Validation of the Binocular Vision Dysfunction Questionnaire (BVDQ)

*Debby L. Feinberg, *†Mark S. Rosner, and ‡Arthur J. Rosner

NeuroVisual Medicine Institute, Bloomfield Hills; †St. Joseph Mercy Hospital, Ypsilanti; and ‡The Oakland University William Beaumont School of Medicine, Rochester, Michigan

Objective: Among patients presenting with dizziness, visual dysfunction must be considered, including vertical heterophoria (VH), a frequently under-identified form of binocular vision dysfunction where there is vertical discrepancy between the lines of sight of the eyes when at physiologic rest. Current self-rated screening measures do not account for complex VH symptomatology including dizziness/ambulation difficulties, nausea, headache, anxiety, neck pain, and reading impairment. VH must be differentiated from vestibular/otolithic etiologies, as their treatment frequently provides inadequate relief, yet treatment of the VH can reduce/eliminate symptoms. The objective of this study is to create a valid measurement tool (binocular vision dysfunction questionnaire) to assist in identifying VH among dizzy patients to aid in appropriate referral.
Study Design: Retrospective case series.
Setting: Tertiary referral center.
Patients: One hundred twenty-six patients presenting to an optometric binocular vision subspecialist diagnosed with VH.
Intervention: Psychometric study. The measurement tool's internal consistency and test–retest reliability was assessed. Confirmatory and exploratory factor analyses were performed. Validity was estimated through correlations with a visual analog scale and validated instruments for headaches, dizziness, and anxiety.
Main Outcome Measures/Results: Excellent reliability demonstrated including Cronbach's alpha of 0.91 and high test–retest reliability. Statistical correlations with established measurements established sound convergent/content validity. Analysis of participants who underwent treatment indicated change in BVDQ score correlates with perception of change in symptom burden.
Conclusions: Results suggest the BVDQ is a valid, reliable screening tool to assist otologists in identifying VH among their dizzy patients. The BVDQ may also be useful for measuring changes with various treatments, and in identifying diverse symptoms associated with BVD/VH **Key Words:** Binocular vision dysfunction—Dizziness—Psychometrics—Vertical heterophoria—Vestibular dysfunction—Vestibulopathy.

Otol Neurotol **42:**e66–e74, 2021.

Among patients presenting with dizziness, visual dysfunction must be considered. Vertical heterophoria (VH) is a form of binocular vision dysfunction (BVD) where the line of sight from one eye is vertically higher than the line of sight from the other eye when at physiologic rest. Patients with VH will present to vestibular clinics to be evaluated for possible vestibular dysfunction. Estimates of VH prevalence range from 7 to 52%, with best estimates at approximately 20% of the general population (1–3). Symptoms caused by BVD are diverse and have been observed to include diplopia, shadowed/overlapping vision, closing/covering an eye to ease visual tasks, asthenopia, difficulty with reflection/glare, and reading impairment (1,4–11). However, many common and impactful medical symptoms are often not recognized as occurring with BVD and VH, including headache, dizziness, ambulation difficulties, anxiety, photophobia, neck pain, balance disturbances, nausea, and motion sickness (Table 1) (1,4–11). Considering that there is no recognized ''gold standard'' test (1,3,12–16), and that no validated scale currently exists to offer clinicians and researchers a brief, comprehensive assessment of these varied symptom domains associated with BVD and VH, these symptoms may be frequently overlooked in clinical treatment of these symptoms and of the vision misalignment (17,18). This is problematic, as patients seeking treatment for these disparate symptoms may not gain adequate relief unless underlying causes such as BVD are identified and referred to the appropriate vision specialist (9,11).

While there is not total agreement about what symptoms correlate with VH in clinical practice (1,4–11), confirmation of typical symptom constellations was supported by recent research that indicated high prevalence of headache, dizziness, and anxiety in 38 traumatic

Address correspondence and reprint requests to Mark S. Rosner, M.D., 2550 South Telegraph Road, Suite 100, Bloomfield Hills, MI 48302; E-mail: DrMark@NVMInstitute.org

The authors disclose no conflicts of interest.
Supplemental digital content is available in the text.
DOI: 10.1097/MAO.0000000000002874

