



Archived at the Flinders Academic Commons:

<http://dspace.flinders.edu.au/dspace/>

Barr CJ, McLoughlin JV, van den Berg ME, Sturnieks DL, Crotty M, Lord SR. Visual Field Dependence Is Associated with Reduced Postural Sway, Dizziness and Falls in Older People Attending a Falls Clinic. *J Nutr Health Aging*. 2016;20(6):671-6.

The final publication is available at Springer via <http://dx.doi.org/10.1007/s12603-015-0681-y>

© 2016 Springer.

Visual field dependence is associated with reduced postural sway, dizziness and falls in older people attending a falls clinic

Christopher J Barr PhD¹, James V McLoughlin MSc¹, Maayken E L van den Berg PhD¹, Daina L. Sturnieks, PhD^{2,3}, Maria Crotty PhD¹, and Stephen R. Lord, DSc^{2,3}

¹*Department of Rehabilitation, Aged and Extended Care, Flinders University, South Australia*

²*Falls and Balance Research Group, Neuroscience Research Australia, Sydney, Australia*

³*Faculty of Medicine, University of New South Wales, Sydney, Australia*

✉ **Correspondence:**

Dr Christopher Barr,

Department of Rehabilitation, Aged and Extended Care

C Block, Repatriation General Hospital

Daws Road

Daw Park

SA5041

South Australia

Email: chris.barr@health.sa.gov.au

Tel: +61 8 82751103

Fax: +61 8 82751130

Abstract

Moving visual fields can have strong destabilising effects on balance, particularly when visually perceived motion does not correspond to postural movements. This study investigated relationships between visual field dependence (VFD), as assessed using the roll vection test, and reported dizziness, falls and sway under eyes open, eyes closed and optokinetic conditions. Ninety five falls clinic attendees undertook the roll vection test (i.e. attempted to align a rod to the vertical while exposed to a rotating visual field). Sway was assessed under different visual conditions by centre of pressure movement. Participants also completed questionnaires on space and motion discomfort, fear of falling, depression and anxiety. Thirty four (35.8%) participants exhibited VFD, i.e. had an error $> 6.5^\circ$ in the roll vection test. Compared to participants without VFD, participants with VFD demonstrated less movement of the centre of pressure across all visual conditions, were more likely to report space and motion discomfort and to have suffered more multiple falls in the past year. VFD was independent of fear of falling, anxiety and depression. VFD in a falls clinic population is associated with reduced sway possibly due to a stiffening strategy to maintain stance, dizziness symptoms and an increased risk of falls.

Key Words: Fallers; Visual Field Dependence; Balance; Stiffening Strategy

1. Introduction

Visual Field Dependence (VFD) is a strong reliance on vision for spatial orientation and balance and is thought to develop as a compensation for reduced vestibular and proprioceptive balance functions. It increases with age [1] and is prevalent not only in older people [2] but also in those with vestibular and anxiety disorders [3, 4].

Visual dependence can lead to 'visual vertigo', particularly in patients with confirmed or suspected vestibular dysfunction [5, 6, 3]. Many patients with anxiety also describe symptoms of imbalance and/or dizziness that can be elicited by specific visual conditions. This particular phenomenon has also been described as 'Space and Motion Discomfort' (SMD), a common problem in some vestibular and anxiety disorders [7] that can be triggered by common everyday situations such as walking within a crowd, adjacent to moving vehicles or looking up at tall buildings.

Moving visual fields can have strong destabilising effects on balance, particularly when visually perceived motion does not correspond to the body movements sensed by the vestibular and somatosensory systems and it has been demonstrated that tilted and moving visual fields can affect the perceived upright [6]. This apparent displacement of the postural vertical appears to be the result of a central re-computation that results from an attempt to resolve the contradictory sensory inputs of the vertical. Moving visual environments can cause postural changes [8], disequilibrium, and motion sickness in healthy adults, and in patients with balance disorders these effects can be even greater [9].

