The Journal of Laryngology & Otology (2013), ***127***, *1169–1176.*
© JLO (1984) Limited, 2013
doi:10.1017/S0022215113002302

MAIN ARTICLE

Vestibular functioning and migraine: comparing those with and without vertigo to a normal population

B J BAKER[1], A CURTIS[2], P TRUEBLOOD[3], E VANGSNES[4]

[1]Physical Therapy Department, Grand Valley State University, Grand Rapids, Michigan, [2]Interdisciplinary Health Sciences Department, Western Michigan University, Kalamazoo, [3]Physical Therapy Department, California State University, Fresno, and [4]Physician Assistants Department, Western Michigan University, Kalamazoo, USA

Abstract

Objective: This study compared vestibular functioning in a migrainous vertigo group, a migraine without vertigo group and a control group. It was hypothesised that the migrainous vertigo group would perform worse in tests of vestibular function and gait than the other groups during a non-migrainous period.

Methods: Sixty-six participants (22 per group) were assessed using the head shake sensory organisation test, the gaze stabilisation test, the dynamic visual acuity test and the functional gait assessment. Separate analyses of variance and planned pair-wise comparisons (alpha = 0.05) were performed.

Results: There was a difference between the results of the non-migraine group and the two migraine groups for the gaze stabilisation pitch test ($p < 0.003$), in which the control group showed faster head movement. There were also group differences in functional gait ($p < 0.0001$); the control group scored highest and the migrainous vertigo group scored lowest. There were no differences in the vestibular spinal reflex and balance tests.

Conclusion: These findings indicate underlying differences in the vestibular ocular reflexes and function of migraine sufferers compared with those who do not suffer migraines, but the difference is most pronounced for those with migrainous vertigo. This suggests that vestibular rehabilitation for migrainous vertigo should focus on vestibular ocular reflexes and functional retraining.

Key words: Migraine; Vertigo; Rehabilitation

Introduction

Migraine in general affects approximately 6 per cent of men and 18 per cent of women.[1,2] It is estimated that 38 per cent of the migraine population also have vertigo.[3] People with migraine and vertigo can be divided into two categories: those with migrainous vertigo (vertigo is directly related to the migraine and there is no other cause of vertigo present)[4] and those with migraine-associated vertigo (vertigo exists separately but in association with the migraine).[5]

Lempert and Neuhauser have developed criteria which aid in the diagnosis of migrainous vertigo.[4] Such criteria are necessary because migrainous vertigo is often underdiagnosed, despite being a relatively prevalent problem,[3–9] and because this condition is currently not recognised as a specific category of migraine by the International Headache Society's classification of migraines.[10] Using Lempert and Neuhauer's categorisation,[4] the current study examined the vestibular system of those with migrainous vertigo by comparing findings of this sample with a migraine without vertigo group and a non-migraine group.

Vestibular rehabilitation for migrainous vertigo was suggested by a small study to be effective in treating abnormalities in vestibular ocular reflexes, vestibular spinal reflexes (and balance) and function.[11] Two larger studies showed the effectiveness of vestibular rehabilitation for migraine-associated vertigo.[12,13] However, assessments of vestibular function, such as the gaze stabilisation test, the dynamic visual acuity test for vestibular ocular reflexes, the head shake sensory organisation test for vestibular spinal reflexes (specifically for balance) and the functional gait assessment for overall function, have not been studied in a migrainous vertigo population. Therefore, it is not known whether there is an underlying functional abnormality in the vestibular system of individuals with migrainous vertigo during a non-migrainous

Presented orally at the American Physical Therapy Association Combined Sections Meeting, 20–24 January 2013, San Diego, California, USA.
Accepted for publication 12 February 2013 First published online 22 October 2013

https://doi.org/10.1017/S0022215113002302 Published online by Cambridge University Press

period, and if so, whether the problem exists in both the vestibular ocular reflexes and the vestibular spinal reflexes (and balance).

The vestibular ocular reflexes and vestibular spinal reflexes (and balance) are part of a complex vestibular system composed of peripheral apparatus and a collection of central nuclei.[14–16] The peripheral apparatus sends messages to the central nuclei regarding angular and linear acceleration of the head.[14–16] The central nuclei process these messages and relay them up and down the spinal cord.[14–16] The superior and medial vestibular nuclei relay messages up to the eyes and control the vestibular ocular reflexes.[15,16] The lateral vestibular nuclei relay messages down to the skeletal muscles and control the vestibular spinal reflexes.[15,16] Communication between the vestibular nuclei and the cerebellum is controlled by the medial vestibular nuclei.[15,16] Exploration of this complex vestibular system can be conducted in several ways using otoneurological tests and functional clinical tests.