TABLE 1. *Symptoms and differential diagnosis of binocular vision dysfunction*

Pain Symptoms	Pain Symptoms Differential Diagnosis (Dif. Dx.):
Headache	Migraine headache
Face ache/''sinus'' pain	Sinusitis
Eye pain or pain with eye movements	Temporomandibular joint (TMJ) disease
	Chronic daily headache
	Traumatic brain injury (TBI)/Persistent Post Concussion Symptoms (PPCS)
Head Tilt Symptoms	**Head Tilt Symptoms Dif. Dx.:**
Neck ache and upper back pain due to a head tilt	Cranial nerve four lesion/superior oblique palsy
	Scoliosis
	Torticollis
Dizziness Symptoms	**Dizziness Symptoms Dif. Dx.:**
Dizziness	Benign Positional Vertigo (BPV)
Lightheadedness	Meniére's disease
Off-balanced	Visual vertigo
Motion sickness (is frequently the first symptom of BVD—can occur very early in childhood)	Psychogenic dizziness
Vertigo	Chronic subjective dizziness
Nausea/cyclic vomiting	Cerebral vascular accident (CVA)
Frequent falls	Neuromuscular weakness
Lack of coordination/clumsiness	Brain tumor
Unsteadiness or drifting to one side while walking; bumping into door jambs	TBI/PPCS
Difficulty walking down grocery aisle	Migraine Associated Vertigo (MAV)
Disorientation	Cervical vertigo
	Superior Semicircular Canal Dehiscence (SSCD)
	Multiple Sclerosis (MS)
	Gastroparesis
Reading Symptoms	**Reading Symptoms Dif. Dx.:**
Difficulty with concentration	Reading or learning disabled
Fatigue with reading	Attention Deficit Disorder /Attention Deficit Hyperactivity Disorder (ADD/ADHD)
Difficulty with reading and reading comprehension	Convergence insufficiency
Skipping lines while reading	Binocular vision abnormality
Using a line guide (finger, ruler, envelope) to maintain one's place while reading	Astigmatism
Words running together while reading	Hyperopia
Losing one's place while reading	TBI/PPCS
Routine Visual Symptoms	**Routine Visual Symptoms Dif. Dx.:**
Blurred vision at near or far distances	Myopia
Difficulty with close up vision (i.e., reading or computer use)	Hyperopia
Difficulty with night vision	Astigmatism
Eye strain	
Sore eyes	
Heterophoria Symptoms	**Heterophoria Symptoms Dif. Dx.:**
Double/overlapping/blurred vision	CVA
Shadowed vision	Neuromuscular weakness
Light sensitivity	Brain tumor
Difficulty with glare or reflection	TBI/PPCS
Closing/covering one eye while reading	
Poor depth perception: difficulty estimating distances while driving; difficulty catching balls	

Psychological Symptoms	Psychological Symptoms Dif. Dx.:
Feeling overwhelmed or anxious in crowds	Anxiety/panic disorder
Agoraphobia	Psychogenic dizziness
Feeling overwhelmed or anxious when in large contained spaces like malls or big box stores	Depression
Feeling overwhelmed or anxious while driving, especially at higher speeds	Agoraphobia
Suicidal ideation due to anxiety	Chronic subjective dizziness
Difficulty maintaining eye contact during conversations	TBI/PPCS

brain injury patients who were subsequently diagnosed with VH (11). This study indicated that 92.1% reported headache, dizziness, or anxiety. The average duration of symptoms was 9.9 years, during which multiple tests were run and multiple treatments/medications were tried, yielding less than adequate symptom relief. Compounding the issue of time without appropriate diagnosis, participants reported that multiple health care providers were consulted, including general practice physicians (68.4%), neurologists (60.5%), physiatrists (55.3%), psychiatrists or psychologists (36.8%), otolaryngologists (29.0%), and chiropractors (21.1%). Evaluation by an ophthalmologist or optometrist occurred in 73.6% of the patients, yet none had been diagnosed with VH before participation in the study. Participants were diagnosed with a variety of other conditions including migraines (52.6%), sinus disorders (23.7%), vertigo (23.7%), anxiety (52.6%), Attention Deficit Disorder/Attention Deficit Hyperactivity Disorder (18.4%) (see Table 1 for complete differential diagnosis). Once successfully evaluated as having VH, however, application of prismatic lenses to treat the patient's VH led to an average subjective reduction of VH symptoms of 80.2%, as well as significant reduction (19.1–60.8%) in all metrics measuring their headache, dizziness, anxiety, and BVD symptom burden (11).

Failure to diagnose BVD leaves symptomatic patients searching for answers. However, the identification of VH has been difficult for reasons including:

1. Individual symptoms of VH are common to many medical conditions and are not commonly recognized as possibly being caused by BVD, which may lead to incomplete/incorrect medical diagnoses. BVD patients do not share one common symptom profile, but rather have unique combinations of symptoms (3,9).
2. Commonly understood BVD symptoms including diplopia, shadowed/overlapping vision, closing/covering an eye to ease visual tasks may not be as indicative of VH as currently understood. In a recent study, these symptoms were not present in a majority of study participants (39.5%, 34.2%, and 34.2%, respectively) (11).
3. Tests designed to detect and measure vertical misalignment frequently yield inaccurate or conflicting results with regard to symptom correlation (1,3,12–16).
4. The amount of prism does not necessarily correlate with severity of symptoms. Patients can be very symptomatic with only small amounts of misalignment. A recent study noted the patient's vertical prism prescription to be between 0.5 and 2.00 diopters for 68%, between 2.50 and 4.00 diopters for 29%, and greater than 4.00 diopters for 3% (mean= 1.92 D; median= 1.5 D) (Fig. 1) (11).
5. There is no screening or diagnostic survey instrument that incorporates all of the VH/BVD symptoms and symptom domains. One common

