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Background and Purpose

Traditional vestibular function testing has measured horizontal semicircular canal function only. Otolith function tests have recently been developed, but their clinical significance has not been determined. The purpose of this study was to investigate the influence of otolith dysfunction on the clinical presentation of individuals with a peripheral vestibular disorder.

Subjects and Methods

Twenty-one subjects with loss of horizontal semicircular canal function only and 37 subjects with combined loss of horizontal semicircular canal and otolith organ function were recruited. All subjects received a comprehensive clinical assessment, including self-report questionnaires and measures of balance performance.

Results

No significant differences were identified between subjects with or without otolith dysfunction with respect to symptom severity, self-perceived handicap, functional limitations, or balance performance.

Discussion and Conclusion

Otolith dysfunction does not significantly influence the clinical presentation of individuals with a peripheral vestibular disorder. Other factors, including symptom severity, may be more influential.

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The peripheral vestibular system lies within the inner ear and is made up of 5 sensory organs. There are 3 semicircular canals (horizontal, posterior, and anterior), which provide information regarding angular head velocity, and 2 otolith organs (utricle and saccule), which register linear acceleration and static tilt with respect to gravity. The otolith organs, therefore, differ from the canal structures in that they respond to linear motion instead of angular motion.[1,2]

Despite this fundamental difference in function between semicircular canal and otolith structures, diagnostic testing of vestibular function has traditionally involved measurement of horizontal semicircular canal function only. In particular, function of the horizontal semicircular canal has been the most commonly measured, using both caloric and rotational chair testing.[3] Until recently there were no simple and clinically useful measures to test the integrity of the otolith organs. Two relatively new tests of otolith function are now in common use: static bias testing (a test of utricular function) and vestibular evoked myogenic potential (VEMP) testing (a test of saccular function).

Static bias testing involves the setting of a dimly illuminated light bar to earth vertical (subjective visual vertical) or earth horizontal (subjective visual horizontal) in the absence of visual cues.[4,5] Using subjects with chronic unilateral vestibular loss, a sensitivity of 43% and a specificity of 100% have been determined for static bias testing.[6] Vestibular evoked myogenic potential testing involves the unilateral delivery of loud monaural clicks and the recording of the responses via skin electrodes on the tonically contracted, ipsilateral sternocleidomastoid muscle.[7,8] In relation to the results of caloric testing, a sensitivity of 59% and a specificity of 100% have been determined for VEMP testing.[9] Good test-retest reliability of VEMP responses also has been reported.[10]

To date, however, there has been very little clinical validation of otolith test results, and whether otolith organ involvement influences the clinical presentation of individuals with a diagnosed vestibular lesion remains unknown. Early studies showed that otolith dysfunction resulted in symptoms such as diplopia, sensations of linear motion and tilt, and a feeling of falling.[1,11] These reports were primarily anecdotal, however, and were published before more simple testing of otolith function became available. More recently, it has been claimed that peripheral vestibular abnormalities involving the otolith organs are suggestive of more severe and extensive lesions.[12,13] Additional information was provided by a study that used VEMP testing to measure saccular function in individuals with Meniere disease.[13] The results demonstrated that subjects with no saccular response on the affected side had poorer balance than those with normal VEMP test results.[13]

This association between balance performance and otolith function also has been demonstrated in early studies in both animals and humans.[14,15] The results of these studies suggest that additional otolith organ involvement adversely influences clinical parameters in individuals with peripheral vestibular dysfunction. Clinical assessment, however, has been limited to a single test of balance function, and the functional consequences of poor balance performance, such as an increased incidence of falls, has not been evaluated.

With static bias and VEMP testing now available as measures of otolith function, it is possible to more comprehensively investigate these issues. The aim of the current study was to compare the clinical presentation of subjects with a diagnosed peripheral vestibular disorder with or without involvement of the otolith structures of the inner ear.

