APTA
American Physical Therapy Association

OPEN

CLINICAL PRACTICE GUIDELINES

Vestibular Rehabilitation for Peripheral Vestibular Hypofunction: An Updated Clinical Practice Guideline From the Academy of Neurologic Physical Therapy of the American Physical Therapy Association

Courtney D. Hall, PT, PhD,
Susan J. Herdman, PT, PhD, FAPTA,
Susan L. Whitney, DPT, PhD, NCS, ATC, FAPTA,
Eric R. Anson, PT, PhD,
Wendy J. Carender, PT, MPT, NCS,
Carrie W. Hoppes, PT, PhD, NCS, OCS, ATC,
Stephen P. Cass, MD, MPH,
Jennifer B. Christy, PT, PhD,
Helen S. Cohen, OTR, EdD, FAOTA,
Terry D. Fife, MD, FAAN, FANS,
Joseph M. Furman, MD, PhD,
Neil T. Shepard, PhD,
Richard A. Clendaniel, PT, PhD,
J. Donald Dishman, DC, MSc, FIACN, FIBE,
Joel A. Goebel, MD, FACS, FRCS,
Dara Meldrum, MSc, PhD,
Cynthia Ryan, MBA,
Richard L. Wallace, MSLS, EdD, AHIP, and
Nakia J. Woodward, MSIS

DOI: 10.1097/NPT.0000000000000382

ABSTRACT

Background: Uncompensated vestibular hypofunction can result in symptoms of dizziness, imbalance, and/or oscillopsia, gaze and gait instability, and impaired navigation and spatial orientation; thus, may negatively impact an individual's quality of life, ability to perform activities of daily living, drive, and work. It is estimated that one-third of adults in the United States have vestibular dysfunction and the incidence increases with age. There is strong evidence supporting vestibular physical therapy for reducing symptoms, improving gaze and postural stability, and improving function in individuals with vestibular hypofunction. The purpose of this revised clinical practice guideline is to improve quality of care and outcomes for individuals with acute, subacute, and chronic unilateral and bilateral vestibular hypofunction by providing evidence-based recommendations regarding appropriate exercises.

Methods: These guidelines are a revision of the 2016 guidelines and involved a systematic review of the literature published since 2015 through June 2020 across 6 databases. Article types included meta-analyses, systematic reviews, randomized controlled trials, cohort studies, case-control series, and case series for human subjects, published in English. Sixty-seven articles were identified as relevant to this clinical practice guideline and critically appraised for level of evidence.

Results: Based on strong evidence, clinicians should offer vestibular rehabilitation to adults with unilateral and bilateral vestibular hypofunction who present with impairments, activity limitations, and participation restrictions related to the vestibular deficit. Based on strong evidence and a preponderance of harm over benefit, clinicians should not include voluntary saccadic or smooth-pursuit eye movements in

isolation (ie, without head movement) to promote gaze stability. Based on moderate to strong evidence, clinicians may offer specific exercise techniques to target identified activity limitations and participation restrictions, including virtual reality or augmented sensory feedback. Based on strong evidence and in consideration of patient preference, clinicians should offer supervised vestibular rehabilitation. Based on moderate to weak evidence, clinicians may prescribe weekly clinic visits plus a home exercise program of gaze stabilization exercises consisting of a minimum of: (1) 3 times per day for a total of at least 12 minutes daily for individuals with acute/subacute unilateral vestibular hypofunction; (2) 3 to 5 times per day for a total of at least 20 minutes daily for 4 to 6 weeks for individuals with chronic unilateral vestibular hypofunction; (3) 3 to 5 times per day for a total of 20 to 40 minutes daily for approximately 5 to 7 weeks for individuals with bilateral vestibular hypofunction. Based on moderate evidence, clinicians may prescribe static and dynamic balance exercises for a minimum of 20 minutes daily for at least 4 to 6 weeks for individuals with chronic unilateral vestibular hypofunction and, based on expert opinion, for a minimum of 6 to 9 weeks for individuals with bilateral vestibular hypofunction. Based on moderate evidence, clinicians may use achievement of primary goals, resolution of symptoms, normalized balance and vestibular function, or plateau in progress as reasons for stopping therapy. Based on moderate to strong evidence, clinicians may evaluate factors, including time from onset of symptoms, comorbidities, cognitive function, and use of medication that could modify rehabilitation outcomes.

Discussion: Recent evidence supports the original recommendations from the 2016 guidelines. There is strong evidence that vestibular physical therapy provides a clear and substantial benefit to individuals with unilateral and bilateral vestibular hypofunction.

Limitations: The focus of the guideline was on peripheral vestibular hypofunction; thus, the recommendations of the guideline may not apply to individuals with central vestibular disorders. One criterion for study inclusion was that vestibular hypofunction was determined based on objective vestibular function tests. This guideline may not apply to individuals who report symptoms of dizziness, imbalance, and/or oscillopsia without a diagnosis of vestibular hypofunction.

Disclaimer: These recommendations are intended as a guide to optimize rehabilitation outcomes for individuals undergoing vestibular physical therapy. The contents of this guideline were developed with support from the American Physical Therapy Association and the Academy of Neurologic Physical Therapy using a rigorous review process. The authors declared no conflict of interest and maintained editorial independence.

Video Abstract available for more insights from the authors (see the Video, Supplemental Digital Content 1, available at: http://links.lww.com/JNPT/A369).

Key words: *clinical practice guidelines, vestibular hypofunction, vestibular rehabilitation*

Hearing and Balance Research Program, James H. Quillen VAMC, Mountain Home, and Physical Therapy Program, Department of Rehabilitative Sciences, East Tennessee State University, Johnson City, Tennessee (C.D.H.); Department of Physical Medicine and Rehabilitation, School of Medicine (Emerita), Emory University, Atlanta, Georgia (S.J.H.); Department of Physical Therapy, School of Health and Rehabilitation Science, University of Pittsburgh, Pittsburgh, Pennsylvania (S.L.W., J.M.F.); Department of Otolaryngology, University of Pittsburgh, Pittsburgh, Pennsylvania (S.L.W., J.M.F.); Department of Otolaryngology, University of Rochester, Rochester, New York (E.R.A.); Department of Otolaryngology, Michigan Medicine, University of

Michigan, Ann Arbor (W.J.C.); Army-Baylor University Doctoral Program in Physical Therapy, Fort Sam Houston, Texas (C.W.H.); Otolaryngology, University of Colorado School of Medicine, Denver (S.P.C.); Department of Physical Therapy, The University of Alabama at Birmingham, Birmingham (J.B.C.); Bobby R. Alford Department of Otolaryngology–Head and Neck Surgery, Baylor College of Medicine, Houston, Texas (H.S.C.); Balance Disorders and Vestibular Neurology, Barrow Neurological Institute, Phoenix, and Department of Neurology, University of Arizona College of Medicine, Phoenix, Arizona (T.D.F.); Otorhinolaryngology, Mayo College of Medicine, Rochester, Minnesota (N.T.S.); Department of Orthopaedics, Doctor of Physical Therapy Division and Department of Head and Neck Surgery & Communication Sciences, Duke University Medical Center, Durham, North Carolina (R.A.C.); College of Chiropractic, Parker University, Dallas, Texas (J.D.D.); Department of Otolaryngology–Head and Neck Surgery, Washington University School of Medicine, Saint Louis, Missouri (J.A.G.); Trinity Biomedical Sciences Institute, Trinity College, Dublin, Ireland (D.M.); Vestibular Disorders Association (VeDA), Portland, Oregon (C.R.); and Quillen College of Medicine Library, East Tennessee State University, Johnson City (N.J.W., R.L.W.).

The American Physical Therapy Association provided grant funding for the update of this CPG.

All members of the Guideline Development Group and Advisory Board completed conflict of interest forms, which included information about grant funding, royalties, device/company shares, legal assistance, patents, device consultant/advocacy, publications, presentations, and clinical practice related to the Clinical Practice Guideline (CPG) topic. Forms were submitted to the Academy of Neurologic Physical Therapy (ANPT) Evidence-Based Documents Committee, who monitored and managed any identified perceived conflicts of interest. All recommendations were written as a group per standard CPG methodology. Therefore, no one individual made all the decisions.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.jnpt.org).

Correspondence: Courtney D. Hall, PT, PhD, James H. Quillen VAMC, Mountain Home, TN 37684 (hallcd1@etsu.edu).

TABLE OF CONTENTS

SUMMARY OF ACTION STATEMENTS

Therapeutic Intervention for Individuals With Peripheral Vestibular Hypofunction

Action Statement 1: EFFECTIVENESS OF VESTIBULAR REHABILITATION IN ADULTS WITH ACUTE AND SUBACUTE UNILATERAL VESTIBULAR HYPOFUNCTION. Clinicians should offer vestibular physical therapy to individuals with acute or subacute unilateral vestibular hypofunction (evidence quality: I; recommendation strength: strong).

Action Statement 2: EFFECTIVENESS OF VESTIBULAR REHABILITATION IN ADULTS WITH CHRONIC UNILATERAL VESTIBULAR HYPOFUNCTION. Clinicians should offer vestibular physical therapy to individuals with chronic unilateral vestibular hypofunction (evidence quality: I; recommendation strength: strong).

Action Statement 3: EFFECTIVENESS OF VESTIBULAR REHABILITATION IN ADULTS WITH BILATERAL VESTIBULAR HYPOFUNCTION. Clinicians should offer vestibular physical therapy to adults with bilateral vestibular hypofunction (evidence quality: I; recommendation strength: strong).

Action Statement 4: EFFECTIVENESS OF SACCADIC OR SMOOTH-PURSUIT EXERCISES IN INDIVIDUALS WITH PERIPHERAL VESTIBULAR HYPOFUNCTION (UNILATERAL OR BILATERAL). Clinicians should not offer saccadic or smooth-pursuit exercises as specific exercises for gaze stability to individuals with unilateral or bilateral vestibular hypofunction (evidence quality: I; recommendation strength: strong).

Action Statement 5: COMPARATIVE EFFECTIVENESS OF DIFFERENT VESTIBULAR REHABILITATION MODALITIES IN INDIVIDUALS WITH VESTIBULAR HYPOFUNCTION. Clinicians may provide targeted exercise techniques to accomplish specific goals appropriate to address identified impairments, activity limitations, and participation restrictions (evidence quality: II; recommendation strength: moderate).

Action Statement 6a. **OPTIMAL BALANCE EXERCISE DOSE IN THE TREATMENT OF INDIVIDUALS WITH PERIPHERAL VESTIBULAR HYPOFUNCTION (UNILATERAL AND BILATERAL).** Clinicians may prescribe static and dynamic balance exercises: (1) for a minimum of 20 minutes daily for at least 4 to 6 weeks for individuals with chronic unilateral vestibular hypofunction (evidence quality: II; recommendation strength: weak); may consider prescribing static and dynamic balance exercises; (2) for individuals with acute/subacute unilateral vestibular hypofunction; however, no specific dose recommendations can be made at this time (evidence quality: II; recommendation strength: expert opinion); and (3) for 6 to 9 weeks for individuals with bilateral vestibular hypofunction (evidence quality: III-IV; recommendation strength: expert opinion).

Action Statement 6b. **OPTIMAL GAZE STABILIZATION EXERCISE DOSAGE OF TREATMENT IN INDIVIDUALS WITH PERIPHERAL VESTIBULAR HYPOFUNCTION (UNILATERAL AND BILATERAL).** Clinicians may prescribe weekly clinic visits plus a home exercise program of gaze stabilization exercises including at a minimum: (1) 3 times per day for a total of at least 12 minutes daily for individuals with acute/subacute unilateral vestibular hypofunction (evidence quality: II; recommendation strength: weak); (2) 3 to 5 times per day for a total of at least 20 minutes daily for 4 to 6 weeks for individuals with chronic unilateral vestibular hypofunction (evidence quality: II; recommendation strength: weak); and (3) 3 to 5 times per day for a total of 20 to 40 minutes daily for approximately 5 to 7 weeks for individuals with bilateral vestibular hypofunction (evidence quality: III; recommendation strength: weak).

Action Statement 7: **EFFECTIVENESS OF SUPERVISED VESTIBULAR REHABILITATION.** Clinicians should offer supervised vestibular physical therapy in individuals with unilateral or bilateral peripheral vestibular hypofunction (evidence quality: I; recommendation strength: strong).

Action Statement 8: **DECISION RULES FOR STOPPING VESTIBULAR REHABILITATION IN INDIVIDUALS WITH PERIPHERAL VESTIBULAR HYPOFUNCTION (UNILATERAL AND BILATERAL).** Clinicians may use achievement of primary goals, resolution of symptoms, normalized balance and vestibular function, or plateau in progress as reasons for stopping therapy (evidence quality: II; recommendation strength: moderate).

Action Statement 9: FACTORS THAT MODIFY REHABILITATION OUTCOMES. Clinicians may evaluate factors that could modify rehabilitation outcomes (evidence quality: I-II; recommendation strength: moderate to strong).

Action Statement 10: **THE HARM/BENEFIT RATIO FOR VESTIBULAR REHABILITATION IN TERMS OF QUALITY OF LIFE.** Clinicians should offer vestibular physical therapy to persons with peripheral vestibular hypofunction with the intention of improving quality of life (evidence quality: level I; recommendation strength: strong).

DIFFERENCES FROM THE PRIOR GUIDELINE

Recent evidence supports the original recommendations from the 2016 Clinical Practice Guidelines (CPGs).[1] There is strong evidence that vestibular physical therapy (VPT) provides a clear and substantial benefit to individuals with unilateral (UVH) and bilateral vestibular hypofunction (BVH). With the exception of extenuating circumstances, VPT should be offered to individuals, especially those older than 50 years, who are experiencing signs (unsteadiness, near-falls, or falls) or symptoms (dizziness, disequilibrium, motion sensitivity, and/or oscillopsia) of vestibular hypofunction. For the majority of individuals, VPT results in improved balance, reduced symptom complaints, improved functional recovery including activities of daily living, reduced fall risk, and improved quality of life. There is some evidence that dynamic postural stability as well as quality of life for individuals with BVH does not improve to the same extent as for individuals with UVH.

- New evidence from 18 randomized clinical/controlled trials (RCTs), 9 prospective and 8 retrospective cohort studies.
- Expanded action statement profiles to explicitly state quality improvement opportunities, intentional vagueness, and implementation and audit.
- New evidence in support of earlier initiation of VPT, within the first 2 weeks of acute onset of UVH.
- Support for consideration of a variety of balance training modalities, including low technology, virtual reality, optokinetic stimulation, platform perturbations, and vibrotactile feedback.
- New recommendations regarding balance exercise dosage (intensity, duration, or frequency) for individuals with chronic UVH and BVH.
- Stronger recommendation supporting the decision to stop therapy with specific considerations in making the decision to stop therapy based on results from 24 new studies.
- Expanded recommendations on factors that may impact rehabilitation outcomes, including the effects of medications and mild cognitive impairment.

LEVELS OF EVIDENCE AND GRADE OF RECOMMENDATIONS

The vestibular hypofunction CPG is intended to optimize rehabilitation outcomes for individuals undergoing VPT as a result of peripheral vestibular hypofunction. As such, the intention of the recommendations is to provide guidance to health care providers managing the health care of individuals with peripheral vestibular hypofunction and clinicians providing VPT. Clinicians should interpret the guidelines in the context of their specific clinical practice, individual situation, and clinical judgment, as well as the potential for harm.

The methods of critical appraisal, assigning levels of evidence to the literature, and assigning level of strength to the recommendations, follow accepted international methodologies of evidence-based practice.[2,3] The guideline is organized to present the definitions of the levels of evidence and grades for action statements, the summary of 11 action statements, followed by the description of each action statement with a standardized profile of information that meets the Institute of Medicine's criteria for transparent clinical practice guidelines. Recommendations for research were included.

Each research article included in this guideline that involved an RCT was appraised by 2 reviewers and assigned a level of evidence based on criteria adapted from the Centre for Evidence-Based Medicine for intervention studies.[4] The grading criteria to determine the level of evidence are described in Table 1. The American Physical Therapy Association (APTA) Critical Appraisal Tool for Experimental Interventions (CAT-EI) was used to appraise relevant articles. Two trained reviewers independently evaluated the quality of each article that reported an RCT using the CAT-EI and assigned a level of evidence based on the critical appraisal score with the additional criteria of randomization, blinding, and at least 80% follow-up. In addition, reviewers rated the overall quality of the study (high, acceptable, low, and unacceptable) based on the combined strengths and weaknesses of the design as defined in the CAT-EI. The guideline development group (GDG) reviewed the quality ratings and adjusted the final level of evidence as appropriate in the case of study limitations. Cohort studies were appraised using the Scottish Intercollegiate Guidelines Network (SIGN) methodology checklist (www.sign.ac.uk) by 2 reviewers from the GDG. Other interventional studies were assigned a level of evidence by the GDG based on the research designs (Table 1).

The grade of recommendation reflects the overall strength of the evidence available to support the action statement. The criteria for the grades of recommendation assigned to each action statement were stated in the previously established methods for the original guideline and are provided in Table 2. Throughout the guideline, each action statement is preceded by a letter grade (A-D) indicating the strength of the recommendation, followed by the statement and summary of the supporting evidence.

TABLE 1. Levels of Evidence for Studies

I	Evidence obtained from high-quality (≥50% critical appraisal score *and* >80% follow-up, blinding, and appropriate randomization) randomized controlled trials
II	Evidence obtained from high-quality cohort (>80% follow-up) study or lesser quality (<50% critical appraisal score *or* the study does not meet requirements for high quality) randomized controlled trials
III	Evidence obtained from case-control study, lower-quality cohort study, or retrospective studies
IV	Evidence obtained from case series
V	Expert opinion

TABLE 2. Definition of Grades of Recommendations[a]

GRADE	RECOMMENDATION	STRENGTH OF EVIDENCE
A	Strong evidence	A preponderance of level I and/or level II studies support the recommendation. This must include at least 1 level I study directly on the topic that supports the recommendation. Recommendation obligation: "should" or "should not."
B	Moderate evidence	A single high-quality randomized controlled trial or a preponderance of level II studies support the recommendation. Recommendation obligation: "may" or "may not."
C	Weak evidence	A single level II study or a preponderance of level III and IV studies support the recommendation. Recommendation obligation: "may" or "may not."
D	Expert opinion	Best practice based on the clinical experience of the guideline development team and guided by the evidence, which may be conflicting. Recommendation obligation: "may consider."

[a]Each action statement is preceded by a **bolded** letter grade (A-D) indicating the strength of the recommendation. This table is available in color online (www.jnpt.org).

INTRODUCTION

Purpose and Scope of the Clinical Practice Guideline

The Academy of Neurologic Physical Therapy (ANPT) of the APTA supports the development of CPGs to assist physical therapists/physical therapist assistants with optimizing rehabilitation outcomes. Specifically, this revised CPG describes the updated evidence since 2015 supporting VPT for individuals with peripheral vestibular hypofunction (see Table 3 for a list of abbreviations used throughout this document and Table 4 for specific definitions and terms). Furthermore, this CPG identifies research areas to improve the evidence supporting clinical management of individuals with peripheral vestibular hypofunction.