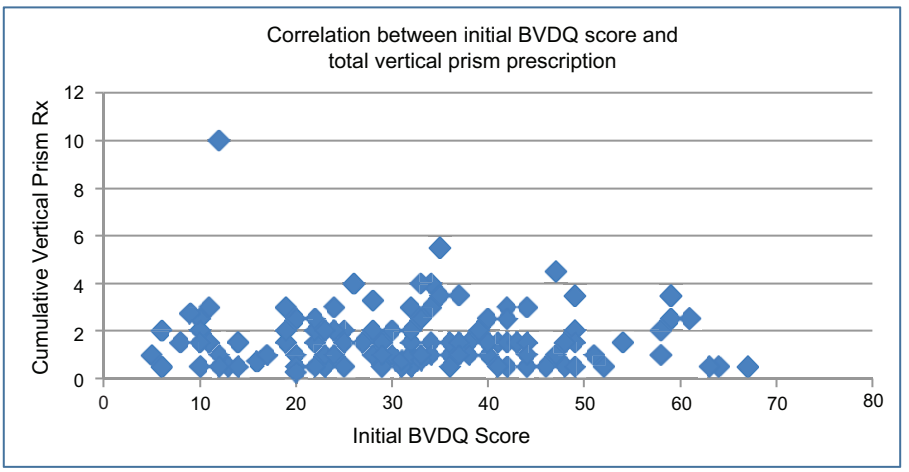

FIG. 1. Correlation between initial BVDQ score and total vertical prism perscription. BVDQ indicates binocular vision dysfunction questionnaire.

validated vision survey instrument that addresses only near task symptoms of VH/BVD is the Convergence Insufficiency Symptom Survey (17,18). Symptoms queried include challenges with reading, headache, asthenopia, difficulty concentrating, and visual fatigue. However, the Convergence Insufficiency Symptom Survey does not address symptoms with far tasks, nor does it query the other symptoms of BVD including dizziness, lightheadedness, nausea, motion sickness, neck pain, head tilt, anxiety, depth perception, and closing/covering an eye to make visual tasks easier. Without a comprehensive survey instrument, many patients with VH/BVD symptoms are not identified or appropriately treated.

Given these difficulties, the purpose of this study was to develop and validate a new survey instrument. Titled the Binocular Vision Dysfunction Questionnaire (BVDQ), this scale may function as a screening instrument to help identify cases of VH/BVD, for appropriate referral to a vision specialist.

METHODS

Development of the BVDQ

The 25-question BVDQ is a self-administered survey instrument that was developed to assess a comprehensive range of symptoms associated with BVD conditions, including VH (Fig. 2). Items were selected for inclusion by this team of optometric binocular vision subspecialists, based on qualitative and statistical analysis of symptom reports from archival data of approximately 3,000 BVD patients. Criteria for inclusion in the BVDQ was based upon the most consistently reported symptoms by participants diagnosed with BVD by a vision professional.

Directions: For each of the following questions, please check the answer that best describes your situation. If you wear glasses or contact lenses, answer the questions assuming that you are wearing them. Always = Every day Frequently = At least 1 time / week Occasionally = Less than 1 time / week Never = Never	ALWAYS	FREQUENTLY	OCCASIONALLY	NEVER
1. Do you have headaches and / or facial pain?				
2. Do you have pain in your eyes with eye movement?				
3. Do you experience neck or shoulder discomfort?				
4. Do you have dizziness and / or light headedness?				
5. Do you experience dizziness, light headedness, or nausea while performing close-up activities (computer work, reading, writing, etc.)?				
6. Do you experience dizziness, light headedness, or nausea while performing far-distance activities (driving, television, movies, etc.)?				
7. Do you experience dizziness, light headedness, or nausea when bending down and standing back up, or when getting up quickly from a seated position?				
8. Do you feel unsteady with walking, or drift to one side while walking?				
9. Do you feel overwhelmed or anxious while walking in a large department store?				
10. Do you feel overwhelmed or anxious when in a crowd?				
11. Does riding in a car make you feel dizzy or uncomfortable?				
12. Do you experience anxiety or nervousness because of your dizziness?				
13. Do you ever find yourself with your head tilted to one side?				
14. Do you experience poor depth perception or have difficulty estimating distances accurately?				
15. Do you experience double / overlapping / shadowed vision at far distances?				
16. Do you experience double / overlapping / shadowed vision at near distances?				
17. Do you experience glare or have sensitivity to bright lights?				