Researchers utilising otoneurological tests have generally found that the working of the vestibular system is normal during the non-migrainous period in people with migrainous vertigo.[7,11,17–22] However, 20 per cent of people with migrainous vertigo have hypoexcitability to caloric stimulation and 10 per cent have directional preponderance of caloric-induced nystagmus.[21,22] These findings are not unique to the migrainous vertigo population and may also be seen in the migraine without vertigo population.[21,22] There are uncertainties as to why vestibular symptoms are different between those who suffer from migraine without vertigo and those who suffer from migrainous vertigo, and why vestibular rehabilitation performed during a non-migrainous period may be effective for migrainous vertigo. In order to determine if all components of the vestibular system are functioning normally in migraine sufferers (both those without vertigo and those with migrainous vertigo) compared with a normal population, studies need to examine vestibular ocular reflexes, vestibular spinal reflexes (and balance) and function. The identification of specific underlying abnormalities in the vestibular system during a non-migrainous period could benefit vestibular rehabilitation in those with migrainous vertigo.

Vestibular ocular reflexes can be measured functionally in two ways, using the gaze stabilisation test and the dynamic visual acuity test.[23] The gaze stabilisation test measures how fast the head can move whilst maintaining a visual image.[23,24] Pritcher *et al.* found that the gaze stabilisation test results were abnormal in people with vestibular dysfunction, especially during pitch plane movements.[24] The findings of Whitney *et al.* also showed that people with vestibular disorders had difficulty with gaze stabilisation during yaw movements, but the effect was greater during pitch movements.[25] The dynamic visual acuity test compares visual acuity with the head still and the head moving.[26] This is also a test of vestibular ocular reflex function. Again, studies have been conducted exploring dynamic visual acuity in people with vestibular disorders,[23–26] but not specifically in those who suffer from migraine without vertigo or migrainous vertigo.

Vestibular spinal reflexes and balance, which can be assessed using the head shake sensory organisation test, has not been studied in the migrainous vertigo population. The head shake sensory organisation test was developed to provide additional information on those with mild vestibular disorders who may be well compensated (an abnormal vestibular system but normal sensory organisation test result).[27–30] Three studies found that the test results were worse in those with vestibular disorders than those without vestibular disorders.[28–30] However, this test has not been employed to study migraine without vertigo or migrainous vertigo.

Functional testing, specifically gait testing, has been used extensively to assess those with vestibular disorders.[31–33] Several gait tests have been developed to test gait function in those with vestibular disorders.[31–33] The most recently developed test is the functional gait assessment, which was developed to evaluate postural stability during gait.[31–33] In one study that used the functional gait assessment, it was found that slow, pitch plane movements of the head were predictive of gait abnormalities in people with vestibular disorders (BJ Baker, unpublished data). In a pilot study examining gait in those affected by migraine, higher functional gait assessment scores were demonstrated for the migraine without vertigo group compared with the migrainous vertigo group during a non-migrainous period.[34]

Differences in the test results of vestibular ocular reflexes, vestibular spinal reflexes (and balance) and function have been found between those with normal and abnormal vestibular systems.[23–34] However, no studies have attempted to define vestibular function, vestibular ocular reflexes, vestibular spinal reflexes (and balance) and function in a migraine without vertigo population or a migrainous vertigo population during a non-migrainous period, and examined the findings in relation to a non-migraine population.

This study aimed to determine whether there is underlying vestibular dysfunction in the migrainous vertigo population compared with the migraine without vertigo population and the non-migraine population, as measured by the gaze stabilisation test, dynamic visual acuity test, head shake sensory organisation test and functional gait assessment. It was hypothesised that there would be a difference in the scores of these tests for the migrainous vertigo population when compared with the other two groups. Evaluation of vestibular functioning in those with migrainous vertigo during a non-migrainous period should aid the efficacy of vestibular rehabilitation for this group, and may even improve treatment techniques.

https://doi.org/10.1017/S0022215113002302 Published online by Cambridge University Press

Materials and methods

Study design and sample

Sixty-six participants aged between 18 and 65 years were recruited from a university campus (via an online listing service) and from local neurological clinics. The study was a descriptive, case–control study. Twenty-two participants were recruited for each of three subject groups: a migraine without vertigo group, a migrainous vertigo group and a control group.

For the 44 participants with a history of migraine, the diagnosis was confirmed by a physician where possible. Attempts were made to verify diagnosis by faxing the physicians for confirmation. Response from physicians was poor; therefore, self-report was used when physician confirmation was not available. Credibility of self-reported diagnosis was increased with the use of a survey (developed by Furman *et al.*), which determined possible and probable migrainous vertigo.[35]

Exclusion criteria included the use of an assistive device, reports of a neurological condition or vestibular condition other than migrainous vertigo, a history of head trauma, or an orthopaedic disorder which affected balance or head movement.

This study was approved by the Western Michigan University Human Subjects Institutional Review Board and the Grand Valley State University Human Research and Review Committee. Each subject was given an informed consent to read, query and then sign. Two different demographic forms were used: one for the participants without migraine and another for those with migraine. The participants with migraine were then asked to sign several disclosure forms and to include the name of their physician (used for contacting the physicians).