To date no studies have reported the prevalence of VFD or have examined the relationship between VFD and sway in older people at increased risk of falls, such as those who attend a falls clinic. This information could be valuable for understanding fall risk and guiding the treatment and clinical rehabilitation in this group. The primary aims of this study were to assess whether VFD, as assessed with the roll vection test [10], is associated with fall rates in a falls clinic population, and to investigate the relationship between VFD and sway characteristics under conditions of eyes open, eyes closed and moving visual scenes using optokinetic stimulation. Secondary aims were to investigate relationships between VFD and space and motion discomfort, anxiety, depression and falls efficacy.

2. Methods

2.1 Participants

The sample comprised a convenience sample of 100 patients who had been referred to the outpatient Falls Clinic at the Repatriation General Hospital; 84 participants reported one or more falls in the previous year and the remaining 16 were referred for investigation of balance problems. No patients had an overt neurological disorder (such patients attend a neurology clinic). The average Physiological Profile Assessment fall risk score for the group was 1.93 (SD=1.19) indicating a high fall risk [11]. Participant characteristics are outlined in Table 1. The only exclusion criterion for this study was an inability to stand unassisted for 60 seconds. The assessments were conducted by one of two physiotherapists and standardised procedures were used to ensure consistency in test administration. The study was approved by the Flinders Human Research Ethics Committee and participants provided written informed consent before participating in the study.

2.2 Assessments

2.2.1 Roll Vection

The Roll Vection Test (RVT) [10] was used to assess perception of the vertical under a visually challenging situation. The RVT apparatus consisted of a dome (opened umbrella), 125cm in diameter, with 8 alternating black and white triangular panels. The dome was mounted horizontally with a bracket onto an adjustable stand via the central shaft of the dome. During the test the dome was rotated by a motor connected to the shaft via sprockets and a belt drive. An axle ran through the shaft and attached to a smaller flat white disc (21cm diameter) such that the rotation of the dome was uncoupled from the rotation of the disc. The disc extended out from the inner surface of the dome to about level with its rim. The white disc was marked with a straight black line across its centre. The participant stood within arm's reach of the disc, with the height of the axis of rotation of the dome and disc adjusted to eye level. At the start of the test the white disc was rotated so that the black line was offset by 26° from vertical.

Participants were instructed to focus on the centre of the static small white disc while the dome rotated counter-clockwise at 16rpm for 30 seconds. At the end of the 30 second trial, and while the dome was still rotating, each participant was instructed to rotate the white disc until the black line was perceived to be vertical. The angular error from true vertical of the black strip on the small disc was measured for each trial using a digital spirit level.

Participants performed 6 trials, 3 with the black line on the disc tilted in the direction of the roll and 3 with the line on the disc tilted in the opposite direction of the roll. The mean deviation in degrees from vertical measured over the 6 trials was recorded as the overall angular error. An error of 6.5° was defined as VFD [10].

2.2.2 Postural sway during standing balance

Standing balance tests were conducted barefoot with feet positioned comfortably apart so that each foot was positioned on one of two adjacent force platforms (AMTI, Watertown, MA). Trials of 30 second duration were recorded for six conditions: eyes open (EO), eyes closed (EC), and optokinetic conditions of forwards optic flow (FW), backwards optic flow (BW), clockwise rotation (CW), and counter-clockwise rotation (CCW). For optokinetic conditions, visual stimuli of alternating black and white segments were projected onto a hemi-spherical immersadome positioned 0.6m in front of the participant. Participants were instructed to look at the centre of the projected video image. Each participant attempted each condition twice, completing up to 12 standing balance trials, with the order of conditions randomised across the trials.

During each standing trial centre of pressure (CoP) data were acquired from each force platform at 100Hz using Nexus v1.4 software (Vicon, Oxford, UK) and filtered using a General Cross Validation Woltring Spline filter. The first 2 seconds of data from each trial were discarded and the overall length of the resultant CoP trajectory (CoP path length, mm) was calculated from CoP co-ordinates. Mean sway parameter values were calculated for each participant who completed two trials of each condition. The Romberg quotient (ratio of sway of EC/EO) and optokinetic quotients (BW, FW, CW, CCW, /EO) were calculated to assess the destabilising effect of each visual condition.