FIG. 2. Binocular vision dysfunction questionnaire.

	ü ALWAYS	ü FREQUENTLY	ü OCCASIONALLY	ü NEVER
18. Do you close or cover one eye with near or far tasks?				
19. Do you skip lines or lose your place while reading (do you use your finger or a ruler or other guides to maintain your position on the page)?				
20. Do you tire easily with close-up tasks (computer work, reading, writing)?				
21. Do you experience blurred vision with far-distance activities (driving, television, movies, chalkboard at school, etc.)?				
22. Do you experience blurred vision with close-up activities (computer work, reading, writing, etc.)?				
23. Do you blink to "clear up" distant objects after working at a desk or working with close-up activities (computer work, reading, writing, etc.)?				
24. Do you experience words running together with reading?				
25. Do you experience difficulty with reading or reading comprehension?				

Scoring:

Scoring is performed by summing the values given to Questions 1 – 25 as follows:

Always = 3; Frequently = 2; Occasionally = 1; Never = 0

Symptom Domains (and questions in each domain):

Headache (1, 2)

Head tilt (3, 13)

Vestibular (4, 5, 6, 7, 8, 11)

Anxiety (9, 10, 12)

Binocular vision (14 - 18)

Reading (19, 24, 25)

Standard vision (20 - 23)

FIG. 2. (Continued).

Itemized and frequency analysis of the initial collected raw responses yielded seven major symptom domains. These included: head and eye pain, dizziness, head tilt/neck pain, reading difficulties, binocular vision symptoms, routine vision symptoms, and anxiety. To ascertain comprehensive diagnostic profiles from patients who may be experiencing symptoms in different domains simultaneously, questions selected for final inclusion into the BVDQ were designed to encompass all seven major symptom domains. Following standard scale construction protocols (19,20), scoring procedures of the BVDQ were designed with a Likert scale rating system. Scoring is ascertained by summing the values for all responses (Always= 3, Frequently= 2, Occasionally= 1, and Never= 0). The maximum score possible is 75; the minimum is 0.

Study Design

This psychometric study's ethical compliance was approved by Western IRB, and the research adheres to the tenets of the Declaration of Helsinki. One hundred twenty-six patients who presented to the authors' optometric binocular vision subspecialist for the assessment of a wide range of visual and other symptoms and who completed comprehensive data sets were included. Diagnosis of VH was based upon observation of symptoms consistent with VH by the researchers, and

confirmed through subjectively reported improvement of VH symptom burden after treatment with prismatic lenses of at least 30% as documented using a 10 cm visual analog scale. To confirm relevance and accuracy of items and symptom groups, responses were collected along with several other measures of diagnostic data and information during standard clinic intake and treatment procedures. To assess test–retest reliability properties and potential utility of the BVDQ as a diagnostic instrument, administrations were given twice before treatment with prismatic lenses.

Internal consistency of the BVDQ was tested using Cronbach's alpha, and statistical correlation analyses with established scales were performed to further establish convergent validity (19). Given that there currently does not exist a survey instrument that quantifies BVD symptoms, we comparedthe results of this questionnaire to that of previously validated questionnaires for headache, dizziness, and anxiety symptoms: Headache Disability Inventory (HDI) (21), Dizziness Handicap Inventory (DHI) (22), and the Zung Self Rating Anxiety Scale (ZSAS) (23). The results of each validated measure were summarized according to scoring indications on each questionnaire, and were subsequently analyzed for correlation with the BVDQ.

Estimates of correlation were assessed with Spearman rank correlation coefficient. The total score for each validated questionnaire was tested for correlation with the total score on the BVDQ. We also evaluated the correlations between the sum of subsets of questions from the BVDQ as specifically related to headache, dizziness, and anxiety, respectively, and total scores on the DHI, HDI, and ZSAS. As an additional measure of construct validity, the sums of the questions related to headache, dizziness, and anxiety, respectively, were correlated with the severity of those specific symptoms as rated by the patient on a scale of 0 to 10.

To measure whether change in the BVDQ correlated with changes in the DHI, HDI, and ZSAS, Spearman rank correlations were performed to assess before and after treatment score differences between questionnaires, as calculated by subtracting the total scores before and after treatment with prismatic lenses. For further construct validity, patient estimates of their percent improvement in overall symptoms, and improvement on a 10 cm visual analog scale were tested for correlation with each other and with change in BVDQ. We also tested to what extent change in BVDQ score correlated with change in the validated measures, and with the rating given on a 0 to 10 scale measuring severity of specific symptoms. Test–retest reliability of the BVDQ was performed on all 126 participants before treatment and between 1 and 16 weeks after the first administration. Spearman rank correlation was used to test the reproducibility of the 25 answers plus the total score on the BVDQ (24).

Dimensional properties and factor structure of the BVDQ were evaluated using confirmatory factor analysis. Considering the results from initial itemized and frequency analyses of archival data, factors hypothesized for confirmatory factor analysis included: headache, dizziness, anxiety, binocular vision dysfunction, standard vision, and head tilt. Estimates were based on evaluation of the model χ^2 and the model root mean square error of approximation (RMSEA) to determine the adequacy of the model fit. According to our statistical model, the chi-square statistic should be near zero and the RMSEA should be less than 0.06 to indicate adequate fit of the factor model (19).

Owing to the experimental nature of this study, an exploratory factor analysis was also performed to elucidate a dimensional structure that could explain the variance of the items and BVDQ as a whole. Accordingly, item-total correlations and interfactor correlations were calculated. Following standard psychometric procedures, we considered loadings greater than 0.4 as important associations, and factors were considered significant when eigenvalues were above 1 (19,20). Latent constructs were interpreted empirically based on the resulting correlations. Varimax rotation of the factors was employed to facilitate greater clarification and understanding of the interrelated components underlying the questionnaire (25).

TABLE 2. *Worst and second worst symptoms*

Worst Symptom	Frequency (%)	Second Worst Symptom	Frequency (%)
Headache	41 (32.5)	Neck ache or pain	31 (24.6)
Dizziness	40 (31.8)	Headache	22 (17.5)
Other	17 (13.5)	Reading difficulty	22 (17.5)
Neck ache or pain	14 (11.1)	Other	21 (16.7)
Reading difficulty	9 (7.1)	Dizziness	17 (13.5)
Anxiety	5 (4.0)	Anxiety	13 (10.3)

RESULTS

Demographics

Among the 126 patients in this study, 92 (73%) were women, and the median age was 40 years (range 6–80 yrs). Eighty-eight patients (70%) reported having dizziness, while 46 (36.5%) reported rotary vertigo. Regarding their worst and second worst presenting symptoms, 41 (33%) reported their worst symptom was headache, and 40 (32%) reported dizziness. The median duration of the worst symptom was 3 years and ranged from 1 month to 58 years (mean of 7.6 yrs). Other reported worst and second worst symptoms are shown in Table 2.

Seventy-eight patients (62%) indicated having a headache more than once a week, and 25 (20%) characterized their headaches as ''severe.'' Forty-one patients (33%) reported sustaining a traumatic brain injury. Patients had undergone multiple testing modalities for the presenting symptoms. Sixty-one (48%) had computer tomographic scans, 60 (48%) had magnetic resonance imaging without or with arterial contrast, and 41 (33%) had both. Twenty-seven (21%) had audiograms and 25 (20%) had electronystagmograms. Fifty-two patients (41%) had been seen by an otolaryngologist and 48% by a neurologist before referral to a vision specialist. The frequencies of clinical problems reported by the patients are summarized in Table 3.

Before intervention, glasses were worn by 73.0% and contact lenses were worn by 15.9%. Eye surgeries were reported by 15.1%, cataracts by 8.7%, glaucoma by 3.2%, and amblyopia by 9.5%. Trouble adjusting to previous eyewear was experienced by 41.3%. Consultation was obtained with an ophthalmologist by 42.9%, optometrist by 25.4%, and 8.7% saw both. Diplopia, shadowed/overlapping vision, and closing/covering an

TABLE 3. *Medical conditions*

Condition	Frequency (%)
Agoraphobia	6 (4.8)
Allergies	70 (55.6)
Anxiety	72 (57.1)
Arthritis	31 (24.6)
Attention deficit hyperactivity	18 (14.3)
Benign proxysmal positional vertigo	11 (8.7)
Cancer	6 (4.8)
Cervical fusion	2 (1.6)
Cervical spine injury	19 (15.1)
Diabetes	7 (5.6)
Dizziness	89 (70.6)
Glaucoma	4 (3.2)
Heart disease	3 (2.4)
Human immune deficiency virus	0 (0.0)
Hypertension	26 (20.6)
Kidney disease	1 (0.8)
Lazy eye	12 (9.5)
Meniére's	2 (1.6)
Migraine	56 (44.4)
Pregnancy	1 (1.3)
Sinus disease	32 (25.4)
Tinnitus	40 (31.8)
Vertigo	46 (36.5)

eye to ease visual tasks were experienced by 23.4, 30.6, and 24.3% respectively.

Myopia, hyperopia, and astigmatism were present and corrected in 51.2, 37.6, and 84.0% of the patients respectively.

Reliability

Analysis of internal consistency properties of the BVDQ resulted in Cronbach's alpha= 0.91, suggesting strong reliability and that scale items are intercorrelated. Analysis of test–retest reliability pretreatment (n= 126) also resulted in a high correlation for both test administrations ($r = 0.85$, $p < 0.01$), suggesting good stability of test scores over time.

Validity

Convergent validity of the BVDQ was estimated through measuring correlations with scores between the BVDQ and the DHI, HDI, and ZSAS before and after treatment. Mean difference scores are shown in Supplemental Content (SC) 1, http://links.lww.com/MAO/B69. Correlation between BVDQ results and validated questionnaire results of categories including: Before intervention; After intervention; and difference between before and after intervention scores was investigated using Spearman Rank Correlation Coefficients between the four scales. These results are shown in SC 2, http://links.lww.com/MAO/B70, SC 3, http://links.lww.com/MAO/B71, and SC 4, http://links.lww.com/MAO/B72.

Statistically significant correlations ranging from mild to high were shown for Before Interventions scores (SC 2, http://links.lww.com/MAO/B70), After Intervention scores (SC 3, http://links.lww.com/MAO/B71), and total difference of scores between the BVDQ and all three validated symptom severity measures used in this study (SC 4, http://links.lww.com/MAO/B72). Spearman correlation coefficients between the sums of the questions related to headache, dizziness, and anxiety, and total scores on the DHI, HDI, and ZSAS are shown in SC 5, http://links.lww.com/MAO/B73. Correlations of BVDQ questions related specifically to headache, dizziness, and anxiety symptoms were measured, and yielded significant correlation with the severity of specific symptoms as rated by the patient on a scale of 0 to 10 (SC 6, http://links.lww.com/MAO/B74).

The dizziness, headache, and anxiety questions of the BVDQ were highly correlated with severity ratings of their respective symptoms ($r = 0.77$, 0.68, and 0.65, $p < 0.01$ for all). In addition, the dizziness questions were moderately related to the severity of anxiety ($r = 0.54$), nausea ($r = 0.60$), and unsteady gait ($r = 0.56$). The anxiety questions were moderately correlated with the severity of dizziness ($r = 0.61$), nausea ($r = 0.44$), and unsteady gait ($r = 0.46$). The headache questions were moderately correlated with the severity of neck ache ($r = 0.51$).

Factor Analyses

Confirmatory factor analysis of the BVDQ partially supported the initial hypothesis of six distinct symptom categories, labeled: Headache, Dizziness, Anxiety, Head Tilt, Binocular Vision Dysfunction, and Standard Vision. The χ^2 analysis indicated significant difference χ^2 (1, $n = 126$) = 68, $p < 0.0001$, and the RMSEA was relatively large at 0.22. Exploratory factor analysis of the BVDQ revealed six possible factors. The first factor, labeled Dizziness and Anxiety, accounts for 8% of the total variance between items, containing five dizziness and four anxiety questions. The second factor, titled Vision, loaded most strongly with binocular and other vision-related questions. The third factor, labeled Headache, loaded with headache, head tilt, and one binocular vision question. The other three factors had relatively weak loadings, but were initially labeled Adjunctive Vision Factors, Quality of Life Impact, and Other Concerns.

Diagnostic Indications

Changes between initial and posttreatment results between the BVDQ and established questionnaires indicated statistical significance. As shown in SC 7, http://links.lww.com/MAO/B75, change between the initial and posttreatment BVDQ correlated with the change in the DHI to a moderate degree ($r = 0.55$, $p < 0.01$). The difference in BVDQ showed mild correlation with changes in HDI ($r = 0.29$, $p < 0.01$) and ZSAS ($r = 0.36$, $p < 0.01$). Relative change in the BVDQ indicated moderate correlation with the patient estimates of percent improvement of overall symptoms ($r = 0.46$, $p < 0.01$) and mild correlation for the VAS ($r = 0.36$, $p < 0.01$) (SC 8, http://links.lww.com/MAO/B76).

Comparison of relative change in BVDQ results yielded moderate correlation with relative changes in the DHI ($r = 0.46$, $p < 0.0001$), and mild correlation with the relative changes in the HDI ($r = 0.26$, $p < 0.0032$), and ZSAS ($r = 0.30$, $p < 0.0006$) (SC 9, http://links.lww.com/MAO/B77). Additionally, relative change in the BVDQ showed high correlation with relative changes in the severity of dizziness as rated by the patient on a 0 to 10 scale (dizziness score: $r = 0.65$, $p < 0.0001$), moderate correlation with headache (headache score: $r = 0.50$, $p < 0.0001$), and mild correlation with anxiety (anxiety score: $r = 0.35$, $p < 0.0001$) (SC 10, http://links.lww.com/MAO/B78).

DISCUSSION

The identification of VH is pertinent to otologists because of the overlap with vestibular symptomatology. Dizziness and vertigo were very common symptoms (70 and 36.5%), making it critical to determine if VH is the etiology, since traditional treatment approaches frequently provide inadequate relief if vision misalignment is causative. Fifty-two patients (41%) had been seen by an otolaryngologist and 60 patients (48%) by a neurologist before VH being diagnosed by the vision specialist. Duration of symptoms before treatment was an average of 7.6 years. Earlier identification of these individuals would presumably result in lowered healthcare costs and reduced overall morbidity from VH.

The BVDQ seems to be a valid, reliable measure of symptom severity related to BVD, making this useful as a screening tool for VH and other BVD-related concerns. While our findings have validated the effectiveness of the BVDQ for screening potential BVD patients and tracking patients' responses to treatment, it is hoped that this measure can reduce the cumbersome task of administering and tracking multiple symptom survey tools. The specific combination of symptoms, degree of symptom severity, and degree of symptom frequency are unique for each patient. Thus, the BVDQ may help clinicians identify both primary and adjunctive symptom domains of BVD patients. Taken together, these findings suggest that the BVDQ may be uniquely suited for identifying potential BVD patients in clinical settings among patients presenting with dizziness.

Future research must include confirming the BVDQ's statistical properties in clinical research treatment settings to further assess its efficacy as a diagnostic tool, and to establish appropriate scoring guidelines. However, strong psychometric properties indicated in the results suggest its potential clinical utility is indicated. Internal consistency of the BVDQ was quite high (Cronbach alpha$= 0.91$), as was test–retest reliability ($r= 0.85$, $p < 0.01$), indicating that the constellation of symptoms represented in the BVDQ was consistent both within the set of questions included and over time. Construct validity of the BVDQ was established through significant correlations between the instrument, subscales of the instrument, and previously validated questionnaires measuring the severity of key elements of the symptom complex not usually associated with BVD; namely, dizziness, anxiety, and headache. We noted particularly strong correlations between dizziness and anxiety (SC 5, http://links.lww.com/MAO/B73). This finding is consistent with previously described connections between these symptoms (26). However, our findings indicate that these may be further connected to a larger group of symptoms in BVD patients.

Another important area for future study includes the elucidation of the BVDQ's factor structure. While χ^2 analysis indicated moderate significance in difference between proposed dimensional structure and the statistical relationship between question symptom clusters χ^2 $(1, n= 126) = 68$, $p < 0.0001$, exploratory analysis indicated factor categories that represent a reorganization of the hypothesized framework that needs to be further clarified. However, these domain areas suggest strong correlation between anxiety and dizziness in this population, along with vision abnormalities, and headache/head tilt. These symptom clusters formed three domains of the syndrome; however, the remaining three dimensions still need further clarification.

The relative change in BVDQ showed moderate correlation with the patients' estimate of change in overall symptoms related to treatment, which implies clinical utility for monitoring improvement over time. The high internal consistency (Cronbach alpha of 0.91) is indicative of strong relationship between the constellation of headache, dizziness, and anxiety symptoms included within the scale. This is also supported by the correlation between the dizziness and anxiety questions on the BVDQ with the patient estimates of symptom severity (SC 6, http://links.lww.com/MAO/B74). While some of these symptoms are not traditionally associated with BVD, findings presented here seem to indicate a correlation that would benefit from further exploration.

The BVDQ seems to be helpful for following patients for improvements in headaches or dizziness, since the relative change in the BVDQ correlated moderately with the relative change in the DHI, and correlated highly with the relative changes in severity of dizziness and moderately with the relative changes in severity of headache as rated on a scale of 0 to 10. The BVDQ may also be somewhat helpful for following patients for improvements with anxiety, as the relative change in the BVDQ correlated mildly with the relative change in the ZSAS and with the relative changes in severity of anxiety as rated on a scale of 0 to 10. These indications would also likely benefit from further study.

Overall, the relative change in BVDQ showed moderate correlation with the patients' estimate of their change in overall symptoms related to treatment, so the change in BVDQ may be considered a reasonable measure of improvement in the overall patient symptom profile.

The weakness in our study comes from the study population. Applying the BVDQ to a population of patients presenting to a vision subspecialist is very likely to give different results than a group of patients

presenting to a vestibular clinic. Future research should be directed toward applying the BVDQ to a broader range of patients presenting to a vestibular clinic, a general Otolaryngology clinic, or a primary care setting. Since ocular misalignment is not unusual among vestibular patients, the implications would be substantial for patients appropriately identified for VH treatment.

Being able to correctly diagnose and treat VH is critical, as treating the associated symptoms using standard medical treatments can result in ineffective symptom reduction when the etiology of the symptoms is due to vision misalignment. Therefore, this survey instrument will be useful to the physician community, to help guide evaluation and referral of these traditionally expensive and difficult-to-treat patients. Furthermore, being able to measure response to treatment will be useful not only for tracking treatment outcomes, but also in identifying residual symptoms that may require interdisciplinary treatment with other medical specialists and therapists.

Acknowledgments: The authors thank Dr. Ben Greenberg for ongoing consultation and assistance in the preparation of this manuscript.

REFERENCES

1. Duke-Elder S, Wybar K. Anomalies of binocular fixation.*System of Opthamology*. St. Loius, MO: The C. V. Mosby Company; 1973 513–76.
2. Jackson DN, Bedell HE. Vertical heterophoria and susceptibility to visually induced motion sickness. *Strabismus* 2012;20:17–23.
3. Surdacki M, Wick B. Diagnostic occlusion and clinical management of latent hyperphoria. *Optom Vis Sci* 1991;68:261–9.
4. Borish IM. Analysis and prescription.*Clinical Refraction.*, 3rd ed. Chicago, IL: The Professional Press, Inc; 1975. 861–938.
5. Bixenman WW. Vertical prisms. Why avoid them? *Surv Ophthalmol* 1984;29:70–8.
6. Roy RR. Symptomatology of binocular stress. *Optom Wkly* 1958;49:907–12.
7. Schrier M. Practice notes on hyperphoria. *BJOD* 1997;5:68–9.
8. Stevens GT. *Functional Nervous Diseases.*. New York: D. Appleton and Company; 1887. 200–6.
9. Doble JE, Feinberg DL, Rosner MS, Rosner AJ. Identification of binocular vision dysfunction (vertical heterophoria) in traumatic brain injury patients and effects of individualized prismatic spectacle lenses in the treatment of postconcussive symptoms: A retrospective analysis. *PM R* 2010;2:244–53.
10. Borish IM. History and eye strain. *Clinical Refraction.*, 3rd ed. Chicago, IL: The Professional Press, Inc; 1975. 307–44.
11. Rosner MS, Feinberg DL, Doble JE, Rosner AJ. Treatment of vertical heterophoria ameliorates persistent post-concussive symptoms: A retrospective analysis utilizing a multi- faceted assessment battery. *Brain Inj* 2016;30:311–7.
12. Karania R, Evans BJ. The mallet fixation disparity test: Influence of test instructions and relationship with symptoms. *Opthal Physiol Opt* 2006;26:507–22.
13. Gall R, Wick B. The symptomatic patient with normal phorias at distance and near: What tests detect a binocular vision problem? *Optometry* 2003;74:309–22.
14. Gray LS. The prescribing of prisms in clinical practice. *Graefes Arch Clin Exper Ophthalmol* 2008;246:627–9.
15. Schroeder TL, Rainey BB, Goss DA, Grosvenor TP. Reliability of and comparisons among methods of measuring dissociated phoria. *Optom Vis Sci* 1996;73:389–97.
16. Wick BB. Prescribing vertical prism: How low can you go? *J Optom Vis Dev* 1997;28:77–85.
17. Borsting EJ, Rouse MW, Mitchell GL, et al. Validity and reliability of the revised convergence insufficiency symptom survey in children aged 9 to 18 years. *Optom Vis Sci* 2003; 80:832–8.
18. Rouse MW, Borsting EJ, Mitchell GL, et al. Validity and reliability of the revised convergence insufficiency symptom survey in adults. *Ophthalmic Physiol Opt* 2004;24:384–90.
19. Hinkin TR, Tracey JB, Enz CA. Scale construction: Developing reliable and valid measurement instruments. *JHTR* 1997;21:100–20.
20. Furr RM, Bacharach VR. *Psychometrics: An Introduction*. Los Angeles: Sage; 2013.
21. Jacobson GP, Ramadan NM, Aggarwal SK, Newman CW. The Henry Ford hospital headache disability inventory (HDI). *Neurology* 1994;44:837–42.
22. Jacobson GP, Newman CW. The development of the dizziness handicap inventory. *Arch Otolaryngol Head Neck Surg* 1990;116:424–7.
23. Zung WK. A rating instrument for anxiety disorders. *Psychosomatics* 1971;12:371–9.
24. Kline RB. *Principles and Practice of Structural Equation Modeling*. New York: The Guilford Press; 2005.
25. Kaiser HF. The varimax criterion for analytic rotation in factor analysis. *Psychometrika* 1958;23:187–200.
26. Eckhardt-Henn A, Breuer P, Thomalske C, Hoffmann S, Hopf H. Anxiety disorders and other psychiatric subgroups in patients complaining of dizziness. *J Anxiety Disord* 2003;17: 369–88.