The primary purpose of this CPG is to revise the previous guideline by systematically assessing the peer-reviewed literature on vestibular rehabilitation for peripheral vestibular hypofunction since publication of the original CPG[1] and make updated recommendations as needed based on the quality of new research. The types of evidence that were included in the CPG were meta-analyses, systematic reviews, RCTs, cohort studies, case-control studies, and case series. Only articles with human subjects, published in English, and published after 2015 were included in this revision.

Numerous outcome measures have been utilized to assess the impact of vestibular dysfunction and to guide and monitor rehabilitation outcomes of VPT. However, there is no consensus as to a core set of outcome measures for use with individuals with vestibular hypofunction. It is beyond the scope of this CPG to make recommendations for specific outcome measures. The Vestibular Evidence Database to Guide Effectiveness task force provided recommendations on outcome measures for persons with vestibular hypofunction (http://www.neuropt.org/professional-resources/neurology-section-outcome-measures-recommendations/vestibular-disorders). A summary of outcome measures categorized according to the International Classification of Functioning, Disability and Health (ICF) model is provided in Tables 5 and 6.

The intention of this CPG is to improve quality of care and functional outcomes for individuals with vestibular hypofunction by providing evidence-based recommendations regarding appropriate exercises to use in the treatment of individuals with acute, subacute, and chronic UVH and in individuals with BVH. When sufficient evidence is lacking, expert

TABLE 3. List of Abbreviations

ABBREVIATION	DEFINITION
ABC	Activities-specific Balance Confidence Scale
ANPT	Academy of Neurologic Physical Therapy
A/P	Anterior-posterior
APTA	American Physical Therapy Association
BBS	Berg Balance Scale
BEST	Balance Evaluation Systems Test
BPPV	Benign paroxysmal positional vertigo
BVH	Bilateral vestibular hypofunction, including partial and complete loss of function
CAT-EI	Critical Appraisal Tool for Experimental Intervention Studies
CDP	Computerized dynamic posturography
CON	Control group
COP	Center of pressure
COR	Cervical ocular reflex
CPG	Clinical practice guideline
cVEMP	cervical vestibular-evoked myogenic potential
DGI	Dynamic Gait Index
DHI	Dizziness Handicap Inventory
DRS	Disability Rating Scale
DVA	Dynamic visual acuity
DVD	Digital video disc
EC	Eyes closed
EO	Eyes open
EXP	Experimental group
FES	Falls Efficacy Scale
FGA	Functional Gait Assessment
FRT	Functional Reach Test
FSST	Four-Square Step Test
FTSST	5 times sit-to-stand test
GDG	Guideline development group
GDS	Geriatric Depression Scale
GSE	Gaze stabilization exercises
GST	Gaze stabilization test
GDG	Guideline development group
10 MWT	10-m walk test
HADS	Hospital Anxiety and Depression Scale
HEP	Home exercise program
HIT	Head Impulse Test
HMD	Head-mounted display or device
ICF	International Classification of Functioning, Disability and Health
JNPT	Journal of Neurologic Physical Therapy
LOE	Levels of evidence

(*continues*)

(*continues*)

TABLE 3. List of Abbreviations (*Continued*)

ABBREVIATION	DEFINITION
m/l	Medial-lateral
MCI	Mild cognitive impairment
MCID	Minimal clinically important difference
mCTSIB	modified Clinical Test of Sensory Interaction on Balance
mini-BEST	mini-Balance Evaluation Systems Test
MST	Motion Sensitivity Test
NHANES	National Health and Nutrition Examination Survey
OFI	Oscillopsia Functional Impact Scale
OKS	Optokinetic stimulus
OSQ	Oscillopsia Severity Questionnaire
PANAS	Positives Affect Negative Affect Scale
PICO	Patient, Intervention, Comparison, Outcome
POD	Postoperative day
POMA	Performance-Oriented Mobility Assessment
PPPD	Persistent postural-perceptual dizziness
PSFS	Patient Specific Functional Scale
PRO	Patient-reported outcomes
QoL	Quality of life
RCT	Randomized controlled/clinical trial
SF-36	36-Item Short Form Health Survey
SIG	Special Interest Group
SIGN	Scottish Intercollegiate Guidelines Network
SLS	Single leg stance
SOT	Sensory organization test
TUG	Timed Up and Go
TUG Dual Task	TUG with cognitive and motor dual tasks
UCLADQ	UCLA Dizziness Questionnaire
UVH	Unilateral vestibular hypofunction, including partial and complete loss of function
UVL	Unilateral vestibular loss
VADL	Vestibular Disorders Activities of Daily Living Scale
VAP	Vestibular Activities and Participation Scale
VAS	Visual analog scale
VeDA	Vestibular Disorders Association
VEMP	Vestibular-evoked myogenic potential
VHQ	Vertigo Handicap Questionnaire
VOR	Vestibulo-ocular reflex
VORx1	VOR times 1 viewing paradigm exercise
VORx2	VOR times 2 viewing paradigm exercise
VPT	Vestibular physical therapy
VR	Virtual reality
VRBQ	Vestibular Rehabilitation Benefits Questionnaire
VSR	Vestibulo-spinal reflex
VSS	Vertigo Symptom Scale
VVAS	Visual Vertigo Analog Scale
vHIT	video head impulse test

(*continues*)

opinion-based recommendations are provided. Evidence-based recommendations concerning exercises that are not appropriate to use in treatment of vestibular hypofunction are presented as well as comparisons of the effectiveness of different exercise approaches, level of supervision in facilitating recovery, appropriate exercise dosage, decision rules for stopping therapy, factors that may modify outcomes, and the impact of VPT on quality of life.

Background and Need for a Clinical Practice Guideline on Vestibular Rehabilitation for Individuals With Peripheral Vestibular Hypofunction

Unilateral vestibular hypofunction is the partial or complete loss of function of one of the peripheral vestibular sensory organs and/or vestibular nerves.[65,66] Acute UVH is most commonly due to vestibular neuritis but may also be due to trauma, surgical transection, ototoxic medication, Meniere's disease, or other lesions of the vestibulocochlear nerve or labyrinth.[65-67] The acute asymmetry in resting vestibular tone typically manifests as vertigo, nausea, and spontaneous nystagmus. Oscillopsia (visual blurring), disequilibrium, and gait/postural instability may also be present.[67,68] Spontaneous rebalancing of the resting firing rate of the tonic vestibular system results in reduction of the nystagmus, vertigo, and nausea, usually within 14 days.[69]

The remaining signs and symptoms of asymmetry of the vestibular system include gait instability, oscillopsia, head movement-induced symptoms, spatial disorientation, and impaired navigation. Improvement of these signs and symptoms requires movement-induced error signals for recovery to occur.[70-73] When there is poor compensation for vestibular hypofunction, the individual's ability to perform activities of daily living, drive, work, and exercise are affected.[74,75] The negative changes in quality of life may lead to anxiety, depression, and deconditioning.[76,77] For some people,

TABLE 4. Definition of Common Terms

TERM AND ABBREVIATION	DEFINITION
Unilateral vestibular hypofunction	Partial or complete loss of one of the peripheral vestibular sensory organs and/or vestibular nerves
Bilateral vestibular hypofunction	Partial or complete loss of both peripheral vestibular sensory organs and/or vestibular nerves
Acute	First 2 wk following the onset of symptoms
Subacute	After the first 2 wk and up to 3 mo following the onset of symptoms
Chronic	The presence of symptoms >3 mo
Vestibulo-ocular reflex	Mechanism to maintain stable vision during head movement. Two components: angular VOR, mediated by the semicircular canals, compensates for head/body rotation; linear VOR, mediated by the otoliths, compensates for translation motion.
Head impulse test	Test of VOR function using high acceleration, small amplitude head rotation in the plane of the semicircular canals being tested.
Gaze stabilization exercises VOR adaptation exercises VOR substitution exercises	Exercises designed to promote gaze stability and developed based on the concepts of VOR adaptation and substitution Exercises developed to induce long-term changes in the neuronal response to head movements with the goal of reducing symptoms and normalizing gaze and postural stability during head movement. Examples of adaptation exercises include VORx1 and VORx2. Exercises developed to promote alternative strategies (eg, central preprogramming of eye movements including saccades) to substitute for impaired vestibular function to enable gaze stability. Examples of substitution exercises include eye-head movements between targets and remembered target exercises.
VSR substitution exercises	Exercises developed to promote alternative strategies (eg, increased reliance on visual and somatosensory cues) to substitute for impaired or lost vestibular function to improve postural and gait stability
Habituation exercises	Exercises or movements that systematically expose the individual to a provocative stimulus that over time with repeated exposure leads to a reduction in symptoms
Balance exercises Low technology	Static (quiet stance) or dynamic exercises to optimize functioning of the systems underlying postural control. These exercises may include center of gravity control training, anticipatory and reactive balance control training, multisensory training, and gait training. Progression of exercises may involve altering visual (eg, visual cues altered—reduced, absent, or moving) and/or somatosensory input (eg, firm, uneven, or moving surfaces), and/or base of support (eg, Romberg, tandem, and single leg stance), and/or head movements, and/or a cognitive task to increase the balance challenge. Examples of dynamic activities include weight shifting, walking with head turns, and performing a secondary task (eg, arm movements) while standing or walking as appropriate based on the individual's capabilities.
High technology	Virtual reality: computer-generated simulation of real or imagined environments within which individuals interact using their own movements, such as Wii Fit Balance Board, Biodex, Cave Automatic Virtual Environments, and head-mounted displays. Optokinetic stimuli: the use of repetitive moving visual patterns provided by optokinetic discs, moving rooms or lower-tech equipment, such as busy screen savers on a computer or videos of busy visual environments.
Augmented sensory feedback	Sensory information delivered via an alternate sensory channel to replace or augment a deficient sense. Vibrotactile feedback: tactile cues provided to an individual when they are leaning/tilting away from vertical more than a predetermined amount. Haptic cues: transmission of information through the sense of touch, such as information provided by a cane. Platform oscillations: horizontal sinusoidal movement combined with oscillations
Compensation	Compensation for a vestibular disorder is a gradual process that is most likely of central origin. The process may involve adaptation of residual VOR gain, substitution of alternative strategies, habituation of symptoms, and regaining postural control
Vertigo	Specific term meaning an illusion of self-motion or of motion of the surrounding environment; typically, a spinning sensation of the body but can also be nonspinning

(*continues*)

TABLE 4. Definition of Common Terms (*Continued*)

TERM AND ABBREVIATION	DEFINITION
Dizziness	Generic term for light-headedness, swimming sensation, giddiness, imbalance, or disturbed spatial orientation
Disequilibrium	The perception of being off-balance or unsteady
Oscillopsia	The perception of visual motion or blurring of a stationary object during head movement. Often described as "bouncing" of objects especially when moving the head quickly or during self-motion.
Presbyvestibulopathy	Age-related chronic vestibular syndrome characterized by unsteadiness, gait disturbance, and/or recurrent falls in the presence of mild bilateral vestibular deficits.
Persistent postural-perceptual dizziness	Persistent dizziness, unsteadiness, or nonspinning vertigo (eg, distorted sensation of swaying of self or environment) lasting ≥3 mo. Typically, the disorder follows occurrences of acute or episodic vestibular or balance-related problems, but may follow nonvestibular insults (eg, psychological distress).

vestibular hypofunction may trigger a chronic condition called persistent postural-perceptual dizziness (PPPD).[78]

Bilateral vestibular hypofunction is a condition caused by reduced or absent function of both peripheral vestibular sensory organs and/or nerves. More than 20 different etiologies have been identified including ototoxic medication, bilateral Meniere's disease, neurodegenerative disorders, infectious disease, autoimmune disease, genetic abnormalities, vascular disease, traumatic onset, and congenital.[68,79] The etiology of BVH is idiopathic in 20% to 51% of cases.[68,80] Common symptoms include oscillopsia with head movement and imbalance.[81] Individuals with BVH experience difficulty walking in the dark and on uneven surfaces. One study found that 30% of individuals with UVH and 50% of individuals with BVH had fallen since the onset of the vestibular deficit.[82] Quality of life is often impacted, and the socioeconomic burden is high due to work-related disabilities.[83,84] Spatial navigation may also be impaired in individuals with vestibular hypofunction, as well as memory, executive function, and attention.[85]

Health Care Burden

Based on data from the National Health and Nutrition Examination Survey for 2001-2004, it is estimated that 35.4% of adults in the United States have vestibular dysfunction (based on a balance test) requiring medical attention.[86] The mean reported annual economic burden for individuals with UVH and BVH is $3500 and $13 000, respectively.[84] A more recent systematic review of the economic burden of vertigo on the health care system suggests that there are high costs associated with lost work due to decreased productivity.[87] Individuals with vertigo annually spend €818 ($965) more on health care expenses than individuals without vertigo.[88] Appropriate treatment is critical because dizziness is a major risk factor for falls; the incidence of falls is greater in individuals with vestibular hypofunction than in healthy individuals of the same age living in the community.[82,89] The direct and indirect medical costs of fall-related injuries are enormous,[90,91] and falls may lead to reduced quality of life.[92] Furthermore, a population-based study demonstrated a significantly increased risk of injury for up to 1 year after an emergency department visit for acute onset of vertigo of peripheral vestibular origin.[93]

Age-adjusted prevalence of peripheral vestibular hypofunction was recently reported to be 6.7% (450 individuals with moderate to serve vertigo within the last 12 months and 190 individuals with no history of dizziness or vertigo from southern Germany were tested); thus, it is estimated that vestibular hypofunction affects between 53 million and 95 million adults in Europe and the United States.[66] Grill et al[66] reported that 6% had unilateral vestibular loss and 4% had bilateral loss. Falls, hearing loss, and worse health were reported in the hypofunction group. The incidence of vestibular neuritis, a common etiology underlying vestibular hypofunction, is reported to be 15 to 162 per 100 000 people.[94-96] Kroenke et al[97] in a meta-analysis estimated that 630 000 clinic visits each year are due to vestibular neuritis or labyrinthitis. However, this figure does not include etiologies such as vestibular schwannoma or bilateral vestibular loss and, therefore, may underestimate the number of individuals with peripheral vestibular hypofunction.

The incidence of dizziness and imbalance complaints in children ages 3 to 17 collected as part of the United States National Health Interview Survey from 2016 was reported by Brodsky et al.[98] Overall, 5.6% of children reported either dizziness (1.2 million children) or imbalance (2.3 million children).[98] In this sample of children, there were no sex differences in dizziness or imbalance complaints.

In the 2008 Balance and Dizziness Supplement to the United States National Health Interview Survey, the reported prevalence of BVH was 64 046 Americans.[99] Of the individuals with BVH, 44% had changed their driving habits and approximately 55% reported reduced participation in social activities and difficulties with activities of daily living.[99] Individuals with BVH had a 31-fold increase in the odds of falling compared with all individuals.[99] The rate of recurrent falls in individuals with BVH is 30%.[89] Additionally, 25% reported a recent fall-related injury.[99]

Age and Vestibular Dysfunction

Vestibular function declines with increasing age.[100-103] Based on a cross-sectional study in Germany, the prevalence of peripheral vestibular hypofunction increased from 2.4% in middle-aged and younger adults to 32.1% in adults 79 years and older.[66] The prevalence of balance impairments

TABLE 5. Summary of Outcome Measures to Assess Individuals With Vestibular Hypofunction Organized Based on the ICF Model[a]

MEASURE	WHAT IT MEASURES
ICF level: body structure/function	
Dynamic visual acuity, instrumented	Computerized assessment of visual acuity during head movement relative to static visual acuity without head movement[5,6]
Dynamic visual acuity, noninstrumented (clinical)	Clinical assessment of visual acuity during head movement relative to static visual acuity without head movement using an eye examination chart[7,8]
Gaze stabilization test, instrumented	Computerized assessment of visual acuity that identifies the most rapid head rotation velocity at which an optotype of fixed size can be identified[9]
Head impulse test, instrumented (video HIT)	VOR gain and presence of overt and covert saccades with a head impulse[10]
Head shake nystagmus test	Clinical assessment of the VOR whereby the persons head is passively moved in the yaw plane to determine whether the person exhibits nystagmus when the head shaking has stopped[11]
Romberg	Assesses static standing balance with feet together[12,13]
Sharpened Romberg	Assesses static standing balance with feet in tandem position (heel touching toe)[12,13]
Sensory organization test	Computerized assessment of postural control by measuring sway under conditions in which visual/somatosensory feedbacks are altered[14,15]
Sensory organization test with head shake	Postural stability during head rotations compared with head still[16]
Subject visual vertical—bucket and instrumented	Test of perceived verticality that can be done with the "bucket test" as a low-tech alternative and with a light bar for instrumented testing[17]
(modified) Clinical Test of Sensory Interaction on Balance	Postural control under various sensory conditions, including eyes open and closed plus firm and foam surfaces[18-20]
Visual analog scale	Symptoms of dizziness, disequilibrium, and vertigo are quantified on a 10-cm line [21,22]
Visual Vertigo Analog Scale	Intensity of visual vertigo in 9 challenging situations of visual motions using a visual analog scale[23]
Motion Sensitivity Test	Motion-provoked dizziness during a series of 16 quick changes to head or body positions[24]
Vertigo Symptoms Scale	Symptoms of balance, somatic anxiety, and autonomic arousal problems[25]
ICF level: activity/participation	
5 times sit-to-stand	A measure of lower extremity strength with published norms in older adults and individuals with vestibular disorders[26-28]
30-s chair stand	A measure of lower extremity strength with published norms in older adults[29]
Functional Reach	A measure of the maximum forward reaching distance while standing in a fixed position[30,31]
Gait velocity (10-m walk test)	Walking at preferred speed[32-34]
Balance Evaluation Systems Test (BESTest)	Assessment of 6 domains contributing to postural control[35]
Mini-BESTest	Abbreviated 14-item version of the BESTest to assess dynamic balance and validated in individuals with balance disorders[36,37]
Berg Balance Scale	14-item measure of static balance and fall risk during common activities[38,39]
Dynamic Gait Index	Postural stability during various walking tasks including change speed, turn head, walk over/around obstacles, and climb stairs[40,41]
Functional Gait Assessment	Postural stability during various walking tasks including tandem, backwards, and eyes closed[42]
Four-Square Step Test	Ability to step over objects forward, sideways, and backwards[43]
Single-leg or unipedal stance test	Ability to maintain stance on 1 leg[44]
Timed Up and Go	Mobility and fall risk[45,46]
Timed Up and Go Dual Task	Mobility under dual-task conditions (cognitive and motor) and fall risk[47,48]

[a]Details regarding recommendations from the Vestibular Evidence Database to Guide Effectiveness task force are available online at http://www.neuropt.org/professional-resources/neurology-section-outcome-measures-recommendations/vestibular-disorders (accessed August 31, 2020).