Assessments and procedures

Participants were tested during a non-migrainous period and during a time when they did not have vertigo, as confirmed by a visual analogue scale for pain and vertigo. Each participant in the migraine groups responded to the questions in the Furman *et al.* survey,[35] which were based on Lempert and Neuhauser criteria for migrainous vertigo.[4]

All participants were tested with the same battery of tests, which included the gaze stabilisation test (yaw and pitch), the dynamic visual acuity test (yaw and pitch), the head shake sensory organisation test (yaw and pitch) and the functional gait assessment. The order of the tests were randomised using a random number table; the order of yaw and pitch movements were also randomised.

Performance in the gaze stabilisation test and dynamic visual acuity test (employed to examine vestibular ocular reflexes) was quantified using the inVision System™, which is part of the NeuroCom EquiTest system (NeuroCom International, Clackamas, Oregon, USA). Static visual acuity and perception time were measured, with the participant seated approximately 3 metres from the computer screen. A head piece was placed on the participant's head to detect the speed and direction of head movement. The participant performed both yaw and pitch head movements (in a random order). The participant moved his or her head, stopping when a visual cue appeared on the screen.

The gaze stabilisation test has been determined to be reliable (intraclass correlation coefficient = 0.75) and valid.[23] The results of this test are recorded in degrees per second and range from 0–200, with 200 being the optimal gaze stabilisation score. The dynamic visual acuity test compares static visual acuity to dynamic visual acuity, and the results are calculated by the computer. Dynamic visual acuity loss was recorded in terms of the logarithm of the minimum angle of resolution, with possible scores ranging from 0 to 1, with 1 indicating a total loss of dynamic visual acuity.[26]

Vestibular spinal reflexes and balance were examined using the head shake sensory organisation test, which is an instrumental test of the vestibular spinal reflexes.[28–30,36] This test was performed on the Smart EquiTest system (NeuroCom International), which is a computerised dynamic posturography instrument that has been shown to be reliable and valid.[36] A harness was placed on the participant for safety, and the participant's feet were positioned as per the Smart EquiTest system protocol. Each participant wore flat, non-slip shoes.

The head shake sensory organisation test required performance in two conditions which physiologically stressed the vestibular system.[28–30,36] In the first condition, referred to as the fixed head shake sensory organisation test, participants' eyes closed and they were stood on a firm surface. The second condition, the sway head shake sensory organisation test, was also performed with eyes closed, but took place on a moveable surface. In each condition, the participant performed yaw and pitch head movements. Equilibrium scores for both conditions of the head shake sensory organisation test were determined by the computer (which entailed a comparison of the head-still condition with the head-moving condition, for both yaw and pitch movements). Total possible scores for the head shake sensory organisation test ranged from 0 to 100 per cent, with 100 per cent demonstrating optimal postural control.[36]

This was followed by the functional gait assessment, a test which required the use of vestibular ocular reflexes and vestibular spinal reflexes (and balance). This 10-item walking test battery has demonstrated reliability (intraclass correlation coefficient = 0.93).[31–33] During this assessment, the subject was guarded to prevent falls. Each item was scored according to the criteria, based on a 4-point scale with a score of 3 being normal.[31] The total score for the 10 tasks was recorded. The total possible score ranges from 0 to 30, with 30 being a perfect score.[31]

https://doi.org/10.1017/S0022215113002302 Published online by Cambridge University Press

Results and analysis

Analyses were performed using the Statistical Package for the Social Sciences version 18.0 (SPSS, Chicago, Illinois, USA). The variables were not normally distributed. Analysis of variance was conducted using Helmert planned comparisons when variables were statistically significant at the alpha = 0.05 level. For the planned comparisons, the control group were first compared with both migraine groups combined and then the two migraine groups were compared.

There were 66 participants in total: 22 in the non-migraine group, 22 in the migraine without vertigo group and 22 in the migrainous vertigo group. Of the 66 participants, 59 were female. There were four males in the non-migraine group, no males in the migraine without vertigo group and three males in the migrainous vertigo group. Participant ages ranged from 18 to 61 years of age. The mean age was 26 years for the non-migraine group (range of 23–57 years), 27 years for the migraine without vertigo group (range of 18–61 years) and 35 years for the migrainous vertigo group (range of 20–57 years). No history of neurological disorders or vestibular disorders other than migrainous vertigo were reported by participants in any of the three groups, and none of the participants suffered from any orthopaedic disorders that would limit participation.

As shown in Table I, there was a significant difference ($p < 0.015$) between the total number of medications used by the non-migraine group (mean = 1.64), the migraine without vertigo group (mean = 3.73) and the migrainous vertigo group (mean = 4.41). However, the difference between the migraine without vertigo group and migrainous vertigo group was not significant when examined using planned comparisons. There were no significant differences between the migraine without vertigo group and the migrainous vertigo group in terms of either the number of non-prescription migraine medications ($p < 0.819$) or that of prescription migraine medications ($p < 0.228$). It should be noted that many of the medications used for vertigo in the migrainous vertigo group were also used for nausea in the migraine without vertigo group.

TABLE I
GROUP MEDICATION DATA

Meds taken	Control†	M†	MV†	*F*	*p*
Total (*n*)	1.64	4.41	3.73	4.49	0.015*
Non-prescription migraine meds (*n*)	0.00	0.32	0.18	0.05	0.819
Prescription migraine meds (*n*)	0.00	0.86	0.68	1.48	0.228

*Bonferroni correction post-hoc analyses revealed that: the control group versus the migraine without vertigo group comparison was not significant ($p = 0.102$), the control group versus the migrainous vertigo group comparison was significant ($p = 0.015$) and the migraine without vertigo group versus the migrainous vertigo group comparison was not significant ($p = 1.00$). †$n = 22$. M = migraine without vertigo; MV = migrainous vertigo; meds = medications

Vestibular ocular reflexes testing (shown in Table II) indicated no statistically significant differences between the three groups for left and right gaze stabilisation test performance in the yaw plane ($p < 0.230$ and $p < 0.222$, respectively). The mean left gaze stabilisation test scores for the yaw plane were: 166.05 degrees per second (standard deviation (SD) = 53.25) for the non-migraine group, 153.46 degrees per second (SD = 49.65) for the migraine without vertigo group and 139.90 degrees per second (SD = 44.78) for the migrainous vertigo group. The mean right gaze stabilisation test scores for the yaw plane were: 167.23 degrees per second (SD = 34.35) for the non-migraine group, 155.00 degrees per second (SD = 47.13) for the migraine without vertigo group and 144.95 degrees per second (SD = 42.65) for the migrainous vertigo group.

There was a statistically significant difference between the three groups for up and down gaze stabilisation test performance in the pitch plane ($p < 0.003$ and $p < 0.002$, respectively) (see Table II). The mean up gaze stabilisation test scores for the pitch plane were: 163.45 degrees per second for the non-migraine group, 125.82 degrees per second for the migraine without vertigo group and 116.91 degrees per second for the migrainous vertigo group. The mean down gaze stabilisation test scores for the pitch plane were: 157.50 degrees per second for the non-migraine group, 123.09 degrees per second for the migraine without vertigo group and 108.68 degrees per second for the migrainous vertigo group. Planned comparisons showed that the difference between the control group and both migraine groups was statistically significant ($p < 0.0001$), but there was no significant difference between the migraine without vertigo group and the migrainous vertigo group in up and down pitch movements ($p = 0.500$ and $p = 0.273$, respectively).

Vestibular ocular reflex testing using the dynamic visual acuity test indicated no statistically significant differences between the three groups for left and right dynamic visual acuity in the yaw plane ($p < 0.434$ and $p < 0.412$, respectively), or up and down in the pitch plane ($p < 0.726$ and $p < 0.958$, respectively).

The vestibular spinal reflex and balance testing results are shown in Table III. There were no statistically significant differences in the head shake sensory organisation test results for the yaw plane, in either the fixed and sway conditions ($p < 0.197$ and $p < 0.068$, respectively), between the non-migraine group (fixed mean = 96 per cent (SD = 4) and sway mean = 74 per cent (SD = 23)), the migraine without vertigo group (fixed mean = 89 per cent (SD = 24) and sway mean = 65 per cent (SD = 27)) and the migrainous vertigo group (fixed mean = 96 per cent (SD = 13) and sway mean = 81 per cent (SD = 16)). There were also no differences in the head shake sensory organisation test results for the pitch plane, in

https://doi.org/10.1017/S0022215113002302 Published online by Cambridge University Press

TABLE II
VESTIBULAR OCULAR REFLEX DATA

Test	Control		M		MV		*F*	df	*p*
	Mean	SD	Mean	SD	Mean	SD			
GST yaw left (degree/sec)	166.05	53.25	153.46	49.65	139.90	44.78	1.503	2	0.230
GST yaw right (degree/sec)	167.23	34.35	155.00	47.13	144.95	42.65	1.541	2	0.222
GST pitch up (degree/sec)	163.45†	34.50	125.82‡	50.28	116.91‡	44.50	6.505	2	0.003*
GST pitch down (degree/sec)	157.50†	25.43	123.09‡	49.37	108.68‡	50.07	6.757	2	0.002*
DVA yaw left (LogMAR)	0.145	0.102	0.191	0.102	0.156	0.146	0.846	2	0.434
DVA yaw right (LogMAR)	0.141	0.125	0.1832	0.092	0.1786	0.130	0.900	2	0.412
DVA pitch up (LogMAR)	0.179	0.141	0.169	0.108	0.206	0.155	0.322	2	0.726
DVA pitch down (LogMAR)	0.174	0.150	0.177	0.148	0.165	0.125	0.042	2	0.958

*$p < 0.05$. †Helmert planned comparison revealed a significant difference between the control group and the two migraine groups ($p < 0.0001$). ‡Helmert planned comparisons between the two migraine groups were not statistically significant for up and down movements ($p = 0.500$ and 0.273, respectively). M = migraine without vertigo; MV = migrainous vertigo; df = degrees of freedom; SD = standard deviation; GST = gaze stability test; degree/sec = degrees per second; DVA = dynamic visual acuity loss; LogMAR = logarithm of the minimum angle of resolution

either the fixed or sway conditions ($p < 0.606$, $p < 0.419$, respectively), between the non-migraine group (fixed mean = 93 per cent (SD = 5) and sway mean = 71 per cent (SD = 17)), the migraine without vertigo group (fixed mean = 90 per cent (SD = 21) and sway mean = 64 per cent (SD = 20)) and the migrainous vertigo group (fixed mean = 94 per cent (SD = 7) and sway mean = 71 per cent (SD = 25)).