2.2.3 Dizziness, anxiety, depression and fear of falling

Participants were asked if they experienced symptoms of dizziness and the number of falls in the past year were recorded. Questionnaires completed by the participants included:

The Goldberg Anxiety and Depression Scales (GAD) [12]. A 50% chance of a clinically important disturbance in anxiety and depressive symptoms can be defined as scale scores of >5 and >2 respectively.

The Situational Characteristics Questionnaire parts I (SCQ-I) and II (SCQ-II) [7] to measure space and motion discomfort. Part I of the questionnaire is recommended for quantifying space and motion discomfort in patients with anxiety or balance disorders, by evaluating situations such as those that involve excessive vestibular stimulation (e.g. dancing) and movements that involve reorientation with respect to gravity (e.g. looking up at tall buildings)[13]. Part II asks participants to rate how uncomfortable they feel on a scale of 0-3 on 9 situations including closing the eyes in a shower, and degree of discomfort as the day progresses [7].

The Falls Efficacy Scale – International (FES-I) [14], to assess fear of falling. A fear of falling of high concern was defined as a score >23 [15]

2.3 Statistical analysis

Chi square tests for contingency tables and group t-tests were used to compare participants with and without VFD (i.e. those with RVT scores of above or below 6.5°). Pearson's correlations were used to contrast VFD as a continuous variable with levels of anxiety, depression, space and motion discomfort, and fear of falling. Data was analysed using SPSS (Chicago, IL, USA) for Windows version 19. Alpha was set to 0.05 for all analyses.

3. Results

Ninety five participants completed all assessments. Demographic and questionnaire data are presented in Table 1. Two participants could not tolerate the RVT, and data were lost for three participants due to equipment malfunction. The mean age of the sample was 82 years, (SD 6.1, range 68-94) and 57 (60%) were women. 69 participants (73%) reported multiple (2 or more) falls in the past year and 36 participants (38%) reported symptoms of dizziness.

3.1 Roll Vection

Results for the RVT are presented in Table 2. Mean error in aligning the rod to the vertical in the RVT was 5.8° (SD 3.8). Participants who reported multiple falls in the previous year had a significantly larger deviation from vertical in the RVT than those who reported no or one fall in this period ($t(93)=3.16$, $p=0.002$). Thirty four participants aligned the rod greater than 6.5° from the vertical and were defined as being VFD.

3.2 VFD and sway

Those with VFD, had a significantly shorter CoP path length in standing balance tests for all 6 conditions compared to those without VFD ($p<0.05$) (figure 1). The quotients of sway CoP path length of eyes closed and each of the OKS conditions with eyes open are presented in table 2. Values greater than 1 indicate a destabilising effect. No significant differences between participants classified as being with or without VFD were found for any of the CoP quotient measures.

3.3 VFD, anxiety, depression, fear of falls, and space and motion discomfort

Those with VFD had significantly higher levels of space and motion discomfort as measured on part II of the situational characteristics questionnaire than those without VFD ($t(93)=2.06$, $p=0.04$) (table 1). There were no significant differences in the Goldberg anxiety and depression scales, fear of falling as measured by the FES-I questionnaire, and the situational characteristics questionnaire part 1 scores between those with and without VFD.

4. Discussion

This study assessed whether there were relationships between VFD and measures of sway, dizziness, anxiety, depression and falls in a falls clinic population. We assessed postural sway in six experimental conditions to challenge the role of vision under optokinetic conditions. The results showed that one third of the sample suffered VFD, based on published criteria and that those with VFD had more falls and demonstrated reduced sway across all balance conditions.

Participants with VFD consistently demonstrated a significantly shortened CoP path length than those without VFD, which was likely due to a stiffening strategy to maintain postural control [16]. EMG analysis has revealed the importance of calf muscle contractions in the control of balance during quiet stance [17]. Increased muscle co-contraction may be the strategy used in this group for managing postural control as a result of less reliable proprioceptive or vestibular input. Several studies have reported age-associated increases in muscle co-activation during dynamic movements (i.e. walking and stair climbing) [18] and under different experimental conditions in response to a postural threat, including platform movements [19, 20], reaching or bending forward [21, 22], voluntary rotations in the lateral or yaw plane [22, 23] and during gait [24]. Increased muscle co-activation in older adults has often been described as a compensatory mechanism to increase joint stiffness to enhance

joint and postural stability [25, 26, 27]. This response has been associated with physiological arousal [16] and fear of falling [28, 29, 30] with the rationale that people who are afraid to fall co-contract in anticipation of postural perturbations [31, 29]. As falls occur in our cohort, it may be that co-contraction is not a sufficient strategy. Older female fallers have been shown to have lower muscle density than non-fallers [32], so the stability offered by co-contraction may not prevent all falls.

The reduced path length for people with VFD, observed across all conditions, including eyes open with no optokinetic stimuli, was not associated with an increase in anxiety, depression, or falls efficacy. Additionally, the Romberg and optokinetic quotients showed a destabilising effect across the group as a whole, with the destabilising effect no different between those with and without VFD. We have previously shown that participants who report having symptoms of dizziness also demonstrate a reduced sway path when exposed to optokinetic stimuli [33]. VFD may be a phenomenon that leads to a general stiffening muscle co-activation, a necessary adaptation to compensate for the poor perception of the subjective vertical, independent of dizziness, anxiety, depression and fear of falling.

The stiffening strategy observed in people with VFD may not be a beneficial postural adaptation. It has been shown that excessive muscle co-activation increases postural rigidity and reduces the degrees of freedom in the postural control system [27, 34]. This may compromise the ability to perform voluntary responses or adjust to unexpected perturbations [35, 36] and hence increase the risk of falling [18]. Nagai et al [37] demonstrated an inverse significant association between muscle co-activation during quiet standing and dynamic postural control, suggesting greater muscle co-activation exerts a

deleterious effect on dynamic postural control. Further research may help clarify whether this stiffening strategy is maladaptive and/or associated with falls.

Visual-vestibular conflict and optokinetic stimulation have been used as intervention strategies for vestibular rehabilitation [38, 39, 40, 4]. However, in this study optokinetic stimulation conditions did not trigger augmented destabilising effects, therefore exposure to optokinetic stimulation may not be an appropriate intervention in rehabilitation for older people at increased risk of falls. Decreasing muscle co-activation as a primary goal of the intervention program may be a preferred approach. Nagai et al [37] have reported that co-activation during postural control decreases after balance training in older adults, which can be associated with improvement of postural control.

Our study results revealed significantly higher levels of space and motion discomfort in elderly fallers with VFD, as measured on part II of the situational characteristics questionnaire. This sub-scale has been recommended for quantifying space and motion discomfort in patients with anxiety and/or balance disorders [41]. However the majority of studies use part I of the scale to measure space and motion discomfort in relation to anxiety disorders [7, 42]. To our knowledge, only one study has made reference to part II of the questionnaire [43] and the scoring system within that refers to unpublished data. It may be that part II of the situational characteristics questionnaire measures a different domain of Space and Motion Discomfort, and could potentially be used to identify different subgroups of patients who have balance issues independent of anxiety.

Certain study limitations are acknowledged. First, it is possible that during the balance tests, participants used reference points outside the immersadome. However, we attempted to minimise this possibility by positioning the 2 meter wide immersadome directly in front of

participants to ensure that it covered more than 130° of visual angle [44]. Second, we have attributed shortened CoP path length to a stiffening strategy due to muscle co-contraction, however we acknowledge we did not measure surface EMG activity of the leg muscles to confirm this. No patients referred to the falls clinic had overt neurological disorders, which would have impacted significantly on their balance. It is acknowledged, however, that other unmeasured co-morbidities may have influenced the visual field dependence and sway tests. Another limitation is the use of retrospective falls data, which are subject to recall bias and do not allow us to draw conclusions about cause and effect.

In summary, our study findings demonstrate that about one third of elderly fallers have VFD as measured by the RVT and that this condition is associated with a sway pattern consistent with a generalized stiffening, presumably as a compensatory strategy to enhance postural stability. Sway did not significantly increase in optokinetic stimuli conditions suggesting that moving visual stimuli does not differentially affect stability in elderly fallers with and without VFD. This and the fact that no associations were observed with anxiety, depression or fear of falling suggest that VFD may be an independent falls risk factor. Rehabilitation of the elderly with VFD with the aim of improving posture and balance should therefore not focus on optokinetic stimuli exposure. Future research should determine if the observed stiffening strategy is in fact maladaptive and further investigate its relationship with falls in older people.

References

- [1] Jonsson R, Sixt E, Landahl S, Rosenhall U (2004) Prevalence of dizziness and vertigo in an urban elderly population. *Journal of vestibular research* **14**:47-52.
- [2] Agrawal Y, Carey JP, Della Santina CC, Schubert MC, Minor LB (2009) Disorders of balance and vestibular function in US adults: data from the National Health and Nutrition Examination Survey, 2001-2004, *Archives of internal medicine* **169**: 938.
- [3] Guerraz M, Yardley L, Bertholon P, Pollak L, Rudge P, Gresty MA, Bronstein AM (2001) Visual vertigo: symptom assessment, spatial orientation and postural control, *Brain : a journal of neurology* **124**: 1646-1656.
- [4] Redfern MS, Furman JM, Jacob RG (2007) Visually induced postural sway in anxiety disorders, *J Anxiety Disord* **21**:704-716.
- [5] Bronstein AM (1995) The visual vertigo syndrome, *Acta oto-laryngologica*. **S 520**: 45-48.
- [6] Bronstein AM (1995) Visual vertigo syndrome: clinical and posturography findings, *J Neurol Neurosurg Psychiatry* **59**: 472-476.
- [7] Jacob RS, Redfern MS, Furman JM (2009) Space and motion discomfort and abnormal balance control in patients with anxiety disorders, *Journal of Neurology, Neurosurgery & Psychiatry* **80**: 74-78.
- [8] Raffi M, Piras A, Persiani M, Squatrito S. (2014) Importance of optic flow for postural stability of male and female young adults. *European journal of applied physiology*, **114**: 71-83.

- [9] Redfern MS, Furman JM (1994) Postural sway of patients with vestibular disorders during optic flow, *Journal of vestibular research : equilibrium & orientation* **4**: 221-230.
- [10] Lord SR, Webster IW (1990) Visual field dependence in elderly fallers and non-fallers. *The International Journal of Aging and Human Development* **31**: 267-277.
- [11] Lord SR, Menz HB, Tiedemann A (2003) A physiological profile approach to falls risk assessment and prevention. *Physical Therapy* **83**:237-252.
- [12] Goldberg D, Bridges K, Duncan-Jones P, Grayson D (1988) Detecting anxiety and depression in general medical settings, *BMJ: British Medical Journal* **297**: 897.
- [13] Jacob RG, Redfern MS, Furman JM (1995) Optic flow-induced sway in anxiety disorders associated with space and motion discomfort, *Journal of Anxiety Disorders* **9**: 411-425.
- [14] Kempen GI, Yardley L, Van Haastregt JC, Zijlstra GR, Beyer N, Hauer K, Todd C (2008), The Short FES-I: a shortened version of the falls efficacy scale-international to assess fear of falling, *Age and ageing* **37**: 45-50.
- [15] Delbaere K, Close JC, Mikolaizak AS, Sachdev PS, Brodaty H, Lord SR (2010) The falls efficacy scale international (FES-I). A comprehensive longitudinal validation study, *Age and ageing* **39**:210-216.
- [16] Adkin AL, Frank JS, Carpenter MG, Peysar GW (2002) Fear of falling modifies anticipatory postural control, *Experimental brain research* **143**: 160-170.
- [17] Vieira TM, Windhorst U, Merletti R. (2010) Is the stabilization of quiet upright stance in humans driven by synchronized modulations of the activity of medial and lateral gastrocnemius muscles? *Journal of Applied Physiology* **108**: 85-97

- [18] Hortobagyi T (2009), Interaction between age and gait velocity in the amplitude and timing of antagonist muscle coactivation, *Gait Posture* **29**: 558-564.
- [19] Accornero N, Capozza M, Rinalduzzi S, Manfredi G (1997) Clinical multisegmental posturography: age-related changes in stance control, *Electroencephalography and Clinical Neurophysiology* **105**: 213-219.
- [20] Maki B, Holliday P, Fernie G (1990) Aging and postural control. A comparison of spontaneous-and induced-sway balance tests, *Journal of the American Geriatrics Society* **38**: 1.
- [21] Cavanaugh JT, Shinberg M, Ray L, Shipp KM, Kuchibhatla M, Schenkman M (1999) Kinematic characterization of standing reach: comparison of younger vs. older subjects, *Clinical Biomechanics* **14**: 271-279.
- [22] McGill S, Yingling V, Peach J (1999) Three-dimensional kinematics and trunk muscle myoelectric activity in the elderly spine—a database compared to young people, *Clinical Biomechanics* **14**: 389-395.
- [23] Schenkman M, Hughes M, Bowden M, Studenski S (1995) A clinical tool for measuring functional axial rotation, *Physical Therapy* **75**: 151-156.
- [24] Hirasaki E, Kubo T, Nozawa S, Matano S, Matsunaga T (1993) Analysis of head and body movements of elderly people during locomotion, *Acta Oto-Laryngologica* **113**: 25-30.
- [25] Manchester D, Woollacott M, Zederbauer-Hylton N, Marin O (1989) Visual, vestibular and somatosensory contributions to balance control in the older adult, *Journal of Gerontology* **44**: M118-M127.

- [26] Melzer I, Benjuya N, Kaplanski J (2001) Age-related changes of postural control: effect of cognitive tasks, *Gerontology* **47**: 189-194.
- [27] Tucker MG, Kavanagh JJ, Barrett RS, Morrison S (2008) Age-related differences in postural reaction time and coordination during voluntary sway movements, *Human movement science* **27**: 728-737.
- [28] Arfken C, Lach H, Birge S, Miller J (1994) The prevalence and correlates of fear of falling in elderly persons living in the community, *American journal of public health* **84**: 565-570.
- [29] Maki B, Holliday P, Topper A (1991) Fear of falling and postural performance in the elderly, *Journal of gerontology* **46**: M123-M131.
- [30] Tinetti ME, Powell L (1993) Fear of falling and low self-efficacy: A cause of dependence in elderly persons, *Journals of Gerontology* **48**: 35-38.
- [31] Carpenter M, Frank J, Silcher C, Peysar G (2001) The influence of postural threat on the control of upright stance, *Experimental Brain Research* **138**: 210-218.
- [32] Frank AW, Farthing JP, Chilibeck PD, Arnold CM, Olszynski WP, Kontulainen SA (2015) Community-dwelling female fallers have lower muscle density in their lower legs than non-fallers: evidence from the Saskatoon Canadian Multicentre Osteoporosis Study (CaMos) cohort, *Journal of Nutrition Health and Aging* **19**:113-20.
- [33] McLoughlin J, Barr C, Sturnieks DL, Lord SR, Crotty M (2013) Older fallers with self-reported dizziness have high levels of anxiety and depression and adopt a stiffening strategy when exposed to optokinetic stimuli, *J Aging Res Clin Practice* **2**: 148-151.

- [34] Wu G (1998) Age-related differences in body segmental movement during perturbed stance in humans, *Clinical Biomechanics* **13**: 300-307.
- [35] Allum J, Carpenter M, Honegger F, Adkin A, Bloem B (2002) Age-dependent variations in the directional sensitivity of balance corrections and compensatory arm movements in man, *The Journal of physiology* **542**: 643-663.
- [36] Wu G (2008) Age-related differences in Tai Chi gait kinematics and leg muscle electromyography: a pilot study, *Archives of physical medicine and rehabilitation* **89**: 351-357.
- [37] Nagai K, Yamada M, Tanaka B, Uemura K, Mori S, Aoyama T, Ichihashi N, Tsuboyama T (2012) Effects of Balance Training on Muscle Coactivation During Postural Control in Older Adults: A Randomized Controlled Trial, *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences* **67**: 882-889.
- [38] Brown LA, Polych MA, Doan JB (2006) The effect of anxiety on the regulation of upright standing among younger and older adults, *Gait Posture* **24**: 397-405.
- [39] Nagai K, Yamada M, Uemura K, Yamada Y, Ichihashi N, Tsuboyama T (2011) Differences in muscle coactivation during postural control between healthy older and young adults, *Archives of gerontology and geriatrics* **53**: 388-343.
- [40] Prado JM, Stoffregen TA, Duarte M (2007) Postural sway during dual tasks in young and elderly adults, *Gerontology* **53**: 274-281.
- [41] Jacob RG, Woody SR, Clark DB, Lilienfeld SO, Hirsch BE, Kucera GD, Furman JM, Durrant JD (1993) Discomfort with space and motion: a possible marker of vestibular dysfunction

assessed by the Situational Characteristics Questionnaire, *Journal of Psychopathology and Behavioral Assessment* **15**: 299-324.

[42] Pavlou M, Davies RA, Bronstein AM (2006) The assessment of increased sensitivity to visual stimuli in patients with chronic dizziness, *J Vestib Res* **16**: 223-231.

[43] Whitney SL, Jacob RG, Sparto PJ, Olshansky EF, Detweiler-Shostak G, Brown EL, Furman JM (2005) Acrophobia and pathological height vertigo: indications for vestibular physical therapy?, *Phys Ther* **85**: 443-458.

[44] Dichgans J, Held R, Young L, Brandt T (1972) Moving visual scenes influence the apparent direction of gravity, *Science* **178**: 1217-1219.

Table 1. Mean (SD) age, roll vection and questionnaire results for the total sample and those with and without visual field dependence (VFD).

Measure	Total (n=95)	VFD (n=34)	non VFD (n=61)	P
Age	82.5 (6.1)	81.4 (7.4)	83.2 (5.2)	.216
Roll Vection (degrees)	5.8 (3.8)	3.5 (1.6)	10.0 (3.1)	<.001
Goldberg Anxiety Score	2.3 (2.7)	2.4 (2.7)	2.3 (2.7)	.737
Goldberg Depression Score	3.4 (2.5)	3.5 (2.7)	3.4 (2.3)	.750
Sit-Q-I Score	2.4 (3.3)	3.3 (4.1)	1.9 (2.6)	.087
Sit-Q-II Score	6.7 (6.1)	8.4 (7.1)	5.7 (5.3)	.042
FES-I Total Score*	28.9 (10.2)	29.8 (7.1)	28.7 (10.8)	.737

*n=62

Sit-Q = situational characteristics questionnaire FES-I = falls efficacy scale international

Table 2. Mean (SD) Romberg and Optokinetic Quotients for postural sway in people with and without visual field dependence (VFD)

Measure	VFD (n=34)	non VFD (n=61)	P
Eyes Closed / Eyes Open	1.28 (0.48)	1.27 (0.39)	0.98
Forwards / Eyes Open	1.33 (0.59)	1.26 (0.35)	0.43
Backwards / Eyes Open	1.09 (0.24)	1.15 (0.26)	0.24
Clockwise / Eyes Open	1.21 (0.41)	1.16 (0.29)	0.54
Counter Clockwise / Eyes Open	1.11 (0.21)	1.15 (0.24)	0.45

Figure 1. Mean (SEM) centre of pressure (CoP) path length for participants with VFD (n=34) and without VFD (n=61). Group differences are significant for all conditions ($p < 0.05$).