TABLE 6. Patient-Reported Outcome Measures for Individuals With Vestibular Hypofunction

MEASURE	WHAT IT MEASURES
Activities-specific Balance Confidence Scale	Confidence in balance without falling or being unsteady across a continuum of activities[49,50]
Balance Exercise Difficulty Scale	Self-report rating of the perceived intensity of balance exercises[51]
Disability Rating Scale	Level of disability based on descriptions of symptoms and limited activities[24]
Dizziness Handicap Inventory	Perceived handicap as a result of dizziness[52]
Hospital Anxiety and Depression Scale	A 14-item scale to identify anxiety and depression among ill patients (the Hospital Anxiety and Depression Scale)[53,54]
Oscillopsia Functional Impact scale	Impact of oscillopsia on daily activities[55]
Oscillopsia Severity Questionnaire	Severity of oscillopsia during various activities[56]
Positive Affect Negative Affect	Validated and reliable tool for assessing depression and anxiety in individuals with dizziness[57]
UCLA Dizziness Questionnaire	Severity, frequency, and fear of dizziness and its effect on quality of life and activities of daily living[58]
Vertigo Handicap Questionnaire	Effects of vertigo on disability, handicap, and psychological distress[59]
Vertigo Symptom Scale	Quantifies number and frequency of symptoms of vertigo, autonomic sensations and anxiety arousal, and somatization[25]
Vestibular Activities and Participation	Effect of dizziness and/or balance problems on ability to perform activity and participation tasks according the ICF WHO document[60]
Vestibular Disorders Activities of Daily Living Scale	Independence in everyday activities of daily living[61]
Vestibular Rehabilitation Benefit Questionnaire	Impact of symptoms on quality of life[62.63]
Visual Analog Scale	Perceived level of symptom (eg, disequilibrium, dizziness, or oscillopsia)[21,64]
Visual Vertigo Analog Scale	Rates the intensity of visual vertigo for challenging situations of visual motions that may provoke dizziness [23]

in individuals older than 70 years is 75%[104] and increases to 85% in those older than 80 years.[86] Age-related vestibular hypofunction (presbyvestibulopathy) may be mild and typically presents with bilateral reduction in vestibular function,[105] but may interact with decline in other sensory systems leading to greater impact on mobility.[106] Older individuals with vestibular and balance disorders have a 5- to 8-fold increase in their risk of falling compared with healthy adults of the same age.[86,89] The higher risk of falling in persons with vestibular hypofunction is particularly concerning due to the high morbidity and mortality associated with falls in older adults.[90] The estimated cost of falls in older adults in 2015 was nearly $50 billion per year, with Medicare and Medicaid covering the majority of those costs.[91] Cost-effective treatments that reduce the risk for falling may, therefore, reduce overall health care costs as well as the cost to personal independence and functional decline of individuals with vestibular dysfunction.

Although vestibular dysfunction is less common in children, with an estimated prevalence of 0.45%,[107] 20% to 70% of all children with sensorineural hearing loss have vestibular loss that may be undiagnosed.[108-110] Additionally, one-third of children with balance problems were found to have a vestibular impairment.[110] An ongoing prospective study of vestibular screening in all infants who are hearing impaired will provide a better understanding of the prevalence of vestibular dysfunction in children.[111]

Efficacy of Vestibular Physical Therapy

Vestibular physical therapy exercises lead to reduced dizziness, improved postural stability thus reducing fall risk, and improved visual acuity during head movements in individuals with vestibular hypofunction.[1,112-117] Systematic reviews concluded that there is moderate to strong evidence supporting VPT for the management of individuals with UVH and BVH, specifically for reducing symptoms, improving gaze and postural stability, and improving function.[65,118] There is also preliminary evidence that visuospatial working memory may be positively impacted by VPT.[119] This updated clinical practice guideline for the treatment of peripheral vestibular hypofunction does not address etiologies covered by existing clinical practice guidelines for benign paroxysmal positional vertigo (BPPV),[120] Meniere's disease,[121] and concussion.[122]

Statement of Intent

This guideline is intended for clinicians, individuals with vestibular dysfunction and their family members, educators, researchers, policy makers, and payers. This guideline is not intended to be construed as or to serve as a standard

of medical care. Standards of care are determined based on all clinical data available for an individual and are subject to change as scientific knowledge and technology advance and patterns of care evolve. These parameters of practice should be considered as guidelines only. Adherence to them will not ensure a successful outcome in every individual, nor should they be construed as including all proper methods of care or excluding other acceptable methods of care aimed at the same results. The ultimate judgment regarding a particular clinical procedure or treatment plan must be based on: (1) clinician experience and expertise in light of the clinical presentation of the individual; (2) the available evidence; (3) the available diagnostic and treatment options; and (4) the individual's values, expectations, and preferences. However, we suggest that significant departures from strong recommendations be documented in the individual's medical record at the time the relevant clinical decision is made.

METHODS

The original vestibular GDG (C.D.H., S.J.H., and S.L.W.) proposed to revise the original CPG to the ANPT of the APTA in November 2018. Three additional members were added to the GDG in April 2019 (W.J.C.) and September 2019 (E.R.A. and C.W.H.). The workgroup submitted and received 1-year grant funding in January 2020 from the APTA to support revision of the guideline. The workgroup solicited members to form an expert multidisciplinary (Audiology, Consumer Advocate, Neurology, Occupational Therapy, Otolaryngology, and Physical Therapy) Advisory Board of people actively involved in the management of individuals with vestibular dysfunction. In addition, academic librarians with methodological expertise in systematic literature searches from East Tennessee State University and the University of Pittsburgh were included on the Advisory Board. The first Advisory Board call took place in December 2019 and 2 subsequent conference calls occurred over the following year. The Advisory Board was intimately involved in the development of the content and scope of the guideline with key questions to be answered and writing/critical edits of the CPG.

Literature Search

A systematic review of the literature was performed by the academic librarians from East Tennessee State University Quillen College of Medicine Library (Nakia Woodward, MSIS, AHIP; Richard Wallace, MSLS, EdD, AHIP) and the University of Pittsburgh Health Sciences Library System (Rose Turner, MLIS) in collaboration with the GDG (C.D.H., S.J.H., and S.L.W.). The literature searches included the following 5 databases: PubMed, Embase, Web of Science, CINAHL, and Cochrane Library. The original Patient, Intervention, Comparison, Outcome (PICO) question was framed as, "Is exercise effective at enhancing recovery of function in individuals with peripheral vestibular hypofunction?" The search query combined terms from the concept sets of patient population (peripheral vestibular hypofunction) and intervention (exercise) to retrieve all article records that included at least 1 term from patient population and intervention (see the Appendix, Supplemental Digital Content 2, available at: http://links.lww.com/JNPT/A370, which demonstrates the search strategies). Limits were used in all databases for 2015-2020 and English language. In PubMed, CINAHL, EMBASE, and Web of Science, an additional level of limits was included to exclude case reports and non-peer-reviewed journal articles. Results from all 5 databases were imported into Endnote (Clarivate, Philadelphia, Pennsylvania). Duplicates were eliminated in Endnote and the references were imported into Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia; available at: www.covidence.org) for the title/abstract and full-text reviews.

The study types included were: meta-analyses, systematic reviews, RCTs, cohort studies, case-control studies, and case series. Inclusion criteria for articles were: human subjects, published in English, and published after 2015. Exclusion criteria included: superior canal dehiscence, blindness, primary diagnosis of BPPV, migraine, central vestibular disorder, or central nervous system pathology (eg, Parkinson disease, multiple sclerosis, stroke, mild brain injury [concussion], and cerebellar ataxia).

The initial systematic search was performed in February 2019 and 1580 potential articles were identified (Figure a). Identification of relevant studies involved a 3-step process: (1) a title/abstract review during which obviously irrelevant articles were removed; (2) a full-text article review using the inclusion/exclusion criteria; and (3) review article reference lists were searched for relevant, missed articles. After duplicates were removed (n = 432), 1148 article titles and abstracts were each reviewed by 2 members of the GDG (W.J.C., C.D.H., S.J.H., and S.L.W.) to exclude obviously irrelevant ones. In the case of disagreement, a third member reviewed the article title and abstract to arbitrate. Based on the title and abstract, 1071 were excluded because of irrelevance to the topic; thus, 77 full-text articles were reviewed. Each full-text article was examined by 2 reviewers from the GDG using the inclusion/exclusion criteria. On the basis of the full-text article, 37 articles were identified as relevant to the CPG.

A follow-up literature search following the same strategy was performed in March 2020, and 373 articles were identified (Figure b). After duplicates were removed (n = 81), 291 article titles and abstracts were each reviewed by 2 members of the GDG (E.R.A., W.J.C., C.D.H., S.J.H., C.W.H., and S.L.W.) to exclude obviously irrelevant papers. Based on the title and abstract, 245 were excluded because of irrelevance to the topic; thus, 46 full-text articles were reviewed. After careful review of the full-text manuscript, 24 articles were identified as relevant to the CPG. The academic librarians identified an article that was missed from the search. In June 2020, a third and final literature search was performed (Figure c) with broader search terms and a sixth database, PEDro, was included (see the Appendix, Supplemental Digital Content 2, available at: http://links.lww.com/JNPT/A370). In addition, systematic reviews and review article reference lists were searched for relevant, missed articles by a graduate assistant and 2 additional articles were identified. At the end of this third search, an additional 6 articles were identified as relevant to the CPG.

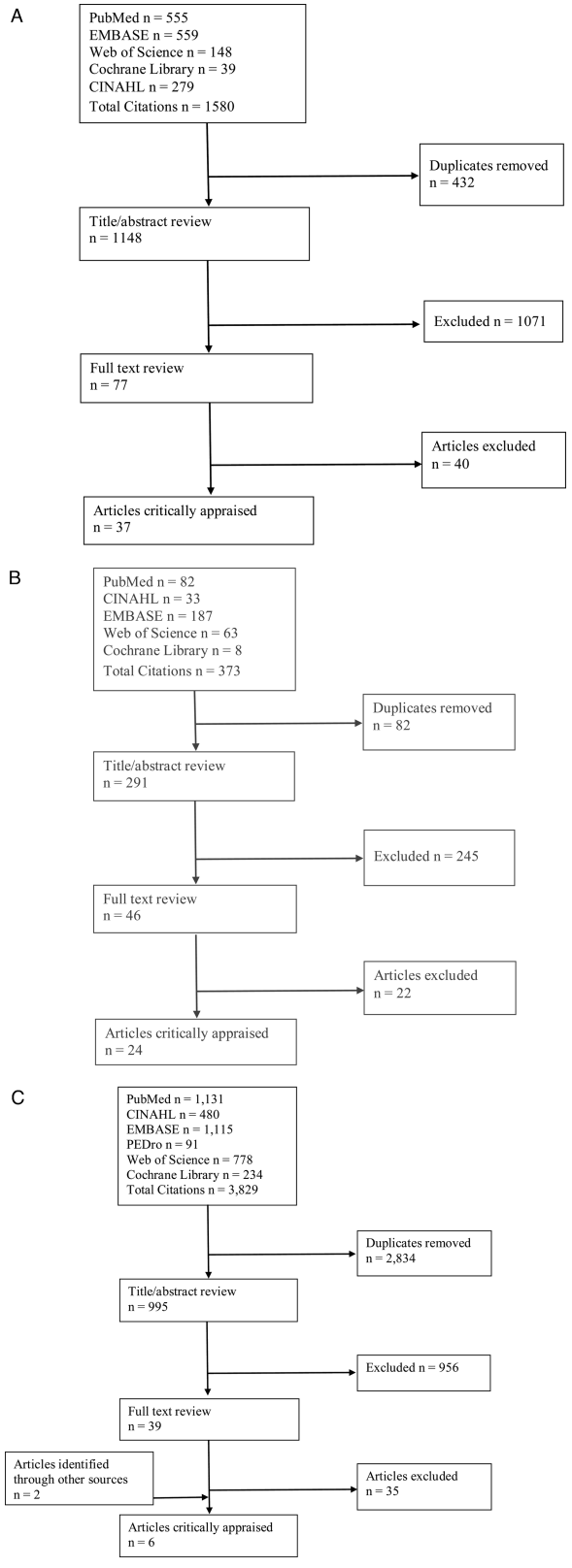

Figure. Flowcharts. (a) Initial identification of relevant articles from February 2015 through March 2019. (b) Identification of additional relevant articles through March 2020. (c) Identification of additional relevant articles from 2015 through June 2020 based on broader search terms.

Critical Appraisal Process

Levels of evidence were determined based on research design using criteria adapted from the Centre for Evidence-Based Medicine for intervention studies (Table 1), assuming high quality (eg, RCTs start at level I and cohort studies start at level II). Study quality was then assessed using critical appraisal tools appropriate to the research design and the level of evidence was adjusted based on the overall quality rating. Research articles that involved RCTs were critically appraised using the CAT-EI. Levels I and II for RCTs were differentiated based on the critical appraisal score plus 3 additional criteria. The critical appraisal score was obtained using the scoring criteria in part B of the CAT-EI that evaluated the methodological rigor of the research design, study execution, and reporting, as well as specific results (outcomes). This section includes 20 questions regarding methodology (12 questions) and research outcomes (8 questions) and each question was assigned a 1-point value and the critical appraisal score was calculated as a percentage. Level I RCTs received a critical appraisal score of at least 50% and included appropriate randomization, blinding, and at least 80% follow-up. Level II RCTs received a critical appraisal score less than 50% or the study did not meet the additional criteria of randomization, blinding, and at least 80% follow-up. Cohort studies were appraised by 2 members of the GDG using the SIGN methodology checklist (www.sign.ac.uk), which specifies that a retrospective study cannot be rated as high quality. The cohort studies included in the CPG were retrospective in nature; thus, were assigned a level III evidence, unless significant flaws were identified in which case the level was downgraded to level IV. Case series were assigned a level IV evidence based on the research design. Few systematic reviews, and a single meta-analysis, were available on VPT; thus, we did not assign them a level of evidence. Rather, we searched the references from these articles to ensure inclusion of all relevant articles, which were individually appraised for level of evidence.

Volunteers to provide critical appraisals of the articles were recruited from the ANPT and Vestibular Special Interest Group (SIG) using an online "Call for Volunteers" as well as an announcement at the annual Vestibular SIG business meeting. Physical therapist volunteers reviewed an online training video created by the APTA CPG Development Group on the use of the CAT-EI. Selected intervention articles were critically appraised by the GDG to establish test standards. Volunteers performed up to 2 practice critical appraisals, which were compared to scoring by the GDG. Volunteers were qualified to review after demonstrating more than 75% agreement with the GDG scoring. Twenty-eight volunteers successfully completed training and participated in the critical appraisal process.

Critical appraisals of each article were performed by 2 reviewers. Discrepancies in scoring were discussed and resolved by the 2 reviewers. In situations where a score could not be agreed upon, the disagreement was resolved by a member of the GDG. Critical appraisals included the level of evidence based on the critical appraisal score and the additional criteria (levels I-II) as well as quality ratings from the CAT-EI (high, acceptable, low, and unacceptable).

The GDG developed an electronic data extraction form of the study characteristics (eg, level of evidence, number of subjects, exercise type and dose, and outcome measures). Critical appraisals and data extraction information were entered by one of the reviewers into an online survey using the Qualtrics platform (Qualtrics, Provo, Utah; available at: www.qualtrics.com) and then exported into Microsoft Excel (Microsoft, Redmond, Washington).

The GDG reviewed the level of evidence and quality rating for each article and adjusted the final level of evidence as appropriate if there were serious study limitations. To minimize bias, GDG members did not review articles of which they were an author. As a group, the GDG discussed and came to consensus on final levels of evidence, which were entered into the data extraction form for use in formulating the recommendations (see the excel file, Supplemental Digital Content 3, available at: http://links.lww.com/JNPT/A371, which includes the data extraction for studies reviewed for the inclusion in the CPG). The level of evidence assigned by the reviewers was downgraded in 6 articles by the GDG because of weaknesses in the research design.

Formulating Recommendations

The data extraction files (from each of the 3 searches) summarized the results for each article (level of evidence, number of subjects, exercise type and dose, outcome measures, results, and benefit/harm) and constituted the evidence tables used to formulate the recommendations. In addition, each article was identified as relevant to specific action statements of the CPG, such as individuals with UVH versus BVH, different types of exercise, dose (intensity, duration, and frequency), or factors that modify outcomes.

Action statements were written by the GDG and external advisory board members with expertise in a particular topic area and deliberated by the GDG to minimize bias and achieve consensus. In addition, the patient perspective was represented by the director of the Vestibular Disorders Association (VeDA), a consumer advocacy group for individuals with vestibular disorders. Specific criteria used to determine the strength of a recommendation were derived from published manuals from the APTA, ANPT, and Institute of Medicine, as well as the developed scoring rubric (Table 2). The GDG developed recommendations for each action statement and considered the quality of research articles, magnitude of benefit, and the degree of certainty that a particular intervention can provide benefit over harm, risks, or costs. Available recommendations using standardized definitions included "strong evidence" (A), "moderate evidence" (B), "weak evidence" (C), and "expert opinion" (D). Furthermore, research recommendations were made on the basis of the limitations of the available evidence. A recommendation of A to D was determined by the quality of articles and magnitude of benefit versus harm.

The strength of the recommendation informed the level of obligation and specific terminology used to formulate the action statement (Table 2). A "strong" recommendation, designated as a high degree of certainty of benefit, resulted in a "should" recommendation. A "strong" recommendation that clinicians "should not" provide an intervention was indicated if a preponderance of harm, risk, or cost was associated with that intervention. A "moderate" recommendation, designated as a moderate degree of certainty of benefit, resulted in a "may" recommendation. Differentiation of "strong" versus "moderate" recommendations (A or B) was made based on the preponderance of level I and/or level II articles ("strong" recommendation) versus a single level I article or preponderance of level II articles ("moderate" recommendation) (Table 2). A "weak" recommendation, designated as a weak level of certainty of moderate to substantial benefit, resulted in a "may" recommendation. Differentiation of "moderate" versus "weak" recommendation (B or C) was made based on the preponderance of level II and III studies (Table 2). An "expert opinion" recommendation resulted in a "may consider" recommendation. For Action Statement 6, regarding exercise dose, the research evidence did not directly address the exercise dose that was used; therefore, the evidence quality of the articles was reported as scored, but the recommendations were limited to "weak" or "expert opinion" because of this limitation. The aggregate evidence quality for each recommendation reflects the total number of studies based on the updated literature search (2015-2020) as well as studies included in the original guideline (1985-2015).

Magnitude of Benefit Versus Harm

For this CPG, "benefit" was defined as decreased symptoms (less vertigo/dizziness and/or imbalance) and/or improved function (less visual blurring with head movement, improved postural stability, and reduced fall risk) as indicated by clinically meaningful changes on appropriate outcome measures. Conversely, "harm" was defined as the potential for physical or emotional damage, risks to patient safety, and costs associated with the intervention. Such harm could include the potential for a transient increase in symptoms and an increased risk of falls or near-falls. In addition, the costs (ie, the cost of equipment or trained personnel), availability, and feasibility of delivering the intervention were considered. Additional costs or burdens included those associated with the therapy sessions (ie, time, travel). Patient values and preferences (their perspectives, beliefs, expectations, and goals) were also considered in the recommendations.

External Review Process by Stakeholders

The complete draft of the CPG was peer-reviewed by the Evidence-Based Document Committee for the ANPT prior to public comment. Comments on the complete draft of the CPG were solicited from the public via email blasts to professional organizations (Audiology, Neurology, Occupational Therapy, Otolaryngology, Physical Therapy, and Bárány Society) as well as postings on the ANPT and Vestibular SIG Web sites and social media in April 2021. In addition, solicitation for feedback from consumers was made via postings on the VeDA Facebook page and email blast to VeDA members. Applicable comments were incorporated into the final version of the guideline after review by the GDG.

Diagnostic Considerations

The focus of this clinical practice guideline is on the treatment of peripheral vestibular hypofunction; thus, studies where the patient group involved primarily central involvement

(eg, traumatic brain injury, concussion, multiple sclerosis, and Parkinson disease) were excluded. Studies in which the patient group involved primarily BPPV were excluded. However, studies that included individuals with central involvement or BPPV in addition to peripheral vestibular hypofunction were included if the data for peripheral vestibular hypofunction could be evaluated separately. The literature search did not include specific diagnoses such as Meniere's disease or vestibular neuritis; rather, the more generic terms, "vestibular diseases" or "vestibular disorders," were used. Individuals with peripheral vestibular hypofunction were included regardless of etiology.

Diagnostic Criteria for Vestibular Hypofunction

Diagnosis of peripheral vestibular hypofunction had to have been confirmed with vestibular function laboratory testing (caloric or rotational chair tests for semicircular canal function or vestibular-evoked myogenic potentials or subjective visual vertical for otolith function) or video head impulse test (vHIT) results for an article to be included in this CPG. Unilateral vestibular hypofunction was determined by responses to bithermal air or water caloric irrigations with at least 25% reduced vestibular responses on 1 side.[123-125] Jongkees[126] described the formula typically used to calculate right-left caloric asymmetry. Rotational chair data on vestibulo-ocular reflex (VOR) gain, asymmetry, and phase have been used to test the vestibulo-ocular system at frequencies up to 1.0 Hz and are utilized to diagnose BVH.[127] When rotational chair testing is not available, caloric responses have been used to identify BVH. Commonly less than 12°/s summed bithermal responses is considered a profound bilateral loss and less than 20°/s is indicative of moderate to severe BVH.[128,129] A VOR gain of less than 0.7 for the horizontal semicircular canal based on vHIT has been shown to be indicative of vestibular hypofunction with a mean sensitivity of 66% and specificity of 86%.[130] The majority of studies included either caloric or vHIT of vestibular function; thus, study findings may be confounded by remaining otolith or vertical semicircular canal function. Little is known about differences in rehabilitation outcomes in individuals with loss of horizontal semicircular canal versus isolated loss of otolith organ function.

For purposes of this guideline, "acute" is defined as the first 2 weeks following onset of symptoms,[131] "subacute" as after the first 2 weeks and up to 3 months following onset of symptoms, and "chronic" as the presence of symptoms longer than 3 months.[78]

Treatment Approach

The primary approach to the management of individuals with peripheral vestibular hypofunction is exercise-based. Whereas management of the individual in the acute stage following vestibular neuritis or labyrinthitis may include medications, such as vestibular suppressants or antiemetics, the evidence does not support medication use for management of individuals with chronic vestibular hypofunction.[132] However, short-term, low-dose antihistamines to relieve symptoms may not adversely impact recovery.[133] A surgical or ablative approach is limited to individuals who have recurrent vertigo or fluctuating vestibular function and symptoms that cannot be controlled by other methods, such as lifestyle modifications or medication. The goal of the ablative approach is to convert a fluctuating deficit into a stable deficit to facilitate central vestibular compensation for UVH.[134]

The original vestibular exercises were developed by Cawthorne and Cooksey in the 1940s.[135] Cawthorne-Cooksey exercises are an approach to VPT designed to decrease symptoms of motion-provoked dizziness. The Cawthorne-Cooksey protocol includes a standardized series of exercises that involve a progression of eye movements only, head movements with eyes open or closed, bending over, sit-stand, tossing a ball, climbing ladders, and walking. The individual's position was progressed from lying down, to sitting, standing, and eventually walking. More recent studies have compared modified Cawthorne-Cooksey exercises to the original protocol,[136] or have utilized Cawthorne-Cooksey exercises as the comparative home program,[117] or have combined Cawthorne-Cooksey exercises with other adjunctive treatments including deep breathing or proprioceptive exercises.[137]

Current VPT in the United States is an exercise-based approach that includes a combination of 4 different exercise components to address the impairments, activity limitations, and participation restrictions identified during evaluation: (1) exercises to promote gaze stability (gaze stabilization exercises, including adaptation and substitution exercises), (2) exercises to habituate symptoms (habituation exercises, including optokinetic exercises), (3) exercises to improve balance and gait (balance and gait training), and (4) walking for endurance.

Gaze stabilization exercises (GSEs) were developed based on the concepts of VOR adaptation and substitution. In the vestibular literature, adaptation has referred to long-term changes in the neuronal firing rate of the vestibular system in response to head movements with the goal of reducing retinal slip.[138] Clinically, this change in firing rate results in reduced symptoms, normalized gaze stability during head movements, and normalized postural stability. Gaze stabilization exercises based on the principles of vestibular adaptation involve head movement while maintaining focus on a target, which may be stationary or moving. These exercises are commonly referred to as adaptation exercises.

Gaze stabilization exercises based on the principles of substitution were developed with the goal of promoting alternative strategies (eg, compensatory saccades or central preprogramming of eye movements), which substitute for missing vestibular function.[139,140] These exercises are commonly referred to as substitution exercises. For example, during active eye-head exercise between targets, a large eye movement to a target is made prior to the head moving to face the target, potentially facilitating the use of preprogrammed eye movements. Adaptation and substitution exercises are typically performed with head movements in the horizontal and vertical planes, although some investigators have had individuals perform GSEs in the roll plane as well.[141]

In the vestibular literature, *habituation* has referred to the reduction in a behavioral response after repeated exposure to a provocative stimulus, with the goal of reducing symptoms related to the vestibular system. Habituation exercises are chosen based on specific movements or situations (eg, busy visual environments) that provoke symptoms.

In this approach, the individual performs several repetitions of body or visual motions that cause mild to moderate symptoms. Habituation involves repeated exposure to the specific stimulus that provokes dizziness and this systematic repetition of provocative movements leads to symptom reduction over time.

More recent habituation approaches involve higher-level technology including the use of optokinetic stimulation (OKS) or virtual reality environments for habituation and/or balance exercises. Optokinetic stimulation involves the use of repetitive moving patterns provided by optokinetic discs, moving rooms, busy screen savers on a computer, or videos of busy visual environments. Virtual reality (VR), defined as "any computer hardware and software system that generates simulations of real or imagined environments with which participants interact using their own movements,"[142] immerses individuals in realistic, visually challenging environments (cave or head-mounted device, HMD) but may also include activities involving nonimmersive gaming environments. Both approaches use stimuli that can be graded in intensity through manipulation of stimulus parameters such as velocity, direction of stimulus motion, size/color of stimulus, cognitive load, and instructions to the participant. In addition, balance challenges can be added by having the individual engage in the OKS or VR activities while standing, weight-shifting, balancing, or walking.

Balance and gait training under challenging sensory and dynamic conditions are typically included as part of VPT. These typically "low-technology" exercises are intended to optimize functioning of the systems underlying postural control and may include center of gravity control training, anticipatory and reactive balance control, multisensory training, and gait training.[143] Center of gravity control exercises may involve weight shifting in stance and/or changing the base of support (eg, Romberg, tandem, and single leg stance) to increase the challenge. Anticipatory and reactive balance exercises may involve the training of different balance recovery strategies (eg, ankle, hip, or stepping strategy) under voluntary and involuntary conditions. Multisensory balance exercises involve balancing under conditions of altered visual (eg, vision removed or OKS), vestibular (eg, head moving), and/or somatosensory (eg, foam or moving surfaces) input. Gait exercises involve dynamic conditions and may include walking with head turns or performing a secondary task (eg, cognitive task such as counting backwards) while walking. The use of a patient-reported balance rating scale to measure perceived intensity of balance exercises may assist clinicians in appropriately modifying the intensity of the balance exercise program.[51,144]

Technological devices are available that have been used to augment balance and gait training such as gaming technology, platform perturbation/oscillations, and vibrotactile feedback. Gaming platforms can be engaging and fun for participants and may work on both VOR gain and postural control simultaneously if the individual is standing. Platform perturbations have been used to enhance postural control in standing. Vibrotactile stimulation delivers sensory information via an alternate sensory channel to replace or augment a deficient sense.[145] The goal is to provide the individual with information about body position in space via a waist belt with vibrating sensors. Vibrotactile feedback is typically used to alert the user when they are leaning/tilting away from vertical more than a predetermined amount.

General conditioning, such as a customized graduated walking program for endurance, is frequently an element of VPT because individuals with peripheral vestibular dysfunction often limit physical activity to avoid symptom provocation. By itself, however, general conditioning exercise not involving a balance component (eg, stationary bicycle, isometric strengthening) has not been found to be beneficial in individuals with vestibular hypofunction.[127,132]

Vestibular Rehabilitation Outcome Measures

A variety of outcome measures have been utilized to assess the impact of vestibular dysfunction; however, there is no consensus as to what aspects of function should be measured. Recommendations for specific rehabilitation outcome measures to be used in the assessment of individuals with vestibular dysfunction have been made by the Vestibular Evidence Database to Guide Effectiveness task force. They used a modified Delphi process to identify and select recommended measures. The vestibular outcome measure recommendations are available online at http://www.neuropt.org/professional-resources/neurology-section-outcome-measures-recommendations/vestibular-disorders. We provide a summary of outcome measures categorized according to the ICF model in Table 5 and patient-reported outcome measures for individuals with vestibular hypofunction (Table 6).

UPDATE AND REVISION OF GUIDELINES

These revised guidelines were updated based on scientific literature published between February 2015 and June 2020. These guidelines will be considered for review in 2026, or sooner if new evidence becomes available. Any updates to the guidelines in the interim period will be noted on the ANPT Web site (www.neuropt.org).

A. Action Statement 1: EFFECTIVENESS OF VESTIBULAR REHABILITATION IN ADULTS WITH ACUTE AND SUBACUTE UNILATERAL VESTIBULAR HYPOFUNCTION. Clinicians should offer VPT to individuals with acute or subacute unilateral vestibular hypofunction (UVH) (evidence quality: I; recommendation strength: strong).

Action Statement Profile

Aggregate evidence quality: Grade A: Strong evidence. Based on 5 level I, 8 level II, and 5 level III studies.

Benefits:

- Improved outcomes in individuals receiving VPT when compared with controls given either no exercise or sham exercise.

Risk, harm, and cost:

- Risk of nausea and possible emesis when exercises are performed during the most acute stages in some individuals.
- Some physicians may want to delay exercises during the early postoperative stage because of risk of bleeding or cerebrospinal fluid leak.
- Risk of provoking temporary dizziness during and after performance of exercises.
- Increased cost and time spent traveling associated with supervised vestibular rehabilitation.
- Exercise participation may increase the risk of falls.

Benefit-harm assessment:

- Preponderance of benefit.

Value judgments:

- Early initiation of VPT may result in shorter episodes of care, improved recovery of balance, reduced symptom complaints, improved functional recovery to include activities of daily living, reduced fall risk, and improved quality of life.

Intentional vagueness:

- Clinicians and organizations need to determine the feasibility of offering VPT to individuals with acute or subacute UVH in view of their patient population, clinician expertise, facility-specific requirements and resources, and payer requirements.

Role of individual preferences:

- Cost and availability of the individual's time and transportation may play a role.

Exclusions:

- Individuals at risk for bleeding or cerebrospinal fluid leak.
- Individuals who no longer experience dizziness or unsteadiness on the basis of UVH do not need formal VPT.
- Individuals with significantly impaired cognitive function who are likely to have poor carryover of learning.
- Very active or frequent vertigo attacks due to Meniere's disease.
- Individuals with severe mobility limitations that preclude meaningful application of therapy (they may be less able to participate).

Quality improvement:

- Vestibular physical therapy for individuals with acute or subacute UVH may differ based on patient-related factors, clinician-related factors, setting, and treatment protocol (eg, timing and dosage), making it difficult to compare data collected in different patient populations and facilities unless the protocol is also specified.
- Standardizing reporting of these patient- and clinician-related factors and treatment protocols within and across clinical settings will enable comparative outcomes research.
- The data collected could be used to study clinician performance relative to patient outcomes and internal and external benchmarks; improve health care processes; and generate new knowledge.

Implementation and audit:

- Clinics and organizations should establish examination and treatment protocol consistency within and among clinicians for individuals with acute or subacute UVH.
- Clinics and organizations should explore delivery of VPT using technology, telehealth, or self-teaching methods as an alternative for some individuals with acute or subacute UVH.

Practice Summary

Strong evidence indicates that VPT provides a clear and substantial benefit to individuals with acute or subacute UVH. With the exception of extenuating circumstances, VPT should be offered to individuals, especially those older than 50 years, who are experiencing signs (eg, unsteadiness, near-falls, or falls) or symptoms (eg, dizziness, disequilibrium, motion sensitivity, and oscillopsia) of UVH. Vestibular physical therapy may result in shorter episodes of care, improved recovery of balance, reduced symptom complaints, improved functional recovery including activities of daily living, reduced fall risk, and improved quality of life. Emerging evidence supports clinicians advocating for earlier initiation of VPT to improve gaze stability.

Evidence Update

Since 2015, 4 level II studies[131,146-148] and 2 level III studies[149,150] relevant to this group of individuals were identified.

Tokle et al[148] in an RCT (level II) compared 2 groups with acute unilateral vestibular neuritis. Both groups received 10 days of prednisolone (60 mg daily for 5 days with another 5 days of tapering). The experimental group (n = 27) was treated with VPT in a group format with additional home

exercise assignments; the control group (n = 38) received no intervention. The experimental group demonstrated a significant improvement in perceived dizziness at 3 and 12 months. At 12 months, significant improvements in Hospital Anxiety and Depression Scale (HADS) scores, Dizziness Handicap Index (DHI) scores, and perception of dizziness as a feeling of unsteadiness and imbalance while standing and/or walking were found in the group treated with VPT compared with the control group. This study adds further evidentiary support to the previous recommendations.

In an RCT (level II) by Ismail et al,[148] 60 individuals aged 20 to 50 years with confirmed acute UVH due to vestibular neuritis were treated within 3 days of symptom onset. Participants were randomized to 3 groups and treated with (1) methylprednisolone 20 mg 3 times per day for 1 week with another week of tapering (n = 20), (2) 6 weeks of VPT (n = 20), or (3) both steroids and VPT (n = 20). The VPT consisted of a home exercise program with GSE (VORx1 and VORx2), balance, and gait exercises; written instructions and drawings of the exercises were provided. All participants were assessed for caloric asymmetry, vestibular-evoked myogenic potential (VEMP) amplitude asymmetry, and DHI scores at 1, 3, 6, and 12 months after vertigo onset. This study had 24 out of 60 participants drop out at the 6- and 12-month follow-up visits stating that they felt well and did not wish to continue. The authors found that there was marked improvement in the extent of canal paresis for all 2 groups at 1 month, and there were no differences between groups. A similar trend in improvement of otolith function was seen in all groups, with almost complete otolith function regained by all groups at 6 months. All groups had improved DHI scores at 1, 2, 6, and 12 months, with no differences between groups. Limitations of this study included lack of a control group that did not receive VPT or steroids or sham therapy, which would account for natural recovery of function. The findings of this study do not add strength to the body of evidence supporting VPT for individuals with acute or subacute unilateral vestibular hypofunction, and is contradictory to the findings of Tokle et al.[148] The participants in the study by Tokle et al[148] were older (range 18-70, mean 52 ± 14 years), which may explain the difference. In addition, in the Tokle et al. study, the individuals received supervised exercises as well as a home exercise program (HEP). There is other evidence of spontaneous recovery of caloric vestibular asymmetry due to vestibular neuritis in about 50% of individuals over time.[151]

Yoo et al[146] (level II) studied 35 individuals with acute vestibular neuritis. Participants were randomized to receive VPT (VORx1 and walking with head turns) and ginkgo biloba with (n = 18) or without (n = 17) the addition of methylprednisolone (48 mg daily for 9 days with another 5 days of tapering). Both groups demonstrated improvements in caloric weakness, VOR gain measured with vHIT, sensory organization test (SOT), and DHI scores at 1- and 6-month follow-ups, with no between-group differences. This study showed improvement in recovery of VOR function, balance, and reduced symptom complaints following VPT, but there was no control group that received no exercises or sham exercises for comparison.

Lacour et al[131] in a prospective cohort study (level II) explored the timing of initiating VPT following acute UVH. Three groups performed GSE for 30 minutes twice weekly for 4 weeks, initiated during the first 2 weeks after onset (n = 10), 3 to 4 weeks after onset (n = 9), or more than 1 month after onset (n = 9). After 4 weeks of VPT, DHI scores improved in all groups, but the group initiating therapy more than 1 month after onset had significantly higher (worse) DHI scores than the other 2 groups. The group initiating therapy during the first 2 weeks after onset had a significant improvement in their dynamic visual acuity (DVA) and angular VOR gain and decreased their percentage of compensatory saccades. This level II study provides preliminary support for offering VPT to individuals earlier (during the acute stage) than later in their recovery process.

Jeong et al[150] in a level III retrospective cohort study compared individuals with and without saccular function based on cervical VEMP (cVEMP) responses in 46 individuals with acute UVH due to vestibular neuritis. VPT consisted of GSE (VORx1 and VORx2) and gait exercises. There were noted improvements in postural control, VOR gain, and DHI scores following VPT. A greater number of individuals with residual dizziness after VPT had absent cVEMPs and more sway on composite posturography, suggesting that combined horizontal canal and saccular dysfunction may explain why some individuals have less robust recovery of subjective dizziness. This study does add strength to the prior recommendation and may give some insight into why some individuals with acute UVH have incomplete recovery of symptoms.

Scheltinga et al,[149] in a level III retrospective cohort study of 30 individuals with acute UVH due to vestibular neuritis, sought to determine whether recovery of VOR function and balance were different in young versus older individuals with UVH. Participants were stratified into 3 age groups (23-35, 43-58, and 60-74 years old), and all of the groups received 10 sessions of balance training. At baseline, the older group had reduced VOR gain during rotary chair testing compared with the younger participants. After 13 weeks, VOR responses in the affected ear and asymmetries improved to within ranges of healthy controls for all groups. The postural stability of the younger participants was not different from age-matched healthy controls at onset or at 13 weeks. Normalization of body sway velocity while balancing on foam with eyes closed occurred at 3.7 weeks for the middle-aged group but took 9.6 weeks for the older group. The older group also displayed greater trunk sway during stance and gait at baseline and increased trunk sway persisted during gait at 13 weeks. While there was no control group that received no balance training or sham therapy, this study suggests that VPT (consisting of balance exercises) contributed to improvements in VOR responses and asymmetries in all age groups. The findings demonstrate that improvement of balance in people 60 years and older occurs slower and may provide support to offering VPT to individuals who are still experiencing imbalance.

Summary of Prior Supporting Evidence and Clinical Interpretation

Vestibular exercises may accelerate functional recovery, particularly in those individuals who self-limit their physical activity due to dizziness and imbalance. The previous guideline

included 5 studies with level I evidence,[152-156] 4 with level II evidence,[140,157-159] and 3 with level III evidence.[160-162]

In the first level I study, Herdman et al[152] assigned individuals scheduled for vestibular schwannoma resection to a VPT or control group. The VPT group (n = 11) performed GSE and the control group (n = 8) performed smooth-pursuit eye movements (no head movement); both groups walked at least once each day. Exercises were started 3 days postoperatively and continued until discharge from the hospital (average = postoperative day 6). By days 5 and 6, the VPT group reported less subjective disequilibrium, some improvement in postural stability and gait stability when walking with head turns compared with the control group.

Enticott et al[154] (level I) examined the effectiveness of GSE for reducing perception of dizziness/imbalance after vestibular schwannoma resection. The VPT group (n = 30) performed GSE, while the control group (n = 27) did not perform any exercises. The VPT group started exercises on postoperative day (POD) 3. The VPT group had lower DHI scores than the control group up to 12 weeks postoperatively. There was no difference between groups in spontaneous nystagmus, subjective complaints of vertigo, and vestibular asymmetry when measured over the 12-week course of the study, which would be expected because these reflect the disruption of the static component of vestibular function that recovers spontaneously.

Mruzek et al[153] (level I) found that VPT (habituation and balance exercises and daily walking) after unilateral vestibular ablation for vestibular schwannoma or Meniere's disease reduced symptom intensity and disability compared with a control group. Individuals were randomized to 3 groups: (1) vestibular exercises plus social reinforcement, (2) vestibular exercises alone, or (3) a control group who performed range of motion exercises plus social reinforcement. Vestibular exercises were initiated on POD 5 and all interventions lasted 8 weeks. Social reinforcement consisted of periodic phone calls to urge adherence and encourage and praise the participants. While all groups improved on the Motion Sensitivity Test (MST), computerized dynamic posturography, and DHI scores, the individuals who performed vestibular exercises had significantly less motion sensitivity. Eight weeks after surgery, the group that performed vestibular exercises plus social reinforcement had better (lower) scores on the physical subscale of the DHI compared with the control group. By contrast, Cohen et al[163] (level I) found no improvement in individuals after acute vestibular schwannoma resection with exercises performed for PODs 2 to 5. The exercises performed in the Cohen et al. study did not include fixation on a target during repeated head movements, which may explain the difference between the Cohen et al. findings and those of studies that found vestibular exercises performed in the acute stage-facilitated recovery. Additionally, Cohen et al. used different outcome measures from other studies, making comparisons difficult.

Vereeck et al[155] (level I) randomized individuals after vestibular schwannoma resection to 12 weeks of vestibular exercises (n = 16 younger, n = 15 older than 50 years) or to a control group (n = 11 younger, n = 11 older than 50 years). Vestibular exercises were initiated 3 to 5 days postoperatively, and included supervised GSE, walking, narrow-based walking with head turning, and treadmill training for a total of 4 sessions with an HEP 3 times per day. The control group was told to walk, read, and watch television while in the hospital, then to gradually increase their activity level once at home. There were no differences in balance measures between groups during the acute/subacute phase, except for tandem gait, which was better in the vestibular exercise group. However, when only older subjects were considered, static balance, Timed Up and Go test (TUG), tandem gait, and Dynamic Gait Index (DGI) were better in those who received vestibular exercises than in controls. Vereeck et al[155] found essentially no benefit in vestibular exercises compared with general instructions in individuals younger than 50 years. This is similar to the findings of Scheltinga et al,[149] who found that postural stability of the younger participants was not different from age-matched healthy controls at onset or at 13 weeks following UVH. Improvement of balance in participants 60 years and older occurred, albeit more slowly compared with the younger cohorts.

Sparrer et al[156] randomized individuals with acute UVH to treatment with a course of Nintendo Wii Fit Balance Board balance exercises (n = 37) or to a control group (n = 34). Individuals in the control group required 2.4 days (standard deviation = 0.4) longer hospitalization on average than the patients in the exercise group. At both 5 days and 10 weeks after exercise, the exercise group had significantly better results on the SOT, DHI, Vertigo Symptom Scale (VSS), and Falls Efficacy Scale (FES) than the control group.

Based on the 5 level I studies discussed earlier,[152-156] 4 studies with level II evidence,[141,157-159] and 3 studies with level III evidence[160-162] reviewed in the previous CPG, there was strong evidence that VPT provides a clear and substantial benefit to individuals with acute or subacute UVH.

Overall Summary

There is no substantive change to the original recommendation from 2016. Some additional more nuanced information has been added to our knowledge base on VPT for acute UVH. For example, in individuals younger than 50 years without other comorbidities, the prognosis is good almost regardless of the treatment rendered.[147,149,155] Ismail et al[147] found no difference among treatment with steroids, VPT, or both steroids and VPT in individuals younger than 50 years with acute UVH due to vestibular neuritis. However, there was little information on the dosage of the VPT delivered. Some level II evidence further adds to the previous recommendation that individuals with acute UVH respond favorably to VPT.[148] Additionally, clinicians should consider initiating VPT within the first 2 weeks of onset of vestibular neuritis.[131]

Research Recommendation 1: The timing of initiation of VPT after acute or subacute onset of UVH should be further examined with respect to optimizing rehabilitation outcomes.

Research Recommendation 2: Researchers should explore delivery of VPT using technology, telehealth, or self-teaching methods as an alternative for some individuals and identify individual-level factors that impact the use of technology on rehabilitation outcomes and patient satisfaction.

Research Recommendation 3: Researchers should identify factors that predict which individuals will need VPT to optimize outcomes and which individuals will recover spontaneously.

A. Action Statement 2: EFFECTIVENESS OF VESTIBULAR REHABILITATION IN ADULTS WITH CHRONIC UNILATERAL VESTIBULAR HYPOFUNCTION. Clinicians should offer VPT to individuals with chronic unilateral vestibular hypofunction (evidence quality: I; recommendation strength: strong).

Action Statement Profile

Aggregate evidence quality: Grade A: Strong evidence. Based on 5 level I, 6 level II, and 2 level III studies.

Benefits:

- Improved outcomes in individuals receiving VPT when compared with controls given either no exercise or sham exercise.

Risk, harm, and cost:

- Increased cost and time spent traveling associated with supervised VPT.
- Increased symptom intensity (dizziness and nausea) during treatment.
- Exercise participation may increase the risk of falls.

Benefit-harm assessment:

- Preponderance of benefit.

Value judgments:

- Importance of optimizing and accelerating recovery of balance, decreasing distress, improving functional recovery to include activities of daily living, and reducing fall risk.

Intentional vagueness:

- Clinicians and organizations need to determine the feasibility of offering VPT to individuals with chronic UVH in view of their patient population, clinician expertise, facility-specific requirements and resources, and payer requirements.

Role of individual preferences:

- Cost and availability of the individual's time and transportation may play a role.

Exclusions:

- Individuals who no longer experience dizziness or unsteadiness on the basis of UVH do not need formal VPT.
- Individuals with significantly impaired cognitive function who are likely to have poor carryover of learning.
- Very active or frequent vertigo attacks due to Meniere's disease.
- Individuals with severe mobility limitations that preclude meaningful application of therapy (they may be less able to participate).

Quality improvement:

- Vestibular physical therapy for individuals with chronic UVH may differ based on patient-related factors, clinician-related factors, setting, and treatment protocol (eg, timing and dosage), making it difficult to compare data collected in different patient populations and facilities unless the protocol is also specified.
- Standardizing reporting of these factors and treatment protocols within and across clinical settings will enable comparative outcomes research.
- The data collected could be used to study clinician performance relative to patient outcomes and internal and external benchmarks; improve health care processes; and generate new knowledge.

Implementation and audit:

- Clinics and organizations should establish examination and treatment protocol consistency within and among clinicians for individuals with chronic UVH.
- Clinics and organizations should explore delivery of VPT using technology, telehealth, or self-teaching methods as an alternative for some individuals with chronic UVH.

Practice Summary

Strong evidence supports recommending VPT for symptomatic individuals with chronic UVH on the basis that VPT provides a clear and substantial benefit. Except for selected circumstances that preclude its use, VPT should be offered to individuals who are still experiencing symptoms (eg, dizziness, unsteadiness, motion sensitivity, and oscillopsia).

Evidence Update

Since 2015, 2 level I studies,[113,136] 4 level II studies,[117,133,164,165] and 2 level III studies[166,167] relevant to this group of individuals were identified.

Meldrum et al[113] in a 2-center, assessor-blinded RCT (level I) explored the effect of VR exercises compared with VPT on changes in gait speed, DVA, DGI, anxiety and depression, Vestibular Rehabilitation Benefits Questionnaire (VRBQ), and Activities-specific Balance Confidence Scale (ABC) in individuals with UVH and symptoms greater than 6 weeks. The mean duration of symptoms was 4.63 ± 4.99 years in the VPT group and 5.85 ± 8.27 years in the VR group. The experimental group (VR; n = 32) performed 15 minutes of balance exercises (5 days out of 7 for 6 weeks) with the Wii Fit Plus system fitted with a rocker board (Frii Board, Swiit Game Gear), and the control group (VPT; n = 36) performed the same intensity and frequency of balance exercises with and without a foam cushion. Additionally, both groups performed GSE and a walking program for 6 weeks. Both groups made significant improvements in gait speed and other gait parameters (gait speed, step length, step width, and percentage of gait cycle spent in double-limb support during self-selected gait speed, walking with head turns, or walking with eyes closed), but there were no statistically significant differences between groups at baseline or after 8 weeks of exercises. There were also no statistically significant between-group differences on the DGI, SOT, or DVA. While VR was not superior to balance exercises, both groups improved following 8 weeks of VPT; but there was no control group for comparison.

Ricci et al[136] in a level I RCT compared DGI, TUG, sit-to-stand, and several other measures in 2 groups of individuals older than 65 years with nonspecific vestibular loss and chronic dizziness of at least 2 months. The study

did not clarify how many subjects in each group had UVH as the cause of their dizziness. The control group (n = 40) performed Cawthorne-Cooksey exercises and the experimental group (n = 42) performed Cawthorne-Cooksey exercises with the addition of activities related to improving flexibility, cognition, sensory interaction, and muscle strength. Both groups performed 16 sessions of 50 minutes each twice weekly for 8 weeks. Both groups improved, and there was no difference in the primary (DGI) or secondary outcome measures between groups. All of the improvements were maintained at 3 months except for the manual TUG and eyes open tandem stance. Aratani et al[168] reported that both groups improved on DHI, ABC, and Vestibular Activities of Daily Living Scale (VADL) scores and there were no between-group differences at 2 or 3 months. This study did show improvement in symptom reduction, balance, and gait outcome measures following VPT, but there was no control group for comparison.

Smółka et al,[118] in an RCT (level II), compared supervised to unsupervised VPT in 2 groups of individuals with chronic unilateral vestibular dysfunction. The experimental group (n = 19) received customized group VPT (general conditioning exercises, balance, gait stability, spatial orientation training, GSE, and visual feedback balance exercises) once a week for 90 minutes over 6 weeks under the supervision of a clinician. The control group (n = 24) performed Cawthorne-Cooksey and balance exercises at home for 15 minutes twice daily for 6 weeks. Following treatment, both groups significantly improved on DHI and visual analog scale (VAS) ratings, but the experimental group demonstrated greater improvements. The TUG improved in both groups, but only the experimental group had a statistically significant improvement on the DGI and Berg Balance Scale (BBS). The authors concluded that the supervised program was more effective; however, the between-group differences could be due to the different modes or dose of exercise.

In a level II study, Micarelli et al[164] compared 2 groups of individuals with chronic UVH receiving VPT with (n = 23) or without (n = 24) a home-based HMD gaming procedure. VPT consisted of GSE, as well as static and dynamic balance and gait exercises altering visual and somatosensory inputs. Both groups were treated for 8 sessions in the clinic and performed twice daily home exercises for 30 to 40 minutes per day for 4 weeks. The HMD procedure was performed in sitting and consisted of a daily 20-minute protocol of 3-dimensional track speed racing in which steering was achieved by tilting the head. The HMD group had significant improvements on static posturography, VOR gain, DHI, and ABC scores compared with the control group (VPT only). This study showed some relative improvement in several measures using the HMD procedure to supplement VPT, but there were differences in exercise dosage between groups. Viziano et al[169] reported that these improvements were maintained at 1 year. This study suggested that VR is a possible adjunct to VPT for individuals with chronic UVH.

Bao et al[165] in a level II RCT studied 8 individuals with chronic UVH who had failed to completely compensate with VPT. All individuals received balance training for 18 sessions over 6 weeks with (n = 4) or without (n = 4) the addition of trunk vibrotactile feedback. There were no statistically significant improvements in balance-related outcome measures (the Mini-Balance Evaluation Systems Test [Mini-BESTest], SOT, gait speed, DGI, and Functional Gait Assessment [FGA]) in either group. This study, with an overall higher balance therapy dosage compared with the studies of Basta[165] (discussed later), did not result in improvements in SOT composite scores; however, the study by Bao et al[165] may have been underpowered. Three times per week training with random, intermittent vibrotactile feedback, even for a longer duration, was not as effective as daily short-term training (2 weeks) with feedback provided on every trial.[133]

Basta et al[133] (level II) studied 42 individuals with chronic vestibular dysfunction, including 14 individuals with UVH. All individuals received customized vibrotactile feedback training for 10 sessions with (n = 21) or without (n = 21) the addition of 20-mg cinnarizine and 40-mg dimenhydrinate 3 times per day. While both groups showed improvement after 10 days of treatment, there were no between-group differences on balance performance or DHI scores. This study demonstrated improvements in recovery of balance and reduced symptom complaints using vibrotactile feedback during balance training, but there was no control group that received no exercises or sham exercises for comparison; therefore, it is not clear that the improvement can be ascribed to the vibrotactile feedback.

In a retrospective study (level III) of 21 individuals with chronic UVH who were treated with VPT (adaptation and habituation exercises), Bayat and Saki[166] reported significant improvements on the DHI following 8 weeks of VPT. The evidence from this study is rated as lower quality because it was a retrospective study and there was no control group.

Crane and Schubert[167] (level III) studied individuals with chronic UVH with DHI scores of greater than 30 out of 100. In this small study (n = 4), subjects performed a 10-minute daily computer-based DVA task that encouraged angular head velocity. After a month of home-based computer head movement tasks, the DHI scores were reduced (improved).

Summary of Prior Supporting Evidence and Clinical Interpretation

The original CPG included 2 level I studies[170,171] and 3 level II studies.[74,154,172] In a level I study, Herdman et al[170] randomized 21 patients with chronic UVH (2 weeks to 3 years in duration) who also had impaired DVA and oscillopsia (measured on a VAS) to receive vestibular (n = 13) or placebo (n = 8) exercises. The vestibular exercises consisted of GSE, while the placebo exercises consisted of saccadic eye movements with the head stationary. Both groups performed 20 minutes of balance and gait exercises daily. The vestibular exercise group showed improvements in DVA with 12 of the 13 participants returned to normal, while the control group showed no change in DVA and no participants returned to normal. Neither time from onset of symptoms to initiation of exercises, age, duration of exercises, or initial DVA contributed significantly to change in DVA.

Loader et al[171] (level I) randomized 24 patients with chronic UVH to a treatment group consisting of exposure to optokinetic stimuli while standing (n = 12) or a control group (n = 12). After 3 weeks of intervention, the treatment group

had significantly better SOT scores compared with the control group. Of note, the treatment group practiced standing balance, which was closely related to the outcome measure.

Giray et al[74] (level II) randomized 41 patients with chronic UVH to receive either VPT (gaze stabilization, visual desensitization, and balance exercises) for 4 weeks (n = 20) or no treatment (n = 21). The VPT group improved on all outcome measures (VAS, DHI, BBS, and modified Clinical Test of Sensory Interaction on Balance [mCTSIB]), while the control group did not change on any of the measures. There were significant differences between groups (favoring VPT) in change scores on all outcome measures.

Based on the 2 level I studies discussed earlier,[170,171] and 3 level II studies[74,154,172] reviewed in the previous CPG, there was strong evidence that VPT provides a clear and substantial benefit for individuals with chronic UVH. With the exception of extenuating circumstances, VPT should be offered to symptomatic individuals.

Overall Summary

There is no substantive change in the original recommendations. Strong evidence continues to support recommending VPT for symptomatic individuals with chronic UVH on the basis that VPT provides a clear and substantial benefit. Use of 20-mg cinnarizine and 40-mg dimenhydrinate 3 times per day did not impede recovery in individuals with chronic vestibular dysfunction undergoing balance training with trunk vibrotactile feedback.[133]

A. Action Statement 3: EFFECTIVENESS OF VESTIBULAR REHABILITATION IN ADULTS WITH BILATERAL VESTIBULAR HYPOFUNCTION. Clinicians should offer VPT to adults with bilateral vestibular hypofunction (evidence quality: I; recommendation strength: strong).

Action Statement Profile

Aggregate evidence quality: Grade A: Strong evidence. Based on 3 level I, 2 level II, 2 level III, and 2 level IV studies.

Benefits:

- Improved outcomes in individuals receiving VPT. Improvements in overall health based on perception of changes in mobility and balance.

Risk, harm, and cost:

- Increased symptom intensity and imbalance when performing the exercises.
- Exercise participation may increase the risk of falls.
- Increased cost and time spent traveling associated with supervised VPT.

Benefit-harm assessment:

- Preponderance of benefit.

Value judgments:

- Benefits of gaze stabilization and balance exercises in individuals with bilateral vestibular hypofunction have been demonstrated with 3 level I studies (although the number of participants was small).

Intentional vagueness:

- Clinicians and/or organizations need to determine the feasibility of offering VPT to individuals with bilateral hypofunction in view of their patient population, clinician expertise, facility-specific requirements and resources, and payer requirements.

Role of individual preference:

- Cost and availability of an individual's time and transportation may play a role.

Exclusions:

- Individuals with significantly impaired cognitive function who are likely to have poor carryover learning.
- Individuals with severe mobility limitations that preclude meaningful application of therapy.

Quality improvement:

- Individuals with BVH who undergo VPT will demonstrate improvements in postural control and gait, thereby reducing their risk of falling. VPT for individuals with BVH will differ based on their premorbid comorbidities, patient-related factors, the setting, clinic equipment, and the treatment protocol provided.
- Standardized reporting of outcomes and protocols across settings will permit comparison of interventions. Specific outcome measures related to activity limitations and participation restrictions of individuals with BVH will allow clinicians to judge whether the patient has improved and if so, what function has improved because of rehabilitation. This new knowledge from standardized outcome measures in persons with BVH will help clinicians make informed decisions about optimal interventions.

Implementation and audit:

- Clinics and organizations should establish examination and treatment protocol consistency within and among clinicians for individuals with BVH.
- Use of evidence-based outcome measures should be systematically utilized and monitored to ensure consistent examination and care for individuals with BVH.

Practice Summary

Based on a preponderance of evidence, there is value in providing VPT to adults with BVH. Improvements have been noted in postural control, gaze stability, and gait in persons who have participated in a VPT or a vibrotactile exercise program.

Evidence Update

A recent level II study reported improvements in DHI scores in adults with BVH.[174] Two level III studies support the recommendation of providing VPT exercises, with no studies refuting the recommendation in persons with BVH.[112,115] Therefore, the recommendation remains strong. In these new level II and III studies, BVH was confirmed according to the Bárány Society criteria for diagnosis.[174]

Lehnen et al[115] (level III) in a randomized crossover design (n = 2) determined the mechanism of improved dynamic vision following GSE. Two individuals with oscillopsia due to chronic BVH completed 4 weeks of either a progressive GSE program (ie, VORx1 and eye-head gaze shifting for 8 minutes, 5 times per day) or an eye movement only

exercise program (ie, saccades and smooth pursuit). The order of intervention was randomized for each individual and was followed by a 4-week washout period, followed by the other intervention. Dynamic vision (a measure like the DVA test), VOR gain, and amplitude of compensatory saccades were measured with vHIT. Following GSE, both individuals improved in dynamic vision by 60% and 75%, attributed to improvements in VOR gain and efficiency of compensatory saccades. From a different recent case report, there is a suggestion that VOR gain adapts following incremental VOR training that involved head motion.[175]

Clinically meaningful changes in gait speed (0.1 m/s) in a sample of 69 individuals with chronic BVH (mean age = 63 years) suggest that VPT may decrease risk of falling and improve overall health (level III).[112] Additionally, there were clinically significant, meaningful changes in DGI and ABC scores.[112] DVA and oscillopsia symptoms also improved. In a longitudinal case report of twice daily VPT while hospitalized and then twice per week for 9 months, a person with an acute BVH showed improvements in postural control and gait between 6 and 12 months suggesting that balance and gait can improve months after onset.[176]

Brugnera et al[177] (level II) examined the effect of 10 days of balance training using a vibrotactile belt to improve postural control in individuals who had not achieved good outcomes with previous VPT and the majority (9 of 13 participants) had chronic BVH. Static and dynamic balance tasks were practiced while wearing a vibrotactile belt, which for the experimental group provided a vibratory stimulus when the individual swayed beyond a preset threshold. No stimulus was provided during the balance exercises for the control group (the power was off). Brugnera et al[177] reported improvements in postural control based on improvements on SOT conditions 5 and 6 only for the experimental group.

Four articles reviewed included individuals with BVH in studies testing the effects of various forms of VPT: Ricci et al[136] (level I), Patarapak et al[178] (level III), Itani et al[179] (level III), and Szturm et al[180] (level IV). However, the participant samples in these studies were a mixture of individuals with both BVH and UVH. Therefore, a clinical judgment could not be made as to the efficacy of exercises specifically for individuals with BVH, and these studies were not included in this action statement.

Summary of Prior Supporting Evidence and Clinical Interpretation

There is consistency between the studies prior to 2015 and the more recent findings. Physical therapists should continue to provide VPT to improve postural control and DVA in individuals with BVH. Individuals with BVH will benefit from a combination of GSE and static/dynamic balance training multiple times per day and possibly over an extended period. The 2016 CPG described 3 level I studies in adults that provided strong evidence to support this recommendation, which also informed the current recommendation.[64,127,181]

The level I studies included in the 2016 CPG included the study by Herdman et al[64] supporting the use of a progression of GSE (4-5 times per day for 20-40 minutes per day for 6 weeks) but not eye movement exercises (placebo) to improve DVA. Two level I studies by Krebs et al[127,181] support the use of a progression of GSE and balance/gait exercises, done at home 1 to 2 times per day for 12 weeks to improve gait speed, postural stability, and gait biomechanics.

Overall Summary

There is no substantive change in the original recommendations from 2016. Based on the review of new evidence since 2015, the recommendation remains strong to provide VPT for individuals with BVH. There is emerging evidence that head movement may be an important factor in optimizing recovery in persons with BVH and that it is possible to see enhancements in the VOR and gait long after onset of BVH.

Research Recommendation 4: Level I studies are needed to determine the effect of VPT in individuals with BVH on various aspects of vestibular function across ICF domains, including at the level of participation (eg, reading and learning, participation in recreation, work, and driving).

Research Recommendation 5: All future studies that include individuals with BVH should consistently confirm the diagnosis of BVH using the Bárány Society diagnostic criteria.

Research Recommendation 6: Studies that use a mixture of individuals with UVH and BVH should analyze the 2 groups separately so that clinical judgments can be made for each group.

Research Recommendation 7: There is a paucity of research on the effectiveness of vestibular rehabilitation in children. Randomized controlled studies are needed to determine the effect of GSE on gaze stability, gross motor abilities, and postural control in children with UVH and BVH.

Research Recommendation 8: Research is needed to determine whether the effective dose of GSE and balance training is dependent on the type (congenital vs acquired) and severity (UVH vs BVH) of the lesion in children.

Research Recommendation 9: Epidemiological studies are needed to confirm the prevalence of UVH and BVH in children.

A. Action Statement 4: EFFECTIVENESS OF SACCADIC OR SMOOTH-PURSUIT EXERCISES IN INDIVIDUALS WITH PERIPHERAL VESTIBULAR HYPOFUNCTION (UNILATERAL OR BILATERAL). Clinicians should not offer saccadic or smooth-pursuit exercises as specific exercises for gaze stability to individuals with unilateral or bilateral vestibular hypofunction (evidence quality: I; recommendation strength: strong).

Action Statement Profile

Aggregate evidence quality: Grade A: Strong evidence. Based on 3 level I RCTs and 1 level III study.

Benefits:

- There is no benefit to head-motion provoked dizziness or imbalance or DVA in individuals performing only saccadic or smooth-pursuit eye movements

without head movements when compared with GSE.

Risk, harm, and cost:

- Smooth-pursuit and saccadic eye movement exercises do not appear to harm individuals with unilateral or bilateral vestibular hypofunction.
- Delay in individuals receiving an effective exercise program.
- Increased cost and time spent traveling associated with ineffective supervised exercises.

Benefit-harm assessment:

- Preponderance of harm.

Value judgments:

- Importance of prescribing an effective exercise program rather than exercises that will not improve gaze stability, symptom complaint, or balance while walking.

Intentional vagueness:

- There is no vagueness because the available literature provides sufficient evidence that the use of saccade and smooth-pursuit exercises (without head movements) is not appropriate for as exercises for gaze stability for individuals with vestibular hypofunction.

Role of individual preferences:

- It is doubtful that individuals would choose to perform an ineffective exercise program.

Exclusions:

- None.

Quality improvement:

- If a clinician decides to use saccade and smooth-pursuit exercises (without head movements), the clinician should document the goal for using the exercises and provide measurement of the outcome.

Implementation and audit:

- Not applicable.

Practice Summary

Note: the saccadic eye movements used in all of these studies are voluntary saccades between 2 targets of the type used when reading and are performed with the head stationary; these should not be confused with compensatory saccadic eye movements seen after a head impulse in many individuals with vestibular hypofunction.

Only one new, level III study compared the effect of GSE to eye movement only exercises (ie, no head movements) on the recovery of individuals with BVH.[115] The findings from this study support the findings of the original CPG that exercises using eye movements without head movements do not improve function in individuals with vestibular hypofunction.

Evidence Update

A recent study by Lehnen et al[115] (level III) compared the efficacy of GSE with eye movement only exercises (ie, no head movements) on recovery of DVA using a crossover design in 2 adults with chronic BVH secondary to aminoglycoside treatment. The control exercises consisted of smooth-pursuit and saccadic eye movement for a minimum of 8 minutes, 5 times per day, for 4 weeks. The experimental exercises consisted of VORx1 and eye-head substitution exercises for a minimum of 8 minutes, 5 times per day, for 4 weeks. In this double-blinded study, DVA to unpredictable head movements improved significantly following performance of GSE. There was no change in DVA after performing the saccadic and smooth-pursuit eye movements (without head movements).

Summary of Prior Supporting Evidence and Clinical Interpretation

Three level I studies have used either saccadic and/or smooth-pursuit eye movements as control (placebo) exercises. Herdman et al[152] randomized individuals scheduled for resection of vestibular schwannoma to either a vestibular exercise group (n = 11) or a control group (n = 8). Exercises were started 3 days after resection of the vestibular schwannoma and continued until the individuals were discharged from the hospital. The control group performed vertical and horizontal smooth-pursuit eye movements against a featureless background. The experimental group performed GSE (VORx1 horizontal and vertical). The exercises were performed 5 times per day for 1 minute each in sitting and standing; all individuals were instructed to walk at least once each day. There were no differences between groups before the initiation of exercises except for age (the experimental group was significantly older). Immediately after surgery, both groups reported significantly more dizziness than before and had increased postural sway. By PODs 5 to 6, the experimental group reported significantly less disequilibrium (VAS) than the control group. The experimental group also had significantly less sway on SOT condition 4 (platform moving and eyes open) than did the control group. Additionally, 50% of the experimental group were able to walk and turn their head without losing their balance compared with none in the control group.

A second level I study by Herdman et al[170] examined individuals with chronic UVH. The experimental group (n = 13) performed adaptation and substitution exercises to improve gaze stability; the control group (n = 8) performed saccadic eye movements against a featureless background with their head stationary. Both groups had weekly clinic visits, and both performed the exercises 4 to 5 times daily for 20-30 minutes plus 20 minutes of gait and balance exercises for 4 weeks. The vestibular treatment group improved significantly in DVA, with 12 of 13 individuals having normal DVA for their age at discharge. In contrast, there was no change in DVA in the control group and no control subject achieved normal DVA for their age.

The final level I study by Herdman et al[64] compared the effects of GSE to the effects of saccadic eye movements without head movements on recovery of DVA in individuals with chronic BVH. As a group, individuals who performed GSE had a significant improvement in DVA, while the control group showed no improvement in DVA. In this study, only type of exercise was significantly correlated with change in DVA. Initial DVA, age, and subjective complaints of oscillopsia and disequilibrium were not correlated with change in DVA.

Overall Summary

The evidence, based on 4 studies, demonstrated that exercises consisting of only eye movements without head movements do not facilitate recovery of DVA in individuals with UVH or BVH.

B. Action Statement 5: COMPARATIVE EFFECTIVENESS OF DIFFERENT VESTIBULAR REHABILITATION MODALITIES IN INDIVIDUALS WITH VESTIBULAR HYPOFUNCTION. Clinicians may provide targeted exercise techniques to accomplish specific goals appropriate for addressing identified impairments, activity limitations, and participation restrictions (evidence quality: II; recommendation strength: moderate).

Action Statement Profile

Aggregate evidence quality: Grade B: Moderate evidence. *Virtual reality*: Based on 2 level I RCTs, 2 level II RCTs, and 1 level III study. *Augmented sensory feedback*: Based on 1 level I and 2 level II studies. *Other modes*: Based on 3 level I RCTs and 5 level II studies.

Benefits:

- Modest evidence that specific modes of VPT can help address specific symptom-related goals and balance/gait impairments.

Risk, harm, and cost:

- Increased cost and time spent traveling associated with supervised VPT.
- Some evidence that VR and some game-based exercises could result in motion sickness of short duration.

Benefit-harm assessment:

- Unknown, not formally assessed.

Value judgments:

- Importance of identifying the most appropriate exercise approach to optimize and accelerate recovery of balance function and decreasing distress, improving functional recovery to include activities of daily living, and reducing fall risk.

Intentional vagueness:

- Clinicians and organizations need to determine the feasibility of offering a variety of balance training modalities in addition to low-technology exercises, such as VR, OKS, platform perturbations, or vibrotactile feedback, in view of their patient population and facility-specific resources.

Role of individual preferences:

- Cost and availability of the individual's time and transportation may play a role.

Exclusions:

- Possible exclusions include active Meniere's disease, and individuals with severe cognitive or mobility impairment that precludes adequate learning and carryover or otherwise impedes meaningful participation in therapy.

Quality improvement:

- Individuals participating in technology-assisted VPT will be monitored to identify whether specific impairments improve with these techniques.

Implementation and audit:

- Use of evidence-based outcome measures should be systematically utilized and monitored to ensure consistent examination and care for individuals with vestibular hypofunction.
- Clinics and organizations should establish consistent examination and treatment protocols that are customized for the individual's specific vestibular signs and symptoms.
- Clinics and organizations should explore delivery of VPT using technology, such as VR or augmented sensory feedback, as adjunct treatment for individuals who do not respond to customary VPT or who are not compliant with vestibular exercises.
- The cost and training associated with clinical implementation of high-technology balance systems (VR, perturbation platforms, and OKS) will need to be justified.

Practice Summary

Based on the literature reviewed up to 2015 and reported in the original CPG, clinicians may offer targeted exercise techniques to accomplish specific goals and improve identified impairments, activity limitations, and participation restrictions (eg, exercises related to gaze stability and visual motion sensitivity for improved stability of the visual world and decreased sensitivity to visual motion, respectively; head movements in a habituation format to decrease sensitivity to head movement-provoked symptoms; and activities related to postural control for improved stability of stance and gait). The literature reviewed from 2015 up to 2020 further supports this contention without changing this recommendation.

Evidence Update

Virtual reality: In a level I RCT, Meldrum et al[113] compared balance training using a VR system (Wii Fit Plus and rocker board [Frii Board, Swiit Game Gear]) to balance training using low-tech, clinic equipment consisting of a foam cushion for individuals with subacute to chronic UVH. Each participant had 4 to 6 weekly clinic visits with the therapist and an HEP. The HEP consisted of GSE, progressive balance exercises, and walking for endurance, and was the same for both groups except the balance exercises were performed either with "gamified" VR or a foam cushion. At the 8-week interval, both groups showed significant improvements in the primary outcome measure (preferred gait speed) compared with baseline, but there was no difference between groups. Additionally, both groups showed significant improvements in SOT and DVA scores from baseline to 8 weeks. At 8 weeks and 6 months, there were no differences between the groups on any of the secondary outcome measures (balance confidence, DGI, DVA, anxiety/depression, sensory integration, self-report symptoms, and quality of life). Both groups had similar high compliance (~77%) with the HEP, but the experimental group reported that the balance exercises were more enjoyable and less tiring than the control group. This study demonstrated no advantage with the use of a "gamified" VR system for balance training over low-tech balance exercises.

Similar findings were reported in a level III study by Rosiak et al[182] that utilized a low-cost, custom-built VR system for balance training of individuals with subacute to chronic UVH. Participants performed supervised balance training for ten 25- to 30-minute sessions over 10 days that included center of gravity control training using VR games (experimental group, n = 25) or computerized posturography tasks with visual feedback (control group, n = 25). All participants were instructed to perform Cawthorne-Cooksey exercises at home 3 times per day. Both groups improved significantly on measures of postural stability and vertigo symptoms. One month after training, there were no significant differences in improvement between groups on the balance measures; however, the VR group reported significantly greater improvement on vertigo symptoms.

In contrast to the findings of Meldrum et al,[113] a level II RCT (Micarelli et al[164]) demonstrated a positive benefit of a VR gaming system to supplement VPT for individuals with chronic UVH. All participants (experimental: n = 23; control: n = 24) were seen twice a week in the clinic and performed 4 weeks of daily home exercises, including GSE, habituation, balance, and gait. In addition, the experimental group played an immersive VR car racing game while wearing an HMD. The visual image from the HMD had a point of view of the racecar and tilting the head to the right and left would steer the car. The experimental group did report nausea with the HMD but that decreased each week. It is notable that the experimental group performed 20 minutes of immersive VR gaming in addition to the VPT exercises performed by both groups; thus, the 2 groups spent differing amounts of time performing exercises, which may have impacted outcomes. Multiple outcome measures (primary measure was VOR gain; secondary measures included ABC, DHI, DGI, and postural sway) were assessed 1 week prior to and after 4 weeks of active therapy. Overall, both groups showed significant improvements in all outcome measures; however, the experimental group showed a modest, but significantly greater improvement in all measures.[164] Furthermore, the gains for both groups and the advantage of the HMD group over the control group were maintained 1 year later (level I).[169]

Similar benefits of using an HMD were reported in a level II study by Micarelli et al[183] for older adults with and without mild cognitive impairment (MCI). All participants improved in multiple outcome measures (posturography, DHI, DGI, and ABC) following VPT with and without an HMD; however, the subjects with MCI in the HMD group improved to a greater extent in terms of posturography, DHI, and DGI compared with those with MCI who performed VPT only.

Augmented sensory feedback: One level I[184] and 2 level II[165,177] studies support the use of augmented sensory feedback for balance training. Coelho et al[184] (level I RCT) examined the benefits to balance and gait through use of an anchor system, which provided haptic cues through hand contact with a weighted cable system that was attached to the ground. Individuals with chronic (>6 months) UVH and BVH who continued to experience dizziness following VPT consisting of Cawthorne-Cooksey exercises participated. In this study, 2 groups performed balance and gait exercises with (n = 14) and without (n = 14) the anchor system and a control group (n = 14) did not perform any exercises. Immediately following the intervention, both exercise groups, with and without anchors, improved in DHI and mini-Balance Evaluation Systems Test (mini-BEST) scores, but were not different from each other. At 3 months post-training, the exercise group with the anchor had improved significantly in gait speed compared with the nonanchor and control groups.

Two level II RCTs investigated the effect of adding a vibratory to VPT.[165,177] These studies used vibrotactile stimuli to augment sensory input used for balance (or a sham device for the control groups) in individuals with BVH (9 of 13 total subjects)[177] and UVH (n = 8).[165] Brugnera et al[177] demonstrated significant improvements for the experimental group (vibratory stimulus) for SOT conditions 5 and 6, DGI and ABC with no significant improvement in the control group (sham) immediately after 10 days of training. Bao et al[165] implemented 6 weeks of gaze stabilization, balance, and gait exercises with an augmented vibratory stimulus or sham and evaluated changes in self-reported balance confidence and balance and gait performance across multiple measures up to 6 months post-training. All participants exhibited improvements in a subset of balance and gait measures that persisted for 6 months following training. The experimental group demonstrated significantly greater improvement in balance confidence than the control group and this effect persisted.

Other modes: Another level I RCT by Ricci et al[136] was performed in older individuals (65 years and older) with long-standing complaints related to UVH. In this study, the control group (n = 40) performed Cawthorne-Cooksey exercises and the experimental group (n = 42) performed the Cawthorne-Cooksey exercises with the addition of flexibility exercises, cognitive activities, sensory interaction training, and muscle-strengthening exercises. The Cawthorne-Cooksey exercises of eye, head, and trunk movements were progressed from being done while lying and then sitting for 1 week each, to standing and then walking for 3 weeks each. Both groups improved significantly; however, there was no difference in the primary (DGI) or secondary outcome measures (TUG Dual Task, Functional Reach Test, 5 times sit-to-stand test, Romberg, Tandem Romberg, single leg stance test, and grip strength) between the 2 protocols. All the improvements were maintained at 3 months except for the manual TUG and eyes open tandem stance. Similar findings are reported for the patient-reported outcomes (PRO) of this study—both groups improved on DHI, ABC, and VADL, with no between-group differences.[168]

A level II RCT by Smółka et al[117] compared customized VPT to Cawthorne-Cooksey exercises for individuals with chronic UVH. The intervention lasted 6 weeks. The customized VPT group (n = 27) performed GSE, balance, and gait training, including computerized posturography and conditioning exercises, one time per week for 90 minutes, in a group-based, supervised session. The Cawthorne-Cooksey group (n = 31) was instructed to perform Cawthorne-Cooksey exercises and simple balance exercises 2 times per day for 15 minutes. Both groups improved significantly in level of symptoms and postural stability, although the customized VPT group demonstrated a significantly greater improvement than the Cawthorne-Cooksey group. The interpretation of the study findings is limited

due to the difference in supervision, intensity, and the progressive balance exercises.

A level II RCT by Koganemaru et al[185] investigated the effect of transcranial direct current stimulation to the cerebellum plus vestibular and balance rehabilitation therapy for individuals with UVH. Compared to a sham stimulation, greater improvement was noted for the DHI in the cerebellar stimulation group, but no differences were seen in the TUG or measures of anxiety. Of note, this study only examined immediate effects after 5 days of training.

In summary, incorporating VR and sensory augmentation into balance training exercises may be appropriate for individuals with UVH and BVH. Interventions utilizing VR for balance training without an immersive visual experience may enhance exercise enjoyment but not provide additional benefits. Immersive VR that incorporates visual and vestibular interaction via HMD with head movement may provide added benefit for both PRO and performance measures. Augmented sensory feedback during balance training may provide additional benefit to balance confidence and measures of balance and gait. The incorporation of additional flexibility, strengthening, and multisensory training to Cawthorne-Cooksey exercises may not provide additional benefit.[136] It is unclear whether customized VPT is superior to Cawthorne-Cooksey exercises for individuals with chronic UVH, as both groups improved significantly in level of symptoms and postural stability and limitations in the study design (differences in supervision, intensity, and exercise progression).[117] There is weak evidence from a single level II RCT that adding cerebellar transcranial direct stimulation to vestibular and balance rehabilitation therapy may improve DHI scores in individuals with UVH.[185]

Summary of Prior Supporting Evidence and Clinical Interpretation

Few studies have directly compared different exercise approaches to VPT for peripheral vestibular hypofunction. In a level I RCT, Pavlou et al[186] compared a customized exercise program (n = 20; balance, gait, Cawthorne-Cooksey, GSE) with exercises performed in an optokinetic environment (n = 20). Both groups improved significantly in SOT and symptom scores; however, the optokinetic stimulus group improved more in the symptom measures. In a level II RCT, Clendaniel[187] compared habituation exercises (n = 4) to GSE (n = 3) in individuals with chronic UVH. Both groups also performed balance and gait exercises and were provided an HEP. In this preliminary study, both exercise interventions resulted in improved ability to perform daily activities, sensitivity to movement, and DVA. In another level II study, Szturm et al[188] compared VPT consisting of GSE and balance exercises performed in the clinic to a home program, with Cawthorne-Cooksey exercises performed only as an unsupervised home program for individuals with chronic UVH. The VPT group showed improvement in both postural stability and vestibular symmetry while those performing the Cawthorne-Cooksey exercises did not. The interpretation of the findings of Szturm et al[188] is confounded by different levels of supervision between groups.

Two studies provided support for using particular exercises for specific problems. One, a level I study by McGibbon et al,[189] randomly assigned individuals with UVH and BVH to either a group-based vestibular exercise intervention or a group-based Tai Chi exercise intervention. The study demonstrated that balance exercises (Tai Chi) selectively improved postural stability while vestibular exercises (adaptation and substitution VOR exercises) selectively improved gaze stability. In a level II study, Jáuregui-Renaud et al[137] compared the effectiveness of Cawthorne-Cooksey exercises, Cawthorne-Cooksey exercises plus training in breathing rhythm, and Cawthorne-Cooksey exercises plus proprioceptive exercises. Although all 3 groups showed improvement in DHI scores and in static balance, the group performing Cawthorne-Cooksey exercises plus breathing training were more likely to have a meaningful clinical improvement in DHI scores and the patients performing Cawthorne-Cooksey plus proprioceptive exercises demonstrated improved postural stability. Although not conclusive, the results from these 2 studies support the concept of exercise specificity in the treatment of patients with vestibular hypofunction.

Pavlou et al[190] demonstrated positive benefits of a dynamic versus static visually stimulating VR environment on symptoms. Individuals with chronic UVH were randomized to a VR regimen incorporating exposure to a static (picture of a crowded environment) or dynamic (moving crowded square environment) VR environment. The groups who performed exercises within the dynamic VR environment had significantly better Visual Vertigo Scores than those who performed exercises inside the static VR environment. The findings provided preliminary evidence in support of dynamic VR environments as a useful adjunct to vestibular exercises.

Overall Summary

There may be benefits to providing specific exercises (eg, balance exercises) for specific impairments (eg, balance and gait impairments), although the optimal mode of these exercises, whether Tai Chi or VR, is not known. When "gamified" VR augments balance exercises, there are no additional benefits other than greater enjoyment, which may increase exercise compliance. However, coupling immersive VR with head movement appears to provide additional benefit, including reduced symptoms and improved balance. While it remains unclear when or if different types of exercises should be introduced, a lack of harm suggests clinicians may include a variety of exercise modalities to encourage engagement in the balance training activities.

Research Recommendation 10: There is sufficient evidence that vestibular exercises compared with no or placebo exercises are effective; thus, future research efforts should be directed to comparative effectiveness research.

Research Recommendation 11: Research in large-scale trials is needed to determine what types of technology-augmented VPT exercises (eg, VR for gaze or postural stability or vibratory stimulus) are most effective for improving specific symptoms and/or minimizing activity limitations and participation restrictions.

Research Recommendation 12: Research is needed to determine the most effective components of VPT (eg, gaze stability, balance, or habituation) and methods of delivering VR (eg, immersive vs nonimmersive devices).

Research Recommendation 13: Randomized controlled studies of longer-term impact on VPT outcomes are needed for emerging and novel treatment options like transcranial direct current stimulation or other forms of neuromodulation.

C, D. Action Statement 6a. OPTIMAL BALANCE EXERCISE DOSE IN THE TREATMENT OF INDIVIDUALS WITH PERIPHERAL VESTIBULAR HYPOFUNCTION (UNILATERAL AND BILATERAL). Clinicians may prescribe static and dynamic balance exercises: (1) for a minimum of 20 minutes daily for at least 4 to 6 weeks for individuals with chronic unilateral vestibular hypofunction (evidence quality: II; recommendation strength: weak); and may consider prescribing static and dynamic balance exercises; (2) for individuals with acute/subacute unilateral vestibular hypofunction; however, no specific dose recommendations can be made at this time (evidence quality: II; recommendation strength: expert opinion); and (3) for 6 to 9 weeks for individuals with bilateral vestibular hypofunction (evidence quality: III-IV; recommendation strength: expert opinion).

Action Statement Profile

Aggregate evidence quality: Indirect evidence due to extrapolation from the available literature. *Acute and subacute UVH*: Grade D: Expert opinion. Based on 3 level I and 2 level II studies. *Chronic UVH*: Grade C: Weak evidence. Based on 9 level I, 6 level II, 2 level III, and 1 level IV studies. *BVH*: Grade D: Expert opinion. Based on 2 level I, 1 level II, and 3 level III studies.

Benefits:

- Improved balance outcomes, and potentially reduced fall risk, with the appropriate exercise dose.

Risk, harm, and cost:

- Risk of provoking temporary dizziness and imbalance during performance of exercises.
- Risk of falling during challenging exercises.
- Increased cost and time spent traveling associated with supervised VPT; however, VR or telehealth visits may be an option.

Benefit-harm assessment:

- Preponderance of benefit over harm.

Value judgments:

- Importance of identifying the most appropriate balance exercise dosage to optimize and accelerate recovery of balance function and to decrease distress, improve functional recovery to activities of daily living, and reduce fall risk.
- Benefit of static and dynamic exercises in individuals with UVH has been demonstrated in numerous level l and level II studies; however, the frequency and intensity of the exercises are based on extrapolation from research studies rather than based on direct evidence.

Intentional vagueness:

- Due to the wide variability in prescribed balance exercise dose (frequency, intensity, and duration), the available literature does not provide sufficient evidence for balance exercise prescription recommendations for individuals with acute and subacute UVH.
- No studies specifically examined balance exercise frequency, duration, or intensity as factors that influence treatment efficacy; thus, suggested balance exercise doses are extrapolated from the available literature and based on the clinical experience of the GDG.
- Clinicians and organizations need to determine the feasibility of offering a variety of balance training modalities, such as VR, OKS, platform perturbations, or vibrotactile feedback, in view of their patient population and facility-specific resources.

Role of individual preferences:

- Type of balance exercises recommended, for example low-technology (altered surface, foot position, vision, head movement, and walking), VR, OKS, digital video disc (DVD)-based, moving platform-based, and augmented with vibrotactile feedback, may play a role in individual acceptance and compliance.

Exclusions:

- Individuals with low fall risk and/or those who are no longer experiencing balance or gait impairments.

Quality improvement:

- Clinicians should attempt to consistently document the specific type of balance training exercises prescribed and include dose parameters (frequency, intensity, and duration).
- Clinicians may consider adding/updating specific balance dose recommendations on patient education materials and/or exercise handouts for individuals with chronic UVH.

Implementation and audit:

- Clinics and organizations should explore delivery of VPT using technology, such as VR or augmented sensory feedback, as adjunct treatment for individuals who do not respond to customary VPT or who are not compliant with vestibular exercises. However, the cost and training associated with clinical implementation of high-technology balance systems (VR, moving platforms, and OKS) will need to be justified.

Practice Summary

No studies to date specifically examined the role of different doses of balance exercises and the effect of balance dosage on outcomes for individuals with vestibular hypofunction. Balance exercise dosage (frequency, duration, and intensity [degree of difficulty]) is an important factor to consider in the treatment of imbalance for individuals with vestibular hypofunction. Too intense and the individual might fall or give up on attempting the exercises; too easy and the exercises would not improve an individual's balance. In this action statement, information on balance dose is supported by comparing the findings from multiple studies on individuals with vestibular hypofunction. Much of the information on dose comes from research that has a specified length of study or from papers that do not provide information on what stopping rule(s) were used to end treatment. In both cases,

the treatment duration is skewed and could mean either treatment was stopped before optimal recovery or continued past the time when the patient had reached a plateau.

Most studies used a combination of low-technology exercises ("traditional" gaze stabilization, habituation, balance, and gait) and/or technology-enhanced exercises (VR, OKS, moving platform training, and vibrotactile feedback). These data suggest that for individuals with:

- Acute and sub-acute UVH: no specific dose recommendation. Studies provide support for incorporation of GSE and balance exercises to promote recovery of postural control in the early stages following vestibular loss. However, examination of specific dose parameters revealed a wide variation in balance exercise time per session/day, frequency per day/week, intensity, and duration precluding recommendation of a specific dose.
- Chronic UVH: clinicians may prescribe progressively challenging static and dynamic balance and gait exercises for a minimum of 20 minutes daily for at least 4 to 6 weeks.
- Chronic BVH: clinicians may consider prescribing daily static and dynamic balance and gait exercises for at least 6 to 9 weeks. However, per expert opinion, clinicians might consider prescribing 2 to 3 balance sessions/day for potentially greater effectiveness.

Supporting Evidence and Clinical Interpretation

Balance exercise dosage was not addressed in the 2016 CPG. No studies specifically compared different levels of balance exercise intensity, duration, or frequency to determine optimal exercise dosing; thus, these recommendations are based on the clinical experience of the GDG and are guided by the evidence. There are numerous studies to date that provide information that balance training is beneficial for individuals with UVH and BVH; however, only studies that included clear details regarding exercise type and corresponding dose (frequency, duration, or intensity) and also reported a balance outcome measure were included in this section. Refer to Action Statements 1 to 3 and 5 for more information regarding the effectiveness of VPT for individuals with vestibular hypofunction.

Acute/Subacute UVH

Evidence Update

Few studies have examined exercise dosage effect on balance outcomes for individuals with acute/subacute UVH; therefore, no specific balance dosage recommendations can be made at this time. However, 3 level I[152,156,191] and 2 level II[141,159] studies provide support for incorporation of GSE and balance exercises to promote recovery of postural control in the early stages following vestibular hypofunction.

Vestibular adaptation exercises improved postural stability in individuals with acute UVH following acoustic neuroma resection.[152] The results of this level I RCT suggest that 20 minutes/day of vestibular adaptation exercises combined with a walking program, performed on PODs 3 through 6, results in improved postural stability in individuals with acute UVH compared with controls.

In a level II prospective randomized study, Strupp et al[141] showed that combined exercises (balance, habituation, and gaze stabilization) performed at high dosage (90 minutes/day) for 1 week followed by 30 minutes of daily HEP for 3 weeks improved postural stability in individuals with acute/subacute UVH. VPT using the Nintendo Wii Fit Balance Board was the focus of a level I investigation by Sparrer et al[156] involving individuals with acute vestibular neuritis. The results of this study reinforce the findings in the Strupp et al[141] study supporting 90 minutes/day for 5 days of VPT that includes a balance exercise component, improves postural control in individuals with acute UVH.

The use of computerized posturography-assisted VPT early after UVH onset was investigated by Marioni et al[159] (level II). The results of this study suggest that 18 minutes each of balance exercises and GSE daily combined with weekly visual feedback weight shifting exercises (20 minutes) over 5 weeks improves postural control for individuals with acute UVH. The effects of weight shifting exercises with (experimental group) and without (control group) visual feedback were examined in a level I study by Cakrt et al[191] involving 17 individuals following vestibular schwannoma resection. The results of this study support the findings of Marioni et al,[159] who showed that visual feedback-based balance training combined with GSE was more effective than no treatment during the acute/subacute phase of recovery of individuals with vestibular neuritis. However, the dose of weight shifting exercise with visual feedback differed across these studies: 20 minutes, once per week for 5 weeks[159] compared with daily for 10 days (5 up to 40 minutes).[191]

Overall Summary for Acute/Subacute UVH

Five studies support the inclusion of balance exercises and/or GSE for individuals with UVH in the acute and subacute phases of recovery. Although these studies suggest early initiation of VPT is feasible, examination of specific dose parameters reveals a wide variation in exercise time per session/day, frequency per day/week, intensity, and duration.

Chronic UVH

Table 7 outlines the details for the type of balance exercises performed (low technology or high technology), the specific clinic and HEP dose, and study outcomes for individuals with chronic UVH. Many of the study details have been presented in other action statements (2 and 5).

Low-Technology Balance Exercises

Evidence Update

Low-technology ("traditional") VPT exercises were used as the primary treatment approach in 1 level I,[136] 2 level II,[74,117] and 1 level III studies[192] and as the control treatment in a level I study.[113] In these studies, the exercise programs consisted of a progression of balance challenges, usually incorporating head movements and walking, as well as GSE, and habituation exercises. Three studies also included an endurance component (walking).[113,117,192] All of these studies included regular clinic visits, 1 to 2 times a week, and daily home exercises monitored for compliance.[113,117,136,192]

TABLE 7. Vestibular Exercises and Dose for Chronic Unilateral Vestibular Hypofunction

AUTHOR/LOE	INTERVENTION	TYPE OF EXERCISES	CLINIC DOSAGE (VISITS/WK, MIN/ SESSION)	HEP DOSAGE (D/WK, MIN/D)	# OF WK	OUTCOME
Low-technology (traditional) balance exercises						
Giray et al[74]; II	EXP: low-tech VPT CON: no treatment	EXP: standing/walking altering visual, vestibular and somatosensory inputs. GSE	EXP: 2x/wk, 30-45 min CON: no treatment	EXP: 2x/d, 30-40 min/d Balance portion: 18-28 min/d	4	EXP: BBS, mCTSIB improved ($P < 0.05$)
Herdman et al[192]; III	EXP: low-tech VPT CON: none	GSE, balance, gait, endurance (walking)	1x/wk, 60-70 min	Total: 60-70 min/d GSE: 3-5x/d Balance: 2x/d Walking: 10-20 min/d	5	Gait speed, DGI improved ($P < 0.001$); 75%-88% with UVH improved significantly in outcome measures
Meldrum et al[113]; I	EXP: Wii Fit virtual reality balance (nonimmersive) CON: low-tech VPT	EXP: Wii Fit + rocker board (SLS, weight shift), GSE, endurance (walking) CON: balance with foam pad, GSE, endurance (walking)	EXP: 1x/wk, 30-40 min CON: 1x/wk, 30-40 min	Balance: 5x/wk, 15 min/d GSE: 7x/wk; 20-35 min/d Walking: 5x/wk 10-30 min/d	6	Both groups improved in gait speed and SOT. No differences between groups at 8 wk and 6 mo
Ricci et al[135]; I	"Multi-Modal" Cawthorne-Cooksey (EXP) Conventional Cawthorne-Cooksey (CON)	EXP: Cawthorne Cooksey with unstable surfaces and altered foot positions, with eye or head movements, walking with ankle weights including slopes	EXP: 2x/wk, 50 min CON: 2x/wk, 50 min	EXP/CON: 1x/d, 24-38 min/d	8	EXP/CON: improved DGI and decreased subjects with fall risk: maintained at 3 mo
Smółka et al[117]; II	EXP: VPT CON: Cawthorne-Cooksey HEP	EXP: endurance, balance with/without visual feedback, gait exercises, gaze stabilization exercises CON: Cawthorne-Cooksey	EXP: 1x/wk, 90 min	CON: 2x/d, 30 min/d	6	EXP: DGI and BBS improved ($P < 0.05$) EXP and CON: improved TUG ($P < 0.05$)
High-technology balance exercises						
Virtual reality						
Meldrum et al[113]; I	EXP: Wii Fit virtual reality balance (nonimmersive VR) CON: low-tech VPT	EXP: Wii Fit + rocker board (SLS, weight shift), GSE, endurance (walking) CON: balance with foam pad, GSE, endurance (walking)	EXP: 1x/wk, 30-40 min CON: 1x/wk, 30-40 min	Balance: 15 min/d 5x/wk GSE: 20-35 min/d, 5x/w Walking: 10-30 min/d, 5x/wk	6	Both groups improved in gait speed and SOT. No differences between groups at 8 wk and 6 mo

(*continues*)

TABLE 7. Vestibular Exercises and Dose for Chronic Unilateral Vestibular Hypofunction (*Continued*)

AUTHOR/LOE	INTERVENTION	TYPE OF EXERCISES	CLINIC DOSAGE (VISITS/WK, MIN/SESSION)	HEP DOSAGE (D/WK, MIN/D)	# OF WK	OUTCOME
Rosiak et al[182]; III	EXP: virtual reality (nonimmersive VR) CON: posturography	EXP: virtual reality games; upper body movements while maintaining COP CON: static posturography with visual feedback	10 sessions over 10 d, 25-30 min/session	Both groups: Cawthorne-Cooksey, 3x/d	2	Both groups improved postural stability; no difference between groups at 1 mo post-intervention
Micarelli et al[164]; II	EXP: low-tech VPT plus immersive VR CON: low-tech VPT	Static/dynamic balance/ gait exercises altering visual, somatosensory and visual inputs, Herdman (2003) GSE protocol	2x/wk, 30-45 min	EXP: HMD virtual reality 20 min/d EXP/CON: 2x/d, total 30-40 min/d	4	EXP: ABC, DHI, vHIT gain and some posturography measures improved
Viziano et al[169]; I	EXP: low-tech VPT plus immersive VR CON: low-tech VPT	Static/dynamic balance/ gait exercises altering visual, somatosensory and visual inputs, Herdman 2003 GSE protocol	2x/wk, 30-45 min	EXP: HMD VR 20 min/d EXP/CON: 2x/d, total 30-40 min/d	4	EXP: ABC, DHI, vHIT gain, and some posturography measures improved and maintained for 12 mo
Micarelli et al[183]; II	EXP: low-tech VPT plus HMD immersive VR CON: low-tech VPT	Static/dynamic balance/ gait exercises altering visual, somatosensory and visual inputs, Herdman 2003 GSE protocol	2x/wk, 30-45 min	EXP: HMD VR 20 min/d EXP/CON: 2x/d, total 30-40 min/d	4	EXP groups (with and without MCI): improved in VOR gain, DGI and static posturography measures compared with controls
Optokinetic stimulus						
Loader et al[171]; I	EXP: OKS (standing) CON: no treatment	EXP: standing, reading randomly projected moving texts	EXP: 3x/wk, 30 min CON: no treatment	None	3	EXP: SOT SOT-4, SOT-6, and composite score improved; EXP significantly better on SOT-1, SOT-6, SOT composite than EXP
Pavlou et al[186]; I	EXP: low-tech VPT plus OKS CON: VPT	EXP: OKS exposure while sitting, standing, walking, tandem walking CON: customized VPT	EXP: 2x/wk, 60 min CON: 2x/wk, 60 min	EXP: OKS 26 min/d CON: 12-30 min/d	8	Composite SOT improved in both groups with greater improvements in EXP group
Rossi-Izquierdo et al[194]; I	EXP: OKS CON: CDP	EXP: standing with OKS planetarium, varied stimulation planes CON: 10 CDP exercises: weight shifting, changing visual surround, moving platform	EXP: 5x/wk, 5-15 min/d CON: 5x/wk, 15-20 min	None	1	EXP: visual preference SOT scores improved; CON: vestibular and somatosensory preference SOT scores improved

(*continues*)

TABLE 7. Vestibular Exercises and Dose for Chronic Unilateral Vestibular Hypofunction (*Continued*)

AUTHOR/LOE	INTERVENTION	TYPE OF EXERCISES	CLINIC DOSAGE (VISITS/WK, MIN/ SESSION)	HEP DOSAGE (D/WK, MIN/D)	# OF WK	OUTCOME
Augmented sensory feedback						
Bao et al[165]; II	EXP: balance exercises plus trunk vibrotactile CON: balance exercises	6 reps of each training task each for 30 s Stand on firm/foam EO/EC, with/ without head movement, walk with head turns, Tandem gait, VORx1	3x/wk, 18 min/d	None	6	Mini-BESTest, SOT, gait speed, DGI, FGA did not significantly improve in either group
Basta et al[133]; II	EXP: balance exercises plus trunk vibrotactile and medication CON: balance exercises plus trunk vibrotactile no medication	5 reps of each training task, 20 s each; EO/EC stance on firm/foam, SLS, marching, Tandem gait, walk with head turns	5x/wk, 10 min/d (10 sessions total)	None	2	EXP/CON: significant improvement in SOT, DHI
Coelho et al[184]; I	EXP1: balance + anchors (haptic support) EXP2: Balance, no anchors CON: no treatment	EXP1/2: standing altering foot position, weight shifting; walking: obstacles, tandem, with eye movements CON: no treatment	EXP1: 2x/wk, 40 min EXP2: 2x/wk, 40 min	No HEP	6	EXP1, EXP2 (with/without anchors): Mini-BESTest, gait speed improved. Only anchor group maintained findings at 3 mo
Nardone et al[196]; I	EXP: horizontal perturbation CON: Cawthorne-Cooksey; Cross-over design	EXP: balance on oscillating platform, EO/EC, 2 frequencies, 2 orientations (A/P, M/L) CON: Cawthorne- Cooksey	EXP: 5 d, 2 x/d, 24 min/ session CON: 5 d, 2x/d, 30 min each	None	2	EXP/CON: POMA scores improved after initial intervention. EXP/CON: decreased body sway after both interventions
Winkler and Esses[195]; I	EXP1: perturbation tilts EXP2: perturbation tilts + HEP CON: HEP	EXP1: 10 perturbation tilts, 30 s each (5 EO/5 EC) EXP2: 10 perturbation tilts, 30 s each (5 EO/5 EC). GSE, balance CON HEP: GSE, balance exercises	EXP1, EXP2: 3x/wk, 5 min/d (20-25 min contact time/session) CON: 1x/wk, 45 min	EXP 1: no HEP EXP2: 3x/d, 15-21 min/d CON: 3x/d, 15-21 min/d	3	EXP1, EXP2: DHI, DGI, Patient Specific Functional Scale and gait improved CON: DHI improved

Abbreviations: ABC, Activities-specific Balance Confidence Scale; A/P, anterior-posterior; BBS, Berg Balance Scale; BESTest, Balance Evaluation Systems Test; CDP, computerized dynamic posturography; CON, control group; DGI, Dynamic Gait Index; DHI, Dizziness Handicap Inventory; EC, eyes closed; EO, eyes open; EXP(1,2), experimental group (1, 2); FGA, Functional Gait Assessment; GSE, gaze stabilization exercises; HEP, home exercise program; HMD, head-mounted device; LOE, level of evidence; MCI, mild cognitive impairment; mCTSIB, modified Clinical Test of Sensory Interaction on Balance; M/L, medial-lateral; OKS, optokinetic stimulation; POMA, Performance Oriented Mobility Assessment; SLS, single leg stance test; SOT, sensory organization test; TUG, Timed Up and Go test; UVH, unilateral vestibular hypofunction; vHIT, video head impulse test; VOR, vestibulo-ocular reflex; VPT, vestibular physical therapy; VR, virtual reality.

In summary, clinicians may implement a treatment plan for individuals with chronic UVH consisting of clinic visits once or twice a week in addition to a daily HEP consisting of a minimum 20 minutes of progressively challenging balance and gait exercises combined with 20 minutes of GSE and a walking program for at least 4 to 6 weeks.

High-Technology Balance Exercises

Evidence Update

Virtual reality was used as the primary treatment approach in 2 level I,[113,169] 2 level II,[164,183] and 1 level III[182] studies. All of the studies combined VR and low-technology vestibular exercises (gaze stabilization, balance, and habituation). Individuals were seen 1 to 2 times per week in the clinic and performed a daily HEP in all 4 level I studies. In the Meldrum et al study,[113] VR-based balance training, performed for 15 minutes, 5 times per week over 6 weeks, was the differentiating factor between treatment groups. The authors concluded that the weight shifting exercises on the Wii Fit Plus did not have an added benefit to the exercise program. In a level III study, Rosiak et al[182] found similar findings to Meldrum et al[113] when individuals with UVH performed balance training with a low-cost, nonimmersive VR system for 10 sessions over 10 days, with each session lasting 25 to 30 minutes. In contrast to the studies by Meldrum et al[113] and Rosiak et al,[182] Micarelli et al[164,183] and Viziano et al[169] found that the use of immersive VR did result in improved balance compared with VPT exercises only. In all 3 studies, the experimental group performed an immersive VR game, wearing a head-mounted display (HMD) for 20 minutes per day over 4 weeks in addition to a 30- to 40-minute HEP (balance, GSE). Differing findings across the Meldrum et al[113] and Rosiak et al[182] compared with Micarelli and colleagues studies[164,169,183] may be explained by: (1) the type of VR utilized (nonimmersive, gamified weight-shifting with visual feedback[113] vs immersive VR environments while performing head movements),[164,169,183] and (2) the type of balance outcome measure (dynamic posturography[113] compared to static posturography).[164,169,183] Additionally, the experimental and control groups in the Meldrum et al study[113] had the same exercise dosage. The experimental groups in the Micarelli studies[164,169,183] received an additional 20 minutes of intervention per session than the control groups; therefore, the dosage between groups was not equivalent.

In summary, VR using the Wii Fit Plus with rocker board (Frii Board, Swiit Game Gear) or center of pressure training did not seem to have any added benefit compared with low-technology balance exercises for improving postural control. However, the use of an HMD while performing head movements resulted in improved postural control and dynamic gait. Overall, the results of these studies support a 4-week program of once to twice weekly clinic visits plus a twice daily HEP (total of 30-40 minutes per day) focused on low-technology balance exercises, gaze stability, and habituation, augmented by 20 minutes/day immersive VR training. Additionally, VR may provide a more enjoyable method of balance training improving exercise compliance, thereby facilitating improved balance outcomes.[113,193,194]

Optokinetic stimulation was the intervention utilized in 3 level I studies[171,186,194] and 1 level IV study.[180] Loader et al[171] found positive effects of training with OKS on postural control as did Rossi-Izquierdo et al[194] and Pavlou et al,[186] although Pavlou et al utilized a greater dosage (8 total weeks) compared to both Loader et al (3 weeks) and Rossi-Izquierdo et al (5 days).

In summary, although 3 level I studies[171,186,195] reported improvement in SOT scores following balance training with OKS, the treatment and control paradigms used in each study were different and it is not possible to make a recommendation concerning dosage. In addition, some caution should be used when interpreting these results; all 4 studies used SOT/mCTSIB as an outcome measure, so findings cannot be generalized to walking and other functional activities of daily living. Therefore, at this time, the use of optokinetic and other visual stimuli as an exercise approach to improve balance may be considered as an adjunct to low-technology VPT (gaze stabilization, habituation, balance, and endurance exercises).

Moving platform-based perturbation balance training was compared with traditional vestibular exercises in 2 level I studies.[195,196] Winkler and Esses[195] compared 3 different treatment protocols: (1) an individualized HEP of exercises plus a 1x/week clinic visit (control group); (2) random surface tilt perturbations of increasing challenge performed 3x/week in the clinic (experimental group 1); and (3) random surface tilt perturbation exercises 3x/week in the clinic plus an individualized HEP (experimental group 2). The HEP consisted of gaze stabilization and balance exercises performed sitting to walking 3x/day for 15 to 21 minutes/day. The perturbation exercises consisted of ten 30-second perturbations (5 eyes open, 5 eyes closed) with gradually more challenging foot positions for up to 20 to 25 minutes of contact time. All groups were treated for 3 weeks. The control group showed significant improvements on the DHI; the experimental groups demonstrated significant improvements in DHI, DGI, Patient Specific Functional Scale, and some gait characteristics. The authors suggest that perturbation balance training requires less dosage than low-technology balance training to result in improved balance and gait outcome measures.

Nardone et al[196] compared balance training using a crossover design with an oscillating platform (translated forward/backward and side to side in a horizontal plane) and Cawthorne-Cooksey exercises. The experimental group performed 8 trials of platform training lasting 3 minutes each (24 minutes/session), 2 sessions per day over 5 consecutive days. Individuals trained with eyes open and closed, at 2 different oscillation frequencies. The control group performed Cawthorne-Cooksey exercises in the clinic, with each session lasting 30 minutes, for 5 days. Eyes closed body sway decreased and the POMA scores increased significantly in both groups with greater improvements observed after completing both interventions. The results of this study suggest that as little as 2 weeks (10 sessions) of approximately 60 minutes/day of supervised platform balance training combined with Cawthorne-Cooksey exercises may lead to improved postural control.

In summary, the results are limited secondary to availability of pertinent studies as well variability in dose and treatment paradigms. Preliminary results suggest that surface tilt perturbation training may be beneficial for

improving functional outcome measures. Furthermore, the authors suggest that perturbation balance training may require a lower dose than low-technology balance training to achieve improved balance and gait.

One level I[184] and 2 level II[165,177] studies support the use of augmented sensory feedback for balance training. In the Coehlo et al[184] study, individuals performed 40 minutes of balance exercises 2 time per week for 6 weeks with and without anchors, which provided haptic feedback and minimal support though the user's hands. There were no differences between groups at baseline. Both exercise groups improved equally in DHI and mini-BEST scores. At 3 months post-training, the exercise group with the anchors had improved significantly in gait speed compared with the nonanchor and control groups. Basta et al[133] and Bao et al[165] examined trunk vibrotactile feedback balance training for individuals with chronic uncompensated UVH. In the Basta et al[133] (level II) study, a dose of 10, 10-minute balance training sessions over 2 weeks, resulted in improved SOT composite scores. In the preliminary randomized control level II study by Bao et al,[164] all participants exhibited improvements in a subset of balance and gait measures after participating in 18 sessions over 6 weeks and the improvements persisted for 6 months following training. However, individuals did not demonstrate significant improvements in SOT composite scores. Each therapy session consisted of 18 minutes of balance exercises (6, 30-second repetitions, of 5 different progressively challenging static/dynamic balance exercises and 1 GSE). It is unclear why this study did not support the SOT-related findings of Basta et al[133]; however, the Bao et al[165] study may have been underpowered and methodical differences may also have been factors.

In summary, few pertinent studies and variability in dose and treatment paradigms limit specific dosage recommendations for augmenting VPT with platform perturbations. Preliminary results suggest that surface tilt perturbation training may be beneficial for individuals with chronic UVH. The emerging evidence is conflicting as to the necessary dose for vibrotactile stimuli to improve postural control.

Overall Summary for Chronic UVH

There is compelling evidence that low-technology balance exercises improve balance for individuals with chronic UVH. In addition to GSE, clinicians may recommend a minimum of 20 minutes of daily, progressively challenging balance exercises for 4 to 6 weeks for individuals with chronic UVH (Table 7). Emerging evidence suggests that VR, OKS, moving platform perturbations, and vibrotactile feedback may also augment improvement in postural control. Conflicting evidence is also present. Many studies combine gaze stability, habituation, balance, and endurance exercises; therefore, it is challenging to determine which specific exercise or combination of exercises drive the improvement in postural control.

Bilateral Peripheral Vestibular Hypofunction

Evidence Update

No studies specifically examine frequency, duration, or exercise intensity as factors that influence treatment efficacy for individuals with BVH. Nevertheless, it is possible to make some preliminary suggestions about exercise dose based on the clinical experience of the GDG and compilation of evidence from several studies.

There are 2 level I studies that provide some insight into successful dose of balance exercises. In the first level I study, Krebs et al[127] examined 8 individuals with BVH who performed either an exercise program consisting of GSE and balance and gait activities or a placebo exercise program. The vestibular exercises were performed weekly in a supervised session and 1 to 2 times per day as an HEP for 8 weeks. The group performing the vestibular exercises demonstrated increased gait speed and improved postural stability compared with the placebo exercise group.

A second level I RCT included both individuals with UVH and BVH.[181] Vestibular physical therapy included a staged progression of gaze stabilization, balance, and gait exercises. Participants were supervised weekly for 6 weeks and performed an HEP at least once per day, 5 days per week. After 6 weeks, Krebs et al[181] determined that individuals with vestibular hypofunction benefitted from VPT based on improved gait biomechanics (preferred gait speed, decreased double support time, and decreased vertical center of mass excursion).

In addition to the 2 level I studies, 1 level II[177] and 3 level III[112,197,198] studies examined the effects of VPT in adults with BVH. Brugnera et al[177] (level II) compared balance training with trunk vibration (n = 7) to a control group training without trunk vibration (n = 6). Individuals with BVH participated in 10 sessions (once daily over 2 weeks). Short-term balance improvements on SOT conditions 5 and 6 were observed only in the vibrotactile training group; however, no long-term follow-up was performed.

Gillespie and Minor[197] (level III) reported that 18 out of 32 of adults with BVH improved in balance and gait after performing an HEP including GSE for a total of 5 to 10 minutes, at least 3 times/day as well as gait and balance exercises. The group that did not improve had more comorbidities than the group that did improve; having 4 or more comorbidities was associated with poorer outcomes.

In another level III study by Brown et al,[198] individuals with BVH performed balance and gait exercises, general strengthening, and flexibility exercises as well as activities to improve vestibular adaptation for those with remaining vestibular function. Individuals with little to no vestibular function were taught vestibulospinal substitution exercises. Individuals attended 4.6 supervised clinic visits (range 2-9) over 3.8 months (range 1-9 months) and performed a daily HEP. Improvements were noted in balance confidence, standing, and walking balance, with 33% to 55% of the individuals improving by a clinically meaningful amount.

In a level III study, Herdman et al[112] reported individuals with BVH (n = 69) improved in all outcome measures except disability following a course of VPT. They participated in weekly clinic visits and completed an HEP consisting of GSE (20-30 minutes daily 3-5 times per day), standing balance exercises on firm and foam surfaces (10-20 minutes daily), and walking (10-20 minutes per day) for 6.6 ± 3.8 weeks. Individuals were discharged when they reached their goals or were no longer improving. However, only 38% to

86% demonstrated a meaningful improvement, depending on the specific outcome measure examined. Balance confidence improved significantly in 64% and walking balance in 80% of individuals.

Overall Summary for BVH

These studies provide preliminary evidence that individuals with BVH may benefit from performing a minimum of once daily balance exercises for 6 to 9 weeks; however, per expert opinion, clinicians might consider prescribing 2 to 3 balance sessions per day for potentially greater effectiveness. Balance exercises should be combined with GSE performed 4 to 5 times per day for a minimum of 20 to 40 minutes daily. Clinicians may need to consider the impact of comorbidities on recovery when determining duration of VPT for individuals with BVH.

C. Action Statement 6b. OPTIMAL GAZE STABILIZATION EXERCISE DOSAGE OF TREATMENT IN INDIVIDUALS WITH PERIPHERAL VESTIBULAