit individuals have better postural stability.30,31 The AMD and glaucoma patients studied were older in comparison with the control group. Studies evaluating the contributions of central and peripheral vision to balance have looked at young subjects.17,18 Perhaps in this cohort, the effects of poor vision were compounded by the effects of increasing age, exerting a negative effect on balance control overall. Of note is that almost half the control group reported a history of at least one fall in the previous 12 months, suggesting that they may have represented a more balance-unstable group in general. It is difficult to ascertain the reasons for the falls reported in this cohort, as it has been shown that older adults with a history of falls are more unstable when required to perform a cognitive task.35

The incidence of falling increases with advancing age,46 and the risk of injurious falls is greater in those with visual impairment.57 The ability to successfully undertake a secondary task whilst walking can predict the fall risk of non–visually impaired older persons.3,5 This study suggests that standing upright is attentionally demanding in those with a visual impairment, and that reliable somatosensory feedback is important for maintaining balance control in this group. It has been suggested that improving somatosensory feedback through specialized footwear could help prevent future falls in some patient groups.48,49 Future work should explore both the effects of cognitive load on successful ambulation and whether the increased somatosensory contribution to balance control may be exploited for fall-prevention interventions in these patient groups.

Acknowledgments

Supported by the Special Trustees of Moorfields Eye Hospital (RTAF); the Crucible Center, part of the cross-council Lifelong Health and Wellbeing Initiative, funded by the Biotechnology & Biological Sciences Research Council (BBSRC), Engineering and Physical Sciences Research Council (EPSRC), Economic and Social Research Council (ESRC), and Medical Research Council (MRC) (RTAF); the College of Optometrists Summer Scholarship Award 2011 (RC); and the Department of Health’s National Institute for Health Research Biomedical Research Center for Ophthalmology at Moorfields Eye Hospital National Health Service Foundation Trust and the University College London Institute of Ophthalmology (AK, GSR).

Disclosure: A. Kotecha, None; R. Chopra, None; R.T.A. Fahy, None; G.S. Rubin, None

References