The functional gait assessment results (Table III) indicated statistically significant differences between the control group (mean = 29.5, SD = 0.67), the migraine without vertigo group (mean = 27.8, SD = 0.19) and the migrainous vertigo group (mean = 26.0, SD = 0.23) ($p < 0.0001$ for the control group *vs* both migraine groups, $p < 0.0001$ for the migraine without vertigo group *vs* the migrainous vertigo group). Planned comparisons showed that there were differences between the control group and the two migraine groups ($p < 0.0001$), and between the migraine without vertigo group and the migrainous vertigo group ($p = 0.002$).

Discussion

Vestibular ocular reflexes, vestibular spinal reflexes (and balance) and function were examined in a control group, a migraine without vertigo group and a migrainous vertigo group during a non-migrainous period. Vestibular ocular reflexes, as measured by the gaze stabilisation test (pitch movements), were faster in the control group than in the two migraine groups. Scores for function, as measured by the functional gait assessment, were highest in the control group and lowest the migrainous vertigo group.

Vestibular spinal reflexes and balance (measured using the head shake sensory organisation test) were not statistically significantly different between the three groups. As vestibular spinal reflexes are controlled by the lateral vestibular nucleus,[15,16] it is possible that the latter is not involved in migraine without vertigo and migrainous vertigo; hence, vestibular spinal reflexes and balance responses are normal in these populations. This finding suggests that vestibular rehabilitation for migrainous vertigo should not concentrate on balance or other vestibular spinal reflex functions.

Vestibular ocular reflexes were measured (in pitch and yaw movements) by both the dynamic visual acuity test and the gaze stabilisation test. The dynamic visual acuity test results showed no statistically significant differences between the three groups. Because dynamic visual acuity is not as reliable between subjects as it is within subjects, it may not have been the most appropriate test for this study.[26]

TABLE III
VESTIBULAR SPINAL REFLEX, BALANCE AND GAIT DATA

Test	Control		M		MV		*F*	df	*P*
	Mean	SD	Mean	SD	Mean	SD			
HS-SOT yaw fixed	96%	4	89%	24	96%	13	1.668	2	0.197
HS-SOT yaw sway	74%	23	65%	27	81%	16	2.805	2	0.068
HS-SOT pitch fixed	93%	5	90%	21	94%	7	0.505	2	0.606
HS-SOT pitch sway	71%	17	64%	20	71%	25	0.882	2	0.419
FGA score	29.5†	0.67	27.8‡	0.19	26.0‡	0.23	19.6	2	0.000*

*$p < 0.05$. †Helmert planned comparison revealed a significant difference between the control group and the two migraine groups ($p < 0.0001$). ‡Helmert planned comparison revealed a significant difference between the between two migraine groups ($p = 0.002$). M = migraine without vertigo; MV = migrainous vertigo; df = degrees of freedom; SD = standard deviation; HS-SOT = head shake sensory organisation test; FGA = functional gait assessment

https://doi.org/10.1017/S0022215113002302 Published online by Cambridge University Press

The gaze stabilisation test results revealed significantly faster up and down pitch movements for the control group compared with the two migraine groups (during a non-migrainous period), but there were no differences between the groups for yaw plane movements. Other researchers' results indicate that movements in a pitch plane are more difficult to perform than movements in a yaw plane, and this may be why significant differences were seen in the pitch plane but not in the yaw plane.[24,25]

Pitch velocity means are clinically important. A gaze stabilisation speed of 120 degrees per second is considered normal for pitch movements, and encompasses everyday functional activities.[24] The control group mean and the migraine without vertigo group mean were both above 120 degrees per second for pitch movements (150 and 125 degrees per second, respectively), but the migrainous vertigo group mean was below 120 degrees per second (108 degrees up and 116 degrees down per second), which is slower than normal. However, there was no statistically significant difference between the two migraine groups in terms of the participants who scored below 120 degrees per second. There was wide variability in the gaze stabilisation test scores in both the migraine without vertigo group and the migrainous vertigo group (Figure 1), which helps to explain this finding.

The differences found for vestibular ocular reflexes could be explained by the lateral and inferior nuclei, which control the vestibular ocular reflexes;[15,16] these may function differently in those who suffer from migraine compared with those who do not. The large variability, especially that observed in the migrainous vertigo group, needs to be studied further. Perhaps the migrainous vertigo population is heterogeneous in regards to vestibular function and cannot be categorised.

Normal vestibular function requires vestibular spinal reflexes, specifically balance, and vestibular ocular reflexes. Functional testing with the functional gait assessment can distinguish between those with vestibular dysfunction and those with normal vestibular functioning.[31–33] A small pilot study showed that functional gait assessment scores were higher in a migraine without vertigo group compared with a migrainous vertigo group.[34] This supports our finding of a difference between the three groups, with the migrainous vertigo group scoring the lowest and the control group scoring the highest. This also indicates that the vestibular systems of individuals with migrainous vertigo function differently to those in the other populations. Furthermore, the difference between the control group and the migraine without vertigo group suggests that there might even be some structural vestibular differences affecting function in those suffering from migraine without vertigo.

The functional gait assessment scores for each of the experimental groups can be compared with age-based

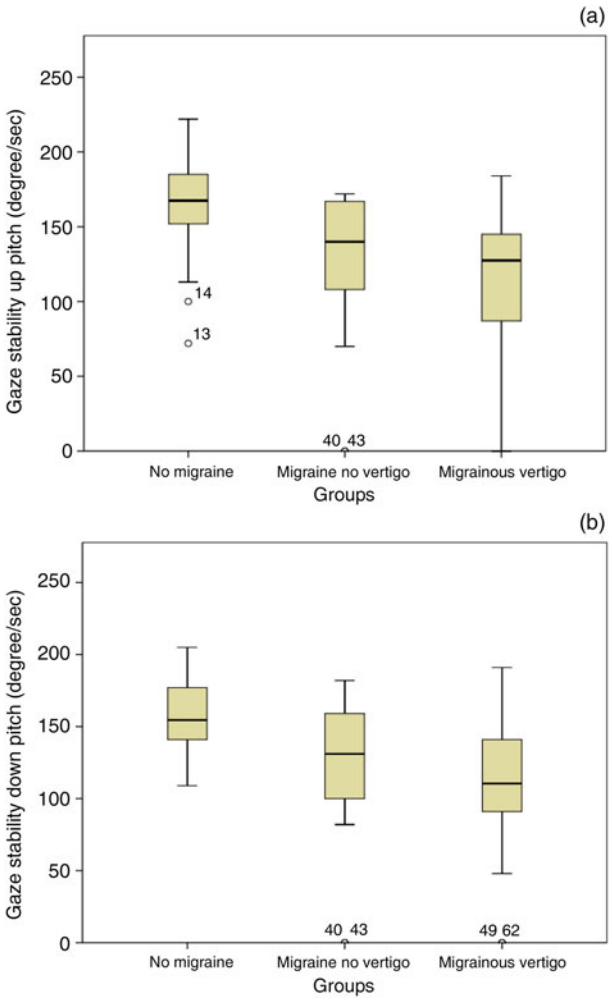


FIG. 1
Gaze stability test pitch results for (a) up and (b) down movements. Degree/sec = degrees per second

norms found in another study.[32] Walker *et al.* determined the normative means of community dwelling adults between the ages of 40 and 89 years on the functional gait assessment.[32] They found an inverse relationship between age and functional gait assessment mean score, wherein the mean score decreased every 10 years. For the 40–49 year age group, the average functional gait assessment score was 29. Normative values were not determined for the 20–29 year age group or the 30–39 year age group, and the values for these groups may be higher than in the 40–49 year age group.[32] In the current study, all three groups had a mean age of less than 40 years. The mean age of the control group was 26 years; this group had a mean functional gait assessment score of 29.5. The mean age of the migraine without vertigo group was 27 years, with a mean score of 27.8. The mean age of the migrainous vertigo group was 35 years, with a mean score of 26.0. Both the migraine without vertigo group and the migrainous vertigo group had scores below those of subjects in the 40–49 year age group in the Walker *et al.* study.

https://doi.org/10.1017/S0022215113002302 Published online by Cambridge University Press

The current study revealed a significant association between the gaze stabilisation test results for pitch movements and the functional gait assessment scores in all three groups. The results of a study by Whitney *et al.* who explored the relationship between gaze stabilisation test scores for pitch movements and scores on functional measures of gait in older people with vestibular dysfunction, support this finding.[25] Our findings demonstrate that this relationship is present even in a younger population.

Our findings suggest that there are differences in the vestibular systems of those who suffer from migraine without vertigo or migrainous vertigo (during a non-migrainous period) compared with a non-migraine population. We found that these differences were similar in both migraine groups. Although there were differences between those without migraine (control group) and those with migraine (the migrainous vertigo, and the migraine without vertigo group), these differences do not explain the presence of vertigo in migrainous vertigo only (and not in migraine without vertigo). There were no baseline differences for vestibular ocular reflexes between the migraine without vertigo group and the migrainous vertigo group. However, there may be increased susceptibility to pathophysiological changes which occur during a migraine in the migrainous vertigo population compared with migraines that occur in the migraine without vertigo population. This is a matter that should be investigated in future studies. There might be a continuum between migraine without vertigo and migrainous vertigo, causing sufferers of the former to experience 'motion sickness' and the latter to experience actual vertigo.

- **Migrainous vertigo is common but underdiagnosed**
- **Otoneurological tests suggest the vestibular system is normal in migrainous vertigo during non-migrainous periods**
- **Gaze stabilisation, dynamic visual acuity, head shake sensory organisation and functional gait test results are abnormal in vestibular disorders**
- **Migrainous vertigo and migraine without vertigo have not been studied using these tests**
- **Gaze stabilisation (pitch) and functional gait showed differences between non-migraine, migraine and migraine with vertigo groups**
- **Gaze stabilisation (pitch) and functional gait performance were related**

The functional gait assessment findings also indicate mild structural vestibular differences in those who suffer from migraine without vertigo and migrainous vertigo, even during a non-migrainous period. The migrainous vertigo group performed significantly worse in the functional gait assessment than the migraine without vertigo group, and both groups performed worse than the control group. This is an important finding and supports the use of vestibular rehabilitation in the treatment of patients with migrainous vertigo during a non-migrainous period. Our research findings can explain why vestibular rehabilitation for migrainous vertigo might be effective. There may be mild underlying vestibular dysfunction that specifically affects vestibular ocular reflexes during non-migrainous periods in both migraine without vertigo and migrainous vertigo. This underlying vestibular abnormality may be accentuated during the migrainous period, resulting in the vertigo reported by the migrainous vertigo population.

Limitations and future directions

The sample size was large enough to provide an appropriate power (80 per cent) to determine differences in the tests examined. However, the sample was non-random. In addition, although we attempted to attain physician confirmation of the participant-reported diagnosis, we were unsuccessful in this attempt for most of the participants. Nevertheless, patient diagnoses were supported by the number and type of migraine medications, and the current findings. Another factor which improved the current method of identifying the correct diagnosis was the use of the Furman *et al.* interview form.[35] This survey has been shown to be reliable and valid.[35] In the current study, the results of the form agreed in all cases with the participant-reported diagnosis of migraine without vertigo or migrainous vertigo. Future studies on the migrainous vertigo population should include assessments of gaze stabilisation pre- and post-vestibular rehabilitation, and there should be further investigation of the relationship between gaze stabilisation and gait in different populations.

Conclusion

There was a statistically significant difference in the gaze stabilisation test results for pitch movements (a measure of vestibular ocular reflexes) between the non-migraine group which was faster, and the two migraine groups (which were slower) during a non-migrainous period. The functional gait assessment also revealed significant differences between all three groups, with the control group scoring the highest and the migrainous vertigo group scoring the lowest during a non-migrainous period. Tests of vestibular spinal reflex components, specifically balance, did not differ between the groups. These findings support the suggestion that there are underlying differences in the vestibular ocular reflexes and function of both the migraine without vertigo population and the migrainous vertigo population, but that these differences are most significant for those with migrainous vertigo.

https://doi.org/10.1017/S0022215113002302 Published online by Cambridge University Press

Acknowledgement

We would like to acknowledge the Blue Cross Blue Shield of Michigan (granting agency).