Method

Subjects

Subjects were recruited from the audiology departments of Alfred Hospital and Royal Victorian Eye and Ear Hospital in Melbourne, Victoria, Australia. All subjects received a full battery of vestibular function tests, including bithermal caloric testing, static bias testing, and VEMP testing. From the results of these tests, subjects were included in the study if they could be categorized as having either:

1. an isolated unilateral loss of horizontal semicircular canal function only
   - more than a 25% difference between left-sided and right-sided horizontal semicircular canal responses demonstrated on caloric testing (ie, degree of canal hypofunction on affected side greater than 25%, where 100% indicates a complete loss of function) and
   - normal otolith function test results, or
2. a combined unilateral loss of horizontal semicircular canal and otolith organ function
   - more than a 25% difference between left-sided and right-sided horizontal semicircular canal responses demonstrated on caloric testing (ie, degree of canal hypofunction on affected side greater than 25%, where 100% indicates a complete loss of function) and either:
   - abnormal static bias test results (utricular pathway function) (ie, a deviation of the subjective visual horizontal greater than 3° from horizontal) or

- abnormal VEMP test results (saccular pathway function) (ie, an amplitude ratio between left-sided and right-sided responses greater than 3:1, so that the side with the smallest amplitude was considered impaired).

The parameters chosen to indicate vestibular pathology in the current study were selected based on an extensive review of the literature.[16–18] For static bias testing, early studies suggested that subjects without impairments or pathology were able to perform this test with a great degree of accuracy, not deviating more than 2 degrees from true horizontal.[19] More recently, values within 3 degrees from horizontal have been considered to be in the normal range for this test,[6] and this broader range was chosen to identify utricular pathology in the current study.

Table 1.
Vestibular Function Test Results[a]

Vestibular Function Test	Canal Involvement Only (n=21)	Canal and Otolith Organ Involvement (n=37)	*P*
Caloric testing			
Degree of canal hypofunction (%), median (IQ range)	81.0 (41.0–100.0)	72.0 (54.0–100.0)	.409
Side of hypofunction			
Right, n (%)	12 (57%)	18 (49%)	.602
Left, n (%)	9 (43%)	19 (51%)	
Static bias testing			
Normal, n (%)	21 (100%)	18 (49%)	
Abnormal, n (%)	0 (0%)	19 (51%)	
Deviation from horizontal (°), mean (SD)	1.3 (1.0)	4.9 (1.5)	
VEMP testing			
Normal, n (%)	21 (100%)	13 (35%)	
Abnormal, n (%)	0 (0%)	24 (65%)	

[a] IQ=interquartile, VEMP=vestibular evoked myogenic potential.

Subjects were not considered appropriate for the study if they were less than 18 years of age, had an unstable (fluctuating) vestibular lesion,[20] had bilateral vestibular pathology, had benign paroxysmal positional vertigo, had significant orthopedic or neurological deficits that influenced balance and mobility performance and prevented reliable completion of the testing procedure, or had insufficient English-language skills or cognitive ability to provide informed consent or to reliably participate in the testing procedure. All subjects gave written informed consent.

Fifty-eight subjects (30 men, 28 women) were recruited for the study. The mean age of the full sample was 53.4 years (SD=13.7, range=24–81). Based on vestibular function test results, there were 21 subjects (36%) with an isolated unilateral loss of horizontal semicircular canal function only and 37 subjects (64%) with a combined unilateral loss of horizontal semicircular canal and otolith organ function (Tab. 1). For subjects with a combined lesion, 13 (35%) had additional utricular involvement only, 18 (49%) had additional saccular involvement only, and 6 (16%) had impaired function of both otolith organs. For those with utricular involvement (with and without additional saccular dysfunction), the mean deviation from horizontal (measured using static bias testing) was 4.9 degrees (SD=1.5, range=3.2–7.7).

Procedure

Following referral to the study, all subjects received a comprehensive clinical assessment at the balance testing facility. The physical therapist who performed the clinical assessment had no knowledge of the vestibular function test results until after the assessment had been completed.

