ORIGINAL ARTICLE

Prevalence of Cognitive and Vestibular Impairment in Seniors Experiencing Falls

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ABSTRACT: ***Background:*** Falls are a growing concern in seniors (≥65 yrs). Cognitive impairment (CI) and vestibular impairment (VI) increase fall risk. The aim of this study is to assess the prevalence of CI and VI in seniors experiencing falls. ***Methods:*** Participants (≥65 yrs) with falls were recruited from Falls Prevention Programs (FPPs) and a Memory Clinic (MC). CI was assessed using the Montreal Cognitive Assessment at FPPs. VI was assessed at an MC and FFPs using the Head Impulse- (video + bedside), Headshake-, Dix-Hallpike test, and test of sensory interaction in balance. Questionnaires included Dizziness Handicap Inventory (DHI) and Activities-specific Balance Confidence Scale (ABC). ***Results:*** Of 41 participants (29 FPPs, 12 MC); mean age was 80.1 ± 7.1 years, and 58.5% were female. Overall, 82.9% had VI. At FPPs, 76.0% had CI, and 72.3% had CI + VI. Bilateral vestibular hypofunction (BVH) was more common than unilateral vestibular hypofunction (UVH) (70.6% vs. 29.4%); $p = 0.016$. Dizziness Handicap (DHI) was not different between those with a VI (23.5 ± 23.9) versus without VI [PVI + no impairment] (10.0 ± 15.4); $p = 0.160$. Balance confidence (ABC) was lowest in VI but not significantly different between those with a VI (63.4 ± 27.3) versus without VI [PVI + no impairment] (85.0 ± 16.5); $p = 0.053$. ***Conclusions:*** VI and CI are prevalent in seniors experiencing falls. For seniors with history of falls, both cognitive and vestibular functions should be considered in the assessment and subsequent treatment. Screening enables earlier detection, targeted interventions, and prevention, reducing the clinical and financial impact.

RÉSUMÉ : Prévalence de déficit cognitif et de déficit vestibulaire chez des personnes âgées victimes de chutes. *Contexte* : Les chutes sont une préoccupation croissante chez les personnes âgées (≥ 65 ans). On sait aussi que les déficits cognitifs (DC) et les déficits vestibulaires (DV) peuvent en accroître le risque. Ainsi, le but de cette étude est d'évaluer la prévalence des DC et des DV chez des personnes âgées victimes de chutes. ***Méthodes* :** Âgés de 65 ans ou plus, nos participants avaient été victimes de chutes. Ils ont été recrutés dans le cadre d'un programme de prévention des chutes (PPC) et au sein d'une clinique de la mémoire (CM). Leurs DC ont été évalués au moyen de l'Évaluation cognitive de Montréal (MoCA) dans le cadre d'un PPC. Quant à leurs DV, ils ont été évalués dans une CM et dans le cadre d'un PPC à l'aide des tests suivants : test d'impulsion de la tête (*head impulse*) par vidéo et au chevet des patients ; manœuvre de secouage de la tête (*headshake*) ; test de Nylen-Bárány ; et test d'intégration sensorielle et d'équilibre (*sensory interaction in balance*). À noter que deux questionnaires ont également été utilisés : le *Dizziness Handicap Inventory* (DHI) et le *Activities-specific Balance Confidence Scale* (ABC). ***Résultats* :** Au total, 41 participants ont été recrutés, soit 29 dans le cadre d'un PPC et 12 autres au sein d'une CM. Leur âge moyen était 80,1 ± 7,1 ans ; 58,5 % d'entre eux étaient de sexe féminin. De façon générale, 82,9 % des participants étaient atteints de DV. Parmi ceux inclus dans un PPC, 76,0 % étaient atteints de DC tandis que 72,3 % étaient atteints à la fois de DC et de DV. Une hypo-fonction vestibulaire bilatérale s'est avérée plus courante qu'une hypo-fonction vestibulaires unilatérale (70,6 % contre 29,4 % ; $p = 0,016$). Les résultats au DHI ne se sont pas avérés différents entre ceux et celles atteints de DV (23,5 ± 23,9) et les autres qui n'en étaient pas atteints [PDV + aucune déficience] (10,0 ± 15,4 ; $p = 0,160$). Les résultats au ABC se sont par ailleurs révélés moins élevés chez les participants atteints de DV ; cela dit, la différence entre ces participants (63,4 ± 27,3) n'était en rien significative par rapport à ceux et celles n'étant pas atteints par un DV [PDV + aucune déficience] (85,0 ± 16,5 ; $p = 0,053$. ***Conclusions* :** Tant les DV que les DC sont donc répandus chez les personnes âgées victimes de chutes. Dans le cas de personnes âgées sans antécédents de chute, les fonctions cognitives et vestibulaires devraient être toutes deux analysées lors d'une évaluation et à l'occasion d'un traitement subséquent. Un tel dépistage permettrait ainsi une détection plus précoce, des interventions davantage ciblées et une meilleure prévention, ce qui en retour contribuerait à réduire l'impact clinique et financier.

Keywords: Falls, Aging, Cognitive Decline, Balance

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Introduction

Falls are a growing concern in Canada and a leading cause of injury in seniors (≥65 yrs). Approximately 20–30% of senior's experience ≥1 falls a year.[1] Current estimates place associated health care costs at $2 billion annually, and this number is expected to rise.[1]

Fall risk factors appear to be multifactorial, suggesting a multifaceted approach is required.[2] Studies have shown a link between cognitive status and increased number of falls in the elderly[3] with cognitive impairment (CI) correlating with a 2–3-fold increased risk of falling.[3] In one study, a falls prevention program (FPP) reduced falls in those with higher cognitive functioning but not in those with more impaired cognition, suggesting that some strategies may not be effective in those with cognitive impairment.[4] Other studies suggest that multimodal exercise programs may be useful for improving balance and gait in those with cognitive impairment; however, the optimal program has not been established and warrants further research.[5] Finally, it has been suggested that cognitive and vestibular impairment (VI) can increase in parallel.[6] In one study, VI was prevalent in patients with either a diagnosis of mild cognitive impairment (MCI) or Alzheimer's Disease (AD),[7] and another study reported higher prevalence of VI in elderly AD patients compared to non-AD patients and young adults.[8]

Often clinically overlooked as a risk factor for falls is the vestibular system, which is responsible for balance and awareness of body positioning in space. A study reported that one in five of elderly persons experience issues with dizziness and balance annually, symptoms common with vestibular impairment.[9] It is known that seniors can have age-related changes in the vestibular system that can lead to symptoms, such as dizziness and balance issues.[10] A cross-sectional survey in the US, that tested vestibular functioning, had previously shown that 35.4% of US adults aged 40 and older had a vestibular impairment, and that this number rose to 85% in those aged 80 and older.[10] Moreover, VI correlated with a 12-fold increased risk of falling in those that were defined as being clinically symptomatic (i.e. experienced dizziness).[10] These numbers suggest a high prevalence of vestibular issues; however, one limitation with the data from the National Health and Nutrition Examination Survey study was that VI was diagnosed solely using the modified clinical test of sensory interaction in balance (mCTSIB), which may have caused an overestimation of those diagnosed with a vestibular impairment.[10] A case-controlled study revealed that among seniors experiencing multiple falls, approximately 80% had a VI, while only 18.5% age-matched controls without falls had a vestibular deficit.[11] As per this study, vestibular functioning was assessed by caloric, electronystagmography (ENG), and Dix-Hallpike test.

Rehabilitation programs are available to reduce symptoms of VI; however, there is little research investigating the prevalence of VI in seniors with CI and experiencing falls. Since CI is common in seniors experiencing falls and there is a research gap about the prevalence of combined cognitive and vestibular impairment, this study investigated the prevalence of VI in participants attending a Memory Clinic (MC) and the prevalence of both cognitive and VI in participants attending a Falls Prevention Program (FPP).

Methods

Full approval was obtained from the University Health Network (UHN) Research Ethics Board (REB) for this study [ID: 17-5055.0]. Written consent was obtained from all subjects, as outlined by the UHN research protocol. All patients were able to consent for themselves.

Participants

Participants were recruited from two community FPPs and an outpatient MC from September 2017 to March 2018. Participants were admitted to the falls prevention program if they or a health care provider had reported a fall in the past year. Participants at FPP were approached by FPP personnel and if they were both interested and meeting study inclusion criteria, they were referred to the study team. Research personnel confirmed inclusion/exclusion criteria. The research personnel did not have information on the total number of participants approached by the FPP personnel. MC subjects were selected from a chart review if they had fallen in the past year, which was indicated in their charts and confirmed when receiving consent.

Inclusion criteria from the FPPs: (1) 65 years or older, (2) English speaking, (3) capable of providing consent, and (4) have fallen in the past year. Participants were excluded if they reported: (1) neurological disease, (2) acute ear infection, (3) severe neck arthritis, or (4) any other illness, which may have prevented participation in the study.

Inclusion criteria from the MC were the same as FPP with the addition of a diagnosis of MCI or early dementia (early AD, Vascular Cognitive Impairment, or Mixed Dementia due to AD and Vascular Cognitive Impairment) as determined by the Montreal Cognitive Assessment (MoCA) score >15 and <26, biomarkers, CSF, and imaging, where appropriate and as outlined in diagnostic criteria.[12–16] These specific diagnoses were made by an MC neurologist, using AD biomarkers and/or imaging, and were recorded in the patient charts. Patients were excluded if they had any of the following comorbidities recorded in their chart: (1) additional neurological disease, (2) psychiatric disorder, (3) acute ear infection, (4) severe neck arthritis, or (5) alternative etiology of dementia (*i.e. Huntington's Disease, Lewy Body Dementia, etc.*).

Data on proprioception and the use of benzodiazepines, hypnotics, and anticholinergic medications were only available for MC patients. These data were collected from their medical charts.

Outcomes – Vestibular Impairment

VI was assessed in seniors experiencing falls from both sites (FPP and MC). The following assessments were used to diagnose vestibular impairment: (1) Dix-Hallpike test,[17] (2) video- and bedside-head impulse test (vHIT and bHIT, respectively),[18] (3) the Headshake Test,[19] and (4) modified clinical test of sensory interaction in balance (mCTSIB).[20] All bedside vestibular tests were performed and interpreted by a vestibular physiotherapist. The vestibular audiologist performed the vHIT test and interpreted the results. Both clinicians were blinded to one another's results. VI was diagnosed if the participant had abnormalities on the Dix-Hallpike, vHIT, bHIT, or Headshake test. Possible

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vestibular impairment (PVI) was diagnosed if a participant failed the mCTSIB alone.[20] VOR loss on either side alone was diagnosed as unilateral vestibular hypofunction (UVH), and loss on both sides was diagnosed as bilateral vestibular hypofunction (BVH). Both the vHIT and bHIT were used, as the researchers were interested in assessing the feasibility and usefulness of the bHIT as a future screening tool for vestibular impairments in FPPs. At present, no vestibular testing is included in the initial assessments at FPPs.

vHIT was performed using ICS impulse Video Goggles [GN Otometrics, Taastrup, Denmark] with a camera speed of 250 frames/s and followed the standard procedure described by McGarvie et al., 2015.[21] Participants were instructed to sit at eye level to a small target that was 1 meter in front of them. Participants were instructed to remove their corrective lenses if needed, and a foam insert was used to minimize slippage of goggles.[21] Eye positioning calibration was carried out for all patients by getting the patient to fixate on laser targets on the wall. Neck range of motion was verified prior to testing, and range of motion was modified if any neck stiffness was reported. The audiologist performed a series of head impulses at varying velocities in the horizontal plane only [>120 deg/s up and 300 deg/s].[21] These movements were in random order and direction. Participants were instructed to focus on the target, as their head position was altered from neutral to 20° left or right. The computer software measured head velocity as compared to eye velocity in the opposite direction in order to assess the VOR. Average vHIT gain was calculated with GN Otometrics software as outlined by McGarvie et al. (2015), and any corrective saccades made during the head impulse were recorded.[21] Each head impulse was then interpreted by the vestibular audiologist to ensure that an acceptable impulse was received. A positive vHIT was defined as (1) gain of 0.8 or lower in the horizontal plane with corrective saccades or (2) an observable overt/covert saccade that measured 50% or greater than that of the head velocity.[22]

For the bHIT, patients were seated at the eye level of the vestibular PT and asked to focus on a distant target that was 6 feet away.[23] The patients' head was rotated 20° to the left or right direction, and a rapid thrust was applied bringing the head back to midline. An abnormal test was the presence of an overt saccade (OS). Despite the poor psychometrics of the bHIT, both the vHIT and bHIT were used to see if clinically, the bHIT could be an option in falls prevention program screenings. The bHIT would be a useful first step in flagging patients for further clinical assessments, as the vHIT is costly, laborious, and not feasible as a screening tool.

The Headshake test was utilized to test for vestibular asymmetry, suggesting a UVH. For the Headshake test, the patient began in an upright seated position, wearing infrared goggles.[19] The patient's head was fixated 30° downward and oscillated horizontally for 30 s at a speed of 2 Hz. Eyes were then monitored for the presence of nystagmus, with elicitation of three or greater beats, indicating vestibular asymmetry.[19]

For the mCTSIB, a pre-calibrated Nintendo Wii™ Balance board containing four transducers was used for the detection of force distribution and the resultant movements in the center of pressure (COP). It communicated the pressure changes to a laptop via Bluetooth for the collection of the COP data. Data obtained included total time standing, path distance travelled (path length), and root mean squares (RMS) [anterior–posterior and resultant directions].[24] The "Balance Workshop" Software was used to capture the data.[20,25,26] A fall prior to 30 s in condition 4 (on foam [AIREX® Balance Pad] with eyes closed) was considered a positive test for possible vestibular impairment, since balance in condition 4 is more reliant on the vestibular system.

Outcomes – Cognitive Impairment

The potential of having a CI was assessed in seniors experiencing falls in an FPP and estimated by performance on the MoCA. The MoCA (Version 7.1) was used to assess cognition and administered by a trained vestibular nurse and a graduate student. A score of 16–25 was categorized as a low MoCA score, while a score lower than 16 was categorized as very low MoCA score. Although no imaging or diagnostic markers were used at FPPs, these scores would typically be seen in those with MCI or dementia, respectively.[27,28] However, due to the absence of additional testing, patients were categorized by performance on MOCA and not given a diagnosis.

Outcomes – Dizziness and Balance Questionnaires

Subjective questionnaires included the Dizziness Handicap Inventory (DHI)[29] to quantify self-perceived handicap due to symptoms of dizziness and the Activities-specific Balance Confidence Scale (ABC)[30] to evaluate a patient's confidence to maintain balance while performing various activities.[29] For the DHI, the higher the score out of 100, the greater the patient's perceived handicap due to dizziness. Scores lower than 67% on the ABC are associated with an increased risk of falling.[31]

Statistics

Descriptive statistics were described using proportions and frequencies. Mean and standard deviations were used to describe continuous variables. Statistical analysis regarding the prevalence of VI included both MC patients and patients from FPPs. Statistical analysis regarding the prevalence of CI included only participants from FPPs. The chi-square test was used to test for differences in the proportion of males versus females in our sample of VI and to assess for differences in the proportion of those diagnosed with BVH versus UVH. Student's t-tests were used to determine differences in mean scores of the DHI and ABC between those with VI or no VI (NVI + PVI). A p-value of <0.05 was considered statistically significant. All statistics were performed using SPSS Software Version 25 [IBM™].

Results

Demographics and Vestibular Impairment

Of the 41 participants who were assessed, 29 (70.7%) participants were from FPPs, and 12 (29.3%) participants were from an MC. The overall mean age was 80.1 ± 7.1 years (81.2 ± 7.1 years in FPP vs. 77.3 ± 6.7 years in MC). Data from our MC patients only revealed 3/12 (25%) had a proprioceptive deficit, and only 3/12 (25%) were on an anticholinergic medication at the time of the study. None of the MC patients were on benzodiazepines or hypnotics. Of our total patient population, 58.5% of all participants were female (69% of participants were female at FPPs vs. 33.3% of participants were female at MC). Overall, 34/41 (82.9%) of those screened had VI, 3/41 (7.3%) had PVI due to failure of condition 4

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Table 1: Prevalence of VI in falls prevention programs and an MC ($N = 41$)

	Prevalence	Age ± SD	Left gain ± SD	Right gain ± SD	ABC (%)	DHI
VI	34/41 (82.9)	81.0 ± 7.2	0.89 ± 0.18	0.96 ± 0.16	63.4 ± 27.3	23.5 ± 23.9
*UVH**	*10/34*	*79.7 ± 7.8*	*1.00 ± 0.16*	*1.07 ± 0.12*	*58.4 ± 32.9*	*22.0 ± 25.3*
*BVH**	*24/34*	*81.3 ± 7.0*	*0.84 ± 0.17*	*0.91 ± 0.15*	*65.5 ± 25.2*	*24.2 ± 23.8*
PVI	3/41 (7.3)	79.0 ± 7.9	1.04 ± 0.16	1.15 ± 0.24	75.2 ± 22.9	18.7 ± 22.0
NVI	4/41 (9.8)	74.3 ± 4.5	0.99 ± 0.06	1.04 ± 0.06	92.3 ± 5.3	3.5 ± 4.7

ABC – activities specific balance confidence scale, BVH – Bilateral vestibular hypofunction, DHI – Dizziness Handicap Inventory, VI – Definite Vestibular Impairment, NVI – No vestibular impairment, PVI – Possible Vestibular Impairment, UVH – Unilateral Vestibular Hypofunction.
*Prevalence of UVH and BVH is within the VI group.

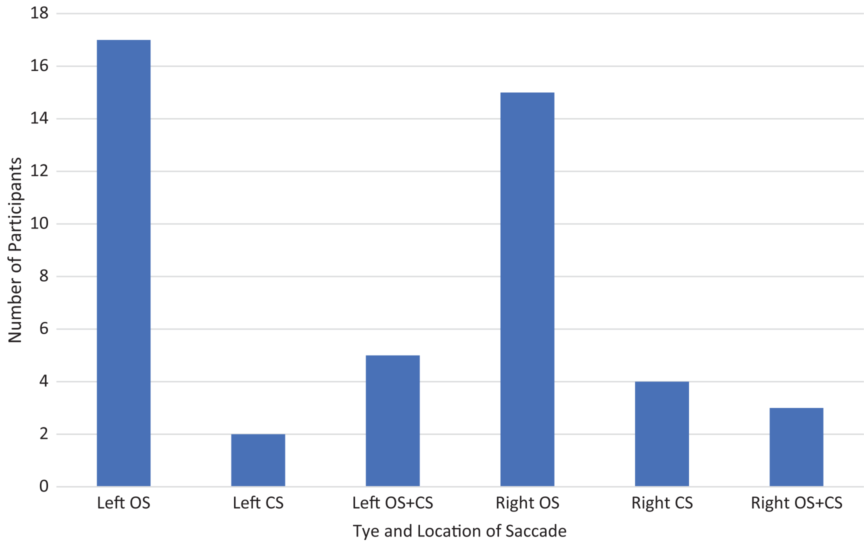

Figure 1: *Presence of OS and CS in those with a VI and an abnormal Video Head Impulse Test (N = 27).*

on the mCTSIB alone, and 4/41 (9.8%) had NVI; see Table 1. Mean age of those with VI was 81.0 ± 7.2 years, and mean age of those with NVI was 74.3 ± 4.5 years. VI was significantly more common in females 23/34 (67.6%) than in males 11/34 (32.4%); $p = 0.040$. Of those with a VI, BVH (70.6%) was significantly more common than UVH (29.4%); $p = 0.016$. Of those with VI, average gain on the vHIT was 0.89 ± 0.18 on the left-hand side and 0.96 ± 0.16 on the right-hand side, respectively. All gain values are shown in Table 1. Overt and covert saccades are shown in Figure 1 and Supplementary Figures 1–4, respectively. MC recruitment is shown in Supplementary Figure 5.

VI was diagnosed based on an abnormal vestibular assessment (Table 2). Some patients declined to complete some parts of the assessment, due to discomfort or physical constraints; i.e. high reliance on a walker to stand. Of these 34 patients with VI, 32/34 (94.1%) participants completed the vHIT, and 27/32 (84.3%) had abnormal results; 33/34 (97.1%) participants completed the bHIT, and 31/33 (93.9%) had abnormal results; 34 (100%) were assessed with the Dix-Hallpike test, and 2/34 (5.9%) were diagnosed with BPPV; 33/34 (94.1%) completed the Headshake test, and 8/33 (24.2%) had nystagmus post headshake. There was discordance between bHIT and vHIT for 4/32 participants that had completed both the bHIT and vHIT. The discordance was attributed to poor fit of the vHIT goggles, resulting in the audiologist to feel that the results were indeterminant. Therefore, in these cases, if corrective saccades were seen by the clinician doing the vHIT, the patient was categorized as positive for vestibular impairment.

Overall, 39/41 patients completed the mCTSIB; 22/39 (62.9%) of those patients failed condition 4 (foam, eyes closed), and 3/22 (13.6%) failed only condition 4 of the mCTSIB, with no other abnormalities on any other test, so were considered to have PVI. All values for path length, RMS, and time standing are included in Table 3.

Cognitive Impairment

Of 29 participants assessed at FPPs, 25 participants completed an MoCA (see Table 4). Four participants were unable to complete the MoCA because of previously diagnosed CI and an inability to understand the MoCA instructions. Overall, 19/25 (76.0%) of participants scored low or very low on the MoCA (Table 4). Of those with poor MoCA scores, 13/25 (52.0%) had MoCA between 16 and 25 (low score), and 6/25 (24.0%) had a score between 0 and 15 (very low score). Of the 22 who

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Table 2: Abnormal tests of vestibular functioning in those with VI ($N = 34$)

Assessment		Prevalence **	Diagnosis
Dix-Hallpike test	Positive	2/34 (5.8%)	BPPV
Video head impulse test	Unilateral	8/32 (25.0%)	Unilateral VORlLoss
	Bilateral	19/32 (59.0%)	Bilateral VOR loss
Bedside head impulse test	Unilateral	11/33 (33.3%)	Unilateral VOR loss
	Bilateral	20/33 (60.6%)	Bilateral VOR loss
Headshake test	Positive	8/33 (24.2%)	Nystagmus

BPPV – Benign paroxysmal positional vertigo, VOR – Vestibulo-ocular reflex.
**Prevalence is based on the proportion of participants completing the tests.

completed an MoCA, 16/22 (72.3%) had both a low/very low score and VI.

Questionnaires

Those with VI had lower mean scores on the ABC, compared to those with PVI or NVI (Table 1). There was a trend for lower confidence scores and suggestion of falls risk on the ABC in those with a VI versus those without VI (PVI + NVI), 63.4 ± 27.3 versus 85.0 ± 16.5; $p = 0.053$, respectively. Most participants [25/41 (60.1%)] had an ABC score greater than 67%, which is above the cutoff for falls risk. Of the 16 with a low confidence score on the ABC (score <67%), 15/16 (93.8%) also had a VI.

Higher mean scores on the DHI suggesting more dizziness handicap were more common in those with VI compared to PVI or NVI (Table 1). However, there was no significant difference in dizziness score between these groups: 23.5 ± 23.9 and 10.0 ± 15.4, respectively; $p = 0.160$.

Discussion

The study results demonstrate that both VI and CI are common in seniors experiencing falls. The high proportion of VI in our study builds on previous findings, suggesting that there is a higher prevalence of vestibular impairments in older adults experiencing falls compared to age-matched non-fallers.[11] In addition, other studies have suggested that there is an increased risk of experiencing a fall in seniors with cognitive impairment.[32,33] However, our study adds to these findings, suggesting that CI may be more common in seniors experiencing falls with VI. Herdman et al.[34] have also suggested that falls are more prevalent in people with VI compared to no VI, in addition to those with BVH compared to UVH.

The vestibular system plays a role in cognition, and this includes perception of self-motion, body awareness, and spatial navigation, spatial learning, and spatial memory.[35] Therefore, it is possible that those with a VI may also have a CI, adding another issue to overcome when designing falls prevention programs. Previous studies have reported associations between VI and impaired visuospatial functioning in those without a formal diagnosis of CI,[6] and in those with either a diagnosis of MCI or AD versus those that are cognitively healthy.[7] In addition, those with MCI or AD have a threefold increased risk of having a VI compared to those without CI.[7] Nakamagoe et al.[8] compared the presence of VI in elderly AD patients versus non-AD patients and young adults and found that there was a significant impairment in balance in 75% of patients with AD (as determined by a stepping test), compared to 25% in non-AD older adults and 0% in younger adults. In addition, VI (as defined by absent/reduced amplitude of eye movement during the caloric test) was more common in older patients with AD, compared to older patients without AD and younger patients.[8] This suggests that both vestibular and cognitive impairment commonly present together and should be considered when designing falls prevention programs.

Both vestibular and cognitive function can be relatively easily screened using validated bedside tests and subjective questionnaires. However, it has been difficult to determine when to screen for vestibular impairment, since not all patients will present with dizziness.[10] This study sought to assess subjective measures of a participant's perceived dizziness; however, despite the high prevalence of VI, the overall DHI scores among all participants were quite low. It is possible that CI may be limiting their ability to complete the questionnaire or recall symptoms. More research is required to assess the validity of the DHI in those with cognitive impairment. Overall participants with VI reported lower balance confidence with activities of daily living (63%). In analyzing the data, there was a trend suggesting higher dizziness handicap and poorer balance confidence in the VI group compared to those with NVI, although the results did not reach statistical significance, likely due to low sample size in the NVI group.

The FPPs known to the authors do not screen for vestibular and/or cognitive impairments, which likely provides a gap in understanding the potential factors impacting a patient's success or failure in the FPP. Also, the current treatment programs in FPPs do not incorporate any vestibular therapy exercise programs, programs that have been demonstrated to be very effective in certain populations, and might be a potential solution for those with both a cognitive and vestibular impairment.[36]

Poor performance on the MoCA was common in those attending an FPP. Overall, 72.3% of those with VI and 100% of those with PVI or no VI performed poorly on the MoCA. Given that education is an essential part of FPP, it is crucial that patients' cognitive function be assessed so as to tailor the FPP for all patients attending.

MCs have an obvious function mitigating and accommodating the impact of CI. Given this study, and other published evidence,[37] that suggest a strong relationship between CI and VI, there could be a role to refer for vestibular assessments and treatments or provide integrated programs. Research suggests that balance training can have a positive effect on memory and spatial cognition;[38] therefore, the collaboration between community falls prevention programs and MCs can improve patient outcomes through referral and design of targeted programs.

The study has some limitations, the most notable being our small sample size, and lack of a control group consisting of seniors with no history of falls. Without a control group, we cannot ascertain if falls are due to vestibular or cognitive impairment, or if both impairments are common in the aging population overall with or without experiencing falls. However, our study does highlight the need to

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Table 3: Modified Clinical Test of Sensory Interaction on Balance (mCTSIB) scores for those with and without a VI ($N = 39$)*

Trial		VI ($N = 32$)	PVI ($N = 3$)	NVI ($N = 4$)
1 – Eyes open, even surface	Total time (/30 s)	30.0 ± 0.0	30.0 ± 0.0	30.0 ± 0.0
	RMS	1.4 ± 0.7	1.7 ± 0.2	1.5 ± 0.6
	Path length (mm)	142.0 ± 70.5	270.2 ± 148.0	137. ± 50.0
2 – Eyes closed, even surface	Total time (/30 s)	29.0 ± 3.8	30.0 ± 0.0	30.0 ± 0.0
	RMS	2.3 ± 1.3	2.9 ± 0.4	1.6 ± 0.7
	Path length (mm)	222.0 ± 116.9	465.2 ± 259.2	211.0 ± 154.1
3 – Eyes open, uneven surface	Total time (/30 s)	27.9 ± 6.9	30.0 ± 0.0	30.0 ± 0.0
	RMS	2.6 ± 1.5	3.6 ± 0.2	2.9 ± 0.8
	Path length (mm)	225.4 ± 139.0	503.3 ± 285.3	257.3 ± 85.2
4 – Eyes closed, uneven surface	Total time (/30 s)	19.7 ± 11.3	8.7 ± 7.0	30.0 ± 0.0
	RMS	5.4 ± 2.2	6.9 ± 2.1	5.7 ± 0.7
	Path length (mm)	316.1 ± 189.7	253.6 ± 292.2	652.8 ± 202.7

VI – Vestibular Impairment, NVI – No Vestibular Impairment, PVI – Possible Vestibular Impairment.
*Two participants with VI were unable to complete the mCTSIB.

Table 4: MoCA performance in seniors experiencing falls at FPPs ($N = 25$)* to assess cognitive functioning

	Low/Very low MoCA score	Mean MoCA ± SD*	Low score 16–25 (%)	Very low score <16 (%)	High score >25 (%)
VI	16/22 (72.3)	21.3 ± 8.2	10 (40.0)	6 (24.0)	6 (24.0)
PVI	2/2 (100.0)	22.5 ± 0.7	2 (8.0)	0 (0.0)	0 (0.0)
NVI	1/1 (100.0)	23	1 (4.0)	0 (0.0)	0 (0.0)

*Only 25 participants had completed an MoCA.

further investigate risk factors in falls. Although our study recruited from both an MC and an FPP, neither can ensure generalizability to the general population. Due to the high prevalence of VI, we could not compare questionnaire results with those having PVI or NVI. Another notable limitation was our limited usage of vestibular function tests to quantify the extent of the vestibular loss; we did not use the caloric test to assess the full spectrum of vestibular function, but we were able to look at the high-velocity range of the VOR with the vHIT. We did have unexpected findings with the HIT. There were a higher number of participants with an abnormal bHIT versus the vHIT. The bHIT has moderate sensitivity for detecting VOR deficits even by experienced clinicians [sensitivity = 66.3–86.84%]. Aside from some indeterminate results with the vHIT due to goggle slippage, the other cause of the discordance between the bHIT and vHIT was likely the cutoff value of 0.80 or less required for an abnormal vHIT. Gain values are often inaccurate in detecting a VI, because they are always averages of all the head impulses [high and low velocity].[39,40] If an abnormal gain was present at a high velocity, but not at a low velocity; then, the average gain may fall within the normal limits. Some participants did, in fact, have abnormal gains at higher head velocities, but the overall gain values were within normal ranges due to the average gain calculation. Another contributor to the discordance was that the audiologist only considered covert or overt saccades in the tracing as abnormal if they were more than 50% of the velocity of the head impulse, whereas all saccades regardless of magnitude were considered abnormal for the bHIT. Although the bHIT has moderate sensitivity for detecting VOR deficits, it is a good test for identifying most normal cases and has been regarded as a clinically useful test and the only bedside test for the examination of high-frequency VOR.[41] Overall, we believe that the bHIT is a useful tool for clinical assessment of patients at risk of falls and should be incorporated into screening assessments as this is an easy, inexpensive test that can detect covert saccades (CS) seen in vestibular impairment, as long as the person who administers the test is properly trained. Furthermore, we did not assess other covariates of interest, which are known to impact risk of falls, such as medication use, proprioceptive deficits, musculoskeletal issues, or hearing-aid use. Given that a small portion of our MC patients had a proprioceptive deficit, we hope to incorporate this assessment into future studies on falls in patients with cognitive impairment.

These limitations do not reduce the significance of our study, which highlights a concern that should be further explored in other sites and in larger populations. Given the consequences of falls for the patient and health care system, all risk factors and solutions must be explored. Given that vestibular and cognitive impairment is common in older adults enrolled in falls prevention programs, novel assessments are warranted to assess fall risk. Dual-task gait function has been used to assess for gait disruptions in individuals with CI so may be a useful tool for participants in falls prevention programs. Moreover, vestibular deficits are amenable to therapy, and targeting the vestibular system may be an approach to reducing the risk of falls in seniors.[36] Additionally, future studies should address all factors

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contributing to risk of falls, given the interplay among the vestibular system, higher cognitive centers, and proprioception.

In conclusion, a comprehensive evaluation of seniors with a history of falls, or at risk of falls, should include both cognitive and vestibular assessments. Effective screening would enable earlier detection, targeted interventions, and prevent falls, which could reduce the clinical and financial impact on both the patient and the health care system.

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Conflict of Interest

The authors report no conflict of interest.

STATEMENT OF AUTHORSHIP

BV is responsible for study design, recruitment, data analysis, and authorship of the manuscript. SS, CW, and WD were responsible for performing tests of vestibular functioning, questionnaires, and editing of the manuscript. CA, NM, and KM assisted with questionnaires. EC and MM assisted with recruitment. JR provided access to vestibular testing equipment and guidance. MCT is the primary investigator.

Supplementary material

To view supplementary material for this article, please visit https://doi.org/10.1017/cjn.2020.154.

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