References

1 Lipton RB, Bigal ME, Diamond M, Freitag F, Reed ML, Stewart WF. Migraine prevalence, disease burden, and the need for migraine preventive therapy. *Neurology* 2007;**68**:343–9
2 Lempert T, Neuhauser H. Epidemiology of vertigo, migraine and vestibular migraine. *J Neurol* 2009;**256**:333–48
3 Troost T. Vestibular migraine. *Curr Pain Headache Rep* 2004;**8**: 310–14
4 Lempert T, Neuhauser H. Migrainous vertigo. *Neurol Clin* 2005; **23**:715–30
5 Cass S, Ankerstjerne J, Yetiser S, Furman J, Balaban C, Aydogan B. Migraine-related vestibulopathy. *Ann Otol Rhinol Laryngol* 1997;**106**:182–9
6 Neuhauser H, von Brevern M, Radtke A, Lezius F, Feldmann M, Ziese T *et al*. Epidemiology of vestibular vertigo: a neurotologic survey of the general population. *Neurology* 2005;**65**:898–904
7 Lempert T, Neuhauser H, Daroff R. Vertigo as a symptom of migraine. *Ann N Y Acad Sci* 2009;**1164**:242–51
8 Neuhauser H, Lempert T. Vertigo and dizziness related to migraine: a diagnostic challenge. *Cephalalgia* 2004;**24**:83–91
9 Furman J, Sparto P, Soso M, Marcus D. Vestibular function in migraine-related dizziness: a pilot study. *J Vestib Res* 2005;**15**: 327–32
10 Headache Classification Subcommittee of the International Headache Society. The International Classification of Headache Disorders: 2nd edition. *Cephalalgia* 2004;**24**(suppl 1):9–160
11 Gottshall K, Moore R, Hoffer M. Vestibular rehabilitation for migraine-associated dizziness. *Int Tinnitus J* 2005;**11**:81–4
12 Whitney S, Wrisley D, Brown K, Furman J. Physical therapy for migraine-related vestibulopathy and vestibular dysfunction with history of migraine. *Laryngoscope* 2000;**110**:1528–34
13 Wrisley D, Whitney S, Furman J. Vestibular rehabilitation outcomes in patients with a history of migraine. *Otol Neurotol* 2002;**23**:483–7
14 Herdman S. *Vestibular Rehabilitation*, 3rd edn. Philadelphia, PA: : FA Davis, 2007
15 Kandel E, Schwartz J, Jessel T. *Principles of Neural Science*. New York, NY: Appleton and Lange, 1991
16 Crutchfield CA, Barnes MR. *Motor Control and Motor Learning in Rehabilitation*. Atlanta: Stokesville Publishing, 1993
17 Casani A, Sellari-Franceschini S, Napolitano A, Muscatello L, Dallan I. Otoneurologic dysfunctions in migraine in patients with and without vertigo. *Otol Neurotol* 2009;**30**:961–7
18 Maione A. Migraine-related vertigo: diagnostic criteria and prophylactic treatment. *Laryngoscope* 2006;**116**:1782–6
19 Kayan A, Hood DJ. Neuro-otological manifestations of migraine. *Brain* 1984;**107**:1123–42
20 von Brevern M, Zeise D, Neuhauser H, Clarke A, Lempert T. Acute migrainous vertigo: clinical and oculographic findings. *Brain* 2005;**28**:365–74
21 Celebisoy N, Gokcay F, Sirin H, Bicak N. Migrainous vertigo: clinical, oculographic and posturographic findings. *Cephalalgia* 2008;**28**:72–7
22 Cutrer FM, Baloh RW. Migraine-associated dizziness. *Headache* 1992;**32**:300–4
23 Ward B, Mohammad M, Whitney S, Marchetti F, Furman J. The reliability, stability, and concurrent validity of a test of gaze stabilization. *J Vestib Res* 2010;**20**:363–72
24 Pritcher M, Whitney S, Marchetti G, Furman J. The influence of age and vestibular disorders on gaze stabilization: a pilot study. *Otol Neurotol* 2008;**29**:982–8
25 Whitney S, Marchetti G, Pritcher M, Furman J. Gaze stabilization and gait performance in vestibular dysfunction. *Gait Posture* 2009;**29**:194–8
26 Schubert M, Migliaccio A, Clendaniel R, Allak A, Carey J. Mechanism of dynamic visual acuity recovery with vestibular rehabilitation. *Arch Phys Med Rehabil* 2008;**89**:500–7
27 Shepard N, Cole N, Bradshaw M, Hyder R, Parent R. *Enhancing Sensitivity of the Sensory Organization Test with the Head-shake: Recommendations for Clinical Application*. Clackamas, Oregon: NeuroCom International, 1998
28 Roma A. Use of the head shake-sensory organization test as an outcome measure in the rehabilitation of an individual with head movement provoked symptoms of imbalance. *J Geriatr Phys Ther* 2005;**28**:58–64
29 Mirsha A, Davis S, Speers R, Shepard N. Head shake computerized dynamic posturography in peripheral vestibular lesions. *Am J Audiol* 2009;**18**:53–60
30 Honaker J, Converse C, Shepard N. Modified head shake computerized dynamic posturography. *Am J Audiol* 2009;**18**:108–14
31 Wrisley D, Marchetti G, Kuharsky D, Whitney S. Reliability, internal consistency, and validity of data obtained with the functional gait assessment. *Phys Ther* 2004;**84**:906–18
32 Walker M, Austin A, Banke G, Foxx S, Gaetano L, Gardner L *et al*. Reference group data for the functional gait assessment. *Phys Ther* 2007;**87**:1468–77
33 Wrisley D, Kumar N. Functional gait assessment: concurrent, discriminative, and predictive validity in community-dwelling older adults. *Phys Ther* 2010;**90**:761–73
34 Ishikawa K, Cao ZW, Wang Y, Wong WH, Tanaka T, Miyazaki S *et al*. Dynamic locomotor function in normals and patients with vertigo. *Acta Otolaryngol* 2001;**121**:241–4
35 Furman J, Marcus D, Balaban C. Migrainous vertigo: development of a pathogenetic model and structured diagnostic interview. *Curr Opin Neurol* 2003;**16**:5–13
36 Pang M, Lam F, Wong G, Au I, Chow L. Balance performance in head-shake computerized dynamic posturography: aging effects and test-retest reliability. *Phys Ther* 2011;**91**:246–53

Address for correspondence:
Dr B J Baker,
Physical Therapy Department,
Grand Valley State University,
301 Michigan St NE,
Grand Rapids,
Michigan 49546, USA

Fax: 001-616-331-5654
E-mail: bakerb@gvsu.edu

Dr B J Baker takes responsibility for the integrity of the content of the paper
Competing interests: None declared

https://doi.org/10.1017/S0022215113002302 Published online by Cambridge University Press