A detailed history of each subject's current vestibular problem was documented, including time since onset of vestibular dysfunction (in months), use of vestibular suppressant medication, diagnosis (if known), current symptoms (eg, vertigo, dizziness, nausea, hearing loss, tinnitus, visual blurring, linear sensations such as feelings of falling or tilt, balance and mobility impairments, fatigue, reduced concentration), functional limitations (eg, stairs, public transport, driving, work), and history of falls in the previous 12 months.

Self-report Measures

Vestibular Symptom Index. Levels of symptom severity were measured using the Vestibular Symptom Index (VSI).[21] The VSI consists of 6 items (impaired balance, dizziness, vertigo, nausea, visual sensitivity, and headache), which are rated on a scale of 0 to 10, with 0 indicating absence of the symptom and 10 indicating perception of the greatest possible severity. A total score out of 60 is calculated, as a sum of the individual scores for each item.

Dizziness Handicap Inventory. Levels of self-perceived handicap were evaluated using the Dizziness Handicap Inventory (DHI).[22] This tool has been shown to have good content and criterion validity,[23] high internal consistency for the total score (Cronbach alpha=.89),[22] and good test-retest reliability (intraclass correlation coefficient [ICC]=.79–.95).[24] The DHI consists of 25 items, which are marked with "yes" (4 points), "sometimes" (2 points), or "no" (0 points). A total score is calculated out of 100, with higher scores indicating a higher level of self-perceived handicap. Individual scores also are calculated for each of the 3 subscales (functional, emotional, and physical). The maximum possible score is 36 for the functional and emotional subscales and 28 for the physical subscale.

Human Activity Profile. Levels of physical activity were evaluated using the Human Activity Profile (HAP).[25] Good test-retest reliability has been determined for this tool in subjects who participated in a smoking cessation program (ICC=.79).[25] The HAP consists of 94 common activities, which are rated as "still doing," "have stopped doing," or "never did." An Adjusted Activity Score (AAS) is recorded, which is calculated by subtracting the number of lower number activities marked as "have stopped doing" from the highest numbered activity still being done.

Disability Rating Scale. Levels of self-perceived functional disability were measured using the Disability Rating Scale (DRS).[26] The DRS is a 6-point scale (0–5), which ranges from subjects having few symptoms and no disability (score=0) to subjects having severe symptoms and long-term disability so that they have been unable to work for more than a year (score=5).

Dizziness and Balance Measures

Step test. Dynamic standing balance was measured using a step test. Good concurrent validity and high test-retest reliability have been reported for this test in both community-dwelling older people who were healthy (ICC>.90) and in patients with stroke who were undergoing inpatient rehabilitation (ICC>.88).[27] The number of times that subjects could step with one foot completely on and then off a 7.5-cm block in 15 seconds was recorded. Each leg was tested separately, and performance on the worst side was used for data analysis.

Sharpened Romberg test. Static standing balance was measured using the sharpened Romberg test. Good concurrent validity and high interrater reliability (ICC=.95–.99) and test-retest reliability (ICC=.73–.93) have been reported for this test in woman over the age of 55 years who were healthy.[28] The subjects were timed while balancing with one foot directly in front of the other foot, with their eyes open and then closed, for as long as possible. A maximum time of 30 seconds was set.

10-m walk test (with and without head rotation). Usual gait speed was measured using a 10-m walk test. High test-retest reliability has been reported for this test in patients with stroke[29] and individuals with Parkinson disease (ICC=.87).[30] The performance of this test with head rotation also has been recommended in the assessment of individuals with vestibular pathology, because it is thought to facilitate the observation of gait deviations and loss of balance in this population.[31,32] Subjects were timed while walking "at their comfortable walking speed," both with and without head turns and using their customary gait aid, to the end of a 10-m walkway, and walking speed (in meters per minute) was calculated.

Tandem walk test. Walking with a reduced base of support was measured using a tandem walk test. Fair interrater reliability has been reported for this test in older community-dwelling adults (ICC=.62).[33] Subjects walked 15 steps along a line on the floor approximately 1.5 cm wide, and the number of correct steps was counted. A correct step was defined as a step on the line with heel to toe not visibly separated. A maximum score of 15 steps was set.

Computerized dynamic posturography. Static standing balance was measured using computerized dynamic posturography (CDP) (Smart Balance Master System*). The Sensory Organization Test, consisting of 6 test conditions, was performed according to the published protocol. Fair test-retest reliability (ICC=.66) has been reported for this test in adults without impairments or pathology.[34,35] An equilibrium score was calculated for each condition, ranging from 0% to 100%, where 0% represents a fall and 100% represents complete stability. A total composite score also was calculated by adding the single equilibrium scores for all trials and dividing the total by 14.

Data Analysis

Statistical analyses were performed using the SPSS software package.† All continuous variables were analyzed for distribution and skew. Due to the number of comparisons being performed, a more conservative level of significance was used, so that *P* values less than .01 were considered to be significant.

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† SPSS Inc, 233 S Wacker Dr, Chicago, IL 60606.

Between-group comparisons were performed to compare the clinical presentations of subjects with or without otolith dysfunction. For normally distributed data, independent *t* tests were used, and for nonnormally distributed variables, Mann-Whitney *U* tests were used. Ordinal data were analyzed using chi-square tests. Multiple linear regression analyses were used to identify any other factors (eg, age, time since onset of symptoms, degree of canal hypofunction, baseline levels of self-perceived handicap and symptom severity) that might have influenced the clinical presentation of subjects with vestibular dysfunction.

Table 2.
Demographic Information for Subjects With or Without Otolith Organ Involvement

Demographic Information	Canal Involvement Only (n=21)	Canal and Otolith Organ Involvement (n=37)	*P*
Mean age, y (SD)	55.0 (13.1)	52.0 (15.4)	.458
Sex			
Male, n (%)	8 (38%)	22 (59%)	.118
Female, n (%)	13 (62%)	15 (41%)	
Marital status			
Married, n (%)	13 (62%)	25 (67%)	.892
Widowed, n (%)	3 (14%)	4 (11%)	
Never married, n (%)	5 (24%)	8 (22%)	
No. of medications, median (IQ[a] range)	1.0 (0.0–4.0)	2.0 (0.5–3.0)	.849
Regular use of vestibular suppressant medication, n (%)	1 (5%)	6 (16%)	.198
Time since onset of vestibular dysfunction (mo), median (IQ range)	12.0 (7.5–39.0)	7.0 (4.5–24.0)	.075
Total no. of concurrent medical conditions, median (IQ range)	2.0 (1.0–2.0)	1.0 (1.0–2.0)	.114
Diagnosis of vestibular neuritis/ labyrinthitis, n (%)	10 (48%)	18 (49%)	.924

[a] IQ=interquartile.

Results

Demographic Profile

Results demonstrated that there were no significant differences between subjects with or without otolith organ involvement in terms of age (t=0.747, P=.458), sex (χ^2=2.449, P=.118), marital status (χ^2=0.228, P=.892), medication use (z=−0.190, P=.849), time since onset of vestibular dysfunction (z=−1.783, P=.075), and number of pre-existing medical conditions (z=−1.579, P=.114) (Tab. 2).

Symptom Severity and Handicap

The results demonstrated that there were no significant differences between subjects with or without otolith organ involvement in terms of the reported severity of their vestibular symptoms, with balance problems and dizziness the most severe complaints for subjects in both groups (Tab. 3). There also were no significant differences between the groups in terms of reports of self-perceived handicap (Tab. 3). The DHI total score was high for subjects in both groups, and there were no significant differences between the groups with respect to DHI total scores (t=−0.102, P=.919) and the functional (t=−0.193, P=.848), emotional (t=−0.069, P=.946), and physical (t=0.070, P=.944) subscales.

Functional Limitations

A wide range of functional limitations were identified for subjects with or without otolith organ involvement, but no significant differences were found between the groups in this regard (t=−1.450, P=.153) (Tab. 3). Approximately one third of the subjects in both groups reported problems with driving (χ^2=0.00, P=.983), as well as work-related issues (eg, reduced concentration or an inability to climb ladders) (χ^2=1.193, P=.275). There also were no significant differences between the groups in terms of how the vestibular problem was disrupting home or work activities (measured using the DRS) (t=−1.099, P=.278) (Tab. 3). Scores from the DRS indicated that almost 10% of the subjects who reported work-related issues had been unable to work for more than 12 months prior to the clinical assessment (DRS score=5; mean age=44.3 years, SD=3.2). In addition, approximately one third of the subjects in both groups had fallen at least once in the previous 12 months (24% of the full sample had fallen more than once in this time period) (χ^2=1.022, P=.312) (Tab. 3).

Balance Impairments

Some impairment in balance function was identified in subjects with or without otolith organ involvement, particularly on those tests that placed greater demand on the vestibular system for balance (eg, sharpened Romberg test with eyes closed and conditions 5 and 6 of CDP testing) (Tab. 4). There were no significant differences, however, between

Table 3.
Vestibular Symptoms, Levels of Handicap, and Functional Limitations Reported by Subjects With or Without Otolith Organ Involvement[a]

	Canal Involvement Only (n=21), Mean (SD)	Canal and Otolith Organ Involvement (n=37), Mean (SD)	*P*
Total VSI score	22.4 (8.7)	18.8 (10.8)	.750
Balance VSI score	4.7 (1.9)	5.1 (1.7)	.479
Dizziness VSI score	3.9 (2.5)	3.7 (2.7)	.865
Vertigo VSI score	3.3 (3.3)	2.0 (2.5)	.161
Nausea VSI score	1.1 (2.1)	1.7 (2.3)	.432
Visual sensitivity VSI score	4.2 (3.1)	2.7 (2.7)	.122
Headache VSI score	3.3 (4.0)	2.9 (3.2)	.757
Total DHI score	48.4 (15.6)	48.9 (19.5)	.919
Functional DHI score	17.1 (8.6)	17.6 (9.0)	.848
Emotional DHI score	14.9 (5.8)	15.0 (8.5)	.946
Physical DHI score	16.4 (5.1)	16.3 (5.5)	.944
Functional status			
HAP AAS score	68.9 (12.3)	73.4 (10.1)	.153
DRS score	2.5 (1.3)	2.9 (1.0)	.278
Driving problems, n (%)	7 (33%)	13 (35%)	.983
Work-related issues, n (%)	5 (24%)	15 (41%)	.275
History of falls in previous 12 mo, n (%)	9 (43%)	11 (30%)	.312

[a] VSI=Vestibular Symptom Index, DHI=Dizziness Handicap Inventory, HAP AAS=Human Activity Profile Adjusted Activity Score, DRS=Disability Rating Scale.

the groups in terms of static or dynamic balance performance, although there was a trend for subjects with a purely canal lesion to perform less well on conditions 5 and 6 of CDP testing (Tab. 4). Further analysis determined that almost half (48%) of those with a purely canal lesion achieved an equilibrium score of 0 on these tests (ie, fell during balance testing and therefore were unable to complete the tests) compared with less than 20% (18.9%) of those with additional otolith organ involvement. When converted to categorical data (equilibrium score=0 versus equilibrium score>0), however, this difference between the groups did not achieve significance (χ^2=3.279, *P*=.070).

Predictors of Clinical Presentation

Multiple linear regression analysis determined that, after adjusting for other predictors of clinical presentation, levels of symptom severity (measured using the VSI) were significantly predictive of DHI total scores in the full sample (*P*<.001). The results determined that for each 1-point increase in the VSI total score, there was a 1-point increase in the DHI total score (Tab. 5). After adjusting for other predictors of clinical presentation, levels of symptom severity also were found to be predictive of HAP AAS scores in the full sample (*P*=.005) (Tab. 6). The results determined that for each 2-point increase in the VSI total score, there was a 1-point decrease in the HAP AAS score. Age, time since onset of vestibular dysfunction, and degree of canal hypofunction were not found to be predictive of clinical presentation in the full sample (Tabs. 5 and 6).

Discussion

This study comprehensively investigated the clinical significance of otolith dysfunction in subjects with a diagnosed vestibular disorder. The sample as a whole represented people of all ages (from 24 to 81 years), from a range of diverse backgrounds. This was an important observation in itself and demonstrated that the disabling effects of vestibular system disease can be wide-reaching in the general community. With the average age of the sample in the early fifties, however, the majority of subjects were of working age and were previously functioning at a relatively high level. As a result of their vestibular disorder, many of these individuals were now reporting long-standing physical, functional, and emotional issues, which had yet to be addressed.

No participants in the study had previously been referred for a comprehensive clinical assessment of their vestibular problem. In particular, work-related issues and driving restrictions were particularly prevalent among the sample, and the incidence of falls was high compared with similar age groups in the wider community.[36] Given the apparent effectiveness of vestibular rehabilitation in managing these types of problems in individuals with vestibular dysfunction,[37–39] it would appear that there are limitations in the current approach to the assessment and management of dizziness and balance problems in the community.[40] In order to more fully understand the clinical presentation of individuals with vestibular dysfunction, the current study used widely

available tests of otolith function to specifically investigate the clinical significance of otolith dysfunction in individuals with a diagnosed vestibular disorder.

Clinical Significance of Otolith Dysfunction

The current study determined that there were no significant differences in clinical presentation between subjects with or without otolith organ involvement. This finding is in contrast to previous research that suggested that a peripheral vestibular deficit involving the otolith structures was a more severe and extensive lesion, with a potentially poorer prognosis for recovery.[12] In addition, saccular dysfunction has been shown to adversely affect balance performance,[13] with the assumption that other clinical parameters, such as symptom severity and self-reported handicap, also would be adversely influenced by otolith organ involvement. The results of the current study do not support this hypothesis. Using a wide range of measures that tested both static and dynamic balance, additional otolith organ involvement was not found to markedly influence balance performance, nor was it found to increase the likelihood of other adverse consequences such as falls.

The contrasting results demonstrated by the current study were unexpected. Certainly, previous research determined that initial balance deficits of otolithic origin, measured in cats, became more difficult to detect over time, suggesting that the otolith deficiency had been compensated for effectively.[15] This might help to explain the results of the current study, where additional otolith involvement was not found to influence balance performance in a group of subjects with predominantly chronic vestibular dysfunction.

Table 4.
Balance and Mobility Measures for Subjects With or Without Otolith Organ Involvement

Balance/Mobility Measure	Canal Involvement Only (n=21)	Canal and Otolith Organ Involvement (n=37)	*P*
Sharpened Romberg test with eyes open (% at maximum score of 30 s), n (%)	14 (67%)	25 (68%)	.944
Sharpened Romberg test with eyes closed (% unable to complete), n (%)	7 (33%)	13 (35%)	.890
Tandem walk test with eyes open (% at maximum score of 15 steps), n (%)	12 (57%)	21 (62%)	.734
Step test (steps), mean (SD)	13.1 (5.4)	14.5 (6.3)	.373
10-m walk test (m/min), mean (SD)	70.0 (15.0)	76.4 (17.6)	.167
10-m walk test with head rotation (m/min), mean (SD)	57.9 (15.1)	67.1 (19.4)	.069
Computerized Dynamic Posturography			
Condition 4 (% sway), median (IQ[a] range)	79.0 (67.7–85.8)	83.2 (78.2–88.1)	.044
Condition 5 (% sway), median (IQ range)	20.3 (0.0–40.7)	34.9 (12.0–51.2)	.100
Condition 6 (% sway), median (IQ range)	6.3 (0.0–58.2)	34.8 (9.5–55.7)	.430
Composite score (% sway), mean (SD)	55.0 (16.8)	61.9 (11.4)	.099

[a] IQ=interquartile.

Alternatively, for subjects with a purely canal lesion, the presence of intact otolith function, in the absence of adequate canal input, may generate an internal mismatch of sensory input in central vestibular pathways. This sensory mismatch may influence the clinical presentation of this group. The more extensive nature of a vestibular lesion that additionally involves the otolith organs may be offset by the potential sensory conflict provided by intact otolith function in subjects with a

Table 5.
Multiple Linear Regression Predicting Dizziness Handicap Inventory Total Scores From Subject Age, Time Since Onset, Degree of Canal Hypofunction, and Symptom Severity[a]

Overall Regression	R^2	$F_{4,34}$	*P*
	0.330	4.186	.007
Predictors of Total DHI Score	β	95% CI for β	*P*
Age (y)	0.031	−0.4, 0.4	.898
Time since onset (mo)	−0.110	−0.1, 0.04	.264
Degree of canal hypofunction (%)	0.002	−0.2, 0.2	.988
Levels of symptom severity (total VSI score)	1.008	−0.5, 1.5	<.001[b]

[a] DHI=Dizziness Handicap Inventory, CI=confidence interval, VSI=Vestibular Symptom Index.
[b] Levels of symptom severity significantly predictive of DHI total scores ($P<.01$).

Table 6.
Multiple Linear Regression Predicting Human Activity Profile Adjusted Activity Score From Subject Age, Time Since Onset, Degree of Canal Hypofunction, and Levels of Handicap and Symptom Severity[a]

Overall Regression	R^2	$F_{5,29}$	P
	0.464	5.014	.002
Predictors of HAP AAS	β	95% CI for β	P
Age (y)	−0.110	−0.3, 0.2	.536
Time since onset (mo)	−0.011	−0.04, 0.1	.724
Degree of canal hypofunction (%)	0.114	−0.01, 0.2	.080
Levels of handicap (total DHI score)	−0.137	−0.4, 0.1	.208
Levels of symptom severity (total VSI score)	−0.531	−0.9, −0.2	.005[b]

[a] HAP AAS=Human Activity Profile Adjusted Activity Score, CI=confidence interval, DHI=Dizziness Handicap Inventory, VSI=Vestibular Symptom Index.
[b] Levels of symptom severity significantly predictive of HAP AAS ($P<.01$).

purely canal lesion. It would seem, therefore, that vestibular disease that affects even one isolated region of the inner ear (eg, an isolated horizontal semicircular canal loss) can have consequences for the overall integration of all vestibular sensory information.[18]

Incidence of Otolith Dysfunction

An interesting and unexpected finding of this study was that otolith organ involvement was common in the study group, and its prevalence may previously have been underestimated in subjects with a diagnosed peripheral vestibular disorder. A combined vestibular lesion was more common in a ratio of 2:1.

Few previous studies, however, have reported the results of both static bias and VEMP testing together in patients with a peripheral vestibular deficit.[41] Taken individually, VEMP testing has identified impaired saccular function in 25% to 54% of the subjects studied,[9,12,42] with the highest percentage of abnormalities (54%) detected in a group with Meniere disease. Static bias testing also has identified impaired utricular function (ie, a deviation of the subjective visual horizontal of more than 3 degrees from horizontal) in almost half (43%) of individuals with longstanding vestibular disease.[6] The enhanced ratio reported in the current study probably reflects the concurrent testing of both utricular and saccular function. In addition, because these 2 otolith structures subserve different functions within the vestibular system, further research using a larger study population is necessary to identify differences in clinical presentation between individuals with utricular versus saccular dysfunction.

Additional Factors That Influence Clinical Presentation

The results of this study suggest that abnormalities detected using these tests of otolith function may provide further information regarding the extent of pathological involvement, but do not reliably identify subjects with increased functional disability and handicap. Likewise, previous research[43–45] has demonstrated that it is not possible to accurately predict the degree of disability or handicap that is produced by vestibular disease simply by considering the results of caloric and rotational chair tests. It is possible that factors other than physiologic status play a more major role in influencing the clinical presentation of individuals with a diagnosed peripheral vestibular disorder. Further research is currently under way to investigate whether these factors (in addition to otolith organ involvement) also influence outcome following a program of vestibular rehabilitation in individuals with a diagnosed vestibular disorder.

In the current study, the reported severity of the vestibular symptoms was found to be highly predictive of clinical parameters, such as handicap scores and functional status. Similar findings have been reported by other authors,[45,46] suggesting that individuals who experience more severe vestibular symptoms also are more likely to be functionally limited and to feel more handicapped by their disorder. In addition, self-report measures such as these are likely to be influenced to some degree by psychological and behavioral issues,[47] and the effect of these factors cannot be underestimated in individuals with vestibular system disease. In particular, individual coping mechanisms, negative beliefs, heightened levels of anxiety and depression, and the strength of social support systems have been shown to severely impair the recovery process.[48,49] Screening for psychological factors, therefore, is an important component of the clinical assessment of individuals with vestibular dysfunction, regardless of diagnostic test results.[50,51] If significant psychological involvement can be identified, then additional cognitive and behavioral strategies may be useful complements to an exercise-based program of vestibular rehabilitation.[51,52]

Limitations

The results obtained in the current study were dependent upon the appropriate allocation of subjects to the 2 study groups. A limitation of the current study was the potential for incorrect allocation of subjects to these groups. The sensitivity of the otolith function tests used in this

study has been reported to be in the range of 40% to 60%[6,9]; therefore, individuals with otolith dysfunction may have been incorrectly allocated to the group with semicircular canal involvement only.

An additional limitation of the current study was the large degree of variability evident within the study samples. In particular, this variability was in terms of age and time since onset of symptoms. Neither of these factors, however, was found to be predictive of clinical presentation in the study population. Previous research studies, specifically investigating the influence of otolith dysfunction, controlled for some of these variables by using well-defined diagnostic groups (eg, subjects with Meniere disease)[13] or by studying subjects only in the acute phase of their vestibular disorder.[12] The population investigated in the current study, however, was very similar to individuals who are commonly seen in an outpatient department for a comprehensive clinical assessment of vestibular dysfunction. The current study, although not without limitations, therefore is particularly relevant to standard clinical practice and illustrates the high degree of variability that exists among individuals with a diagnosed peripheral vestibular disorder.

A final limitation of the current study was that many of the measures used were originally designed for other patient populations, and there is a need for concurrent validity and reliability testing in individuals with vestibular dysfunction. In addition, further analysis determined that, for the current study, the power was low, and therefore finding no difference between the groups may have been due to the small size of the study population. Sample size calculations at a power of 0.8 subsequently determined that 100 subjects would be required in each group to identify a difference between the samples.

Conclusion

No significant differences were found in the clinical presentation of subjects with a diagnosed peripheral vestibular disorder, irrespective of whether the otolith organs were or were not involved. This is in contrast to previous literature and suggests that the presence of intact otolith function in subjects with a purely canal lesion may create an internal sensory mismatch of signals in central vestibular pathways. The degree of expected disability that is produced by a more extensive combined canal and otolith lesion may be more than offset by the potential sensory conflict provided by intact otolith function in people with a purely canal lesion. It also may be that other factors, such as symptom severity and psychological issues, play a more major role in influencing the clinical presentation and functional consequences associated with vestibular dysfunction.

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This study received approval from the research and ethics committees at Alfred Hospital and Royal Victorian Eye and Ear Hospital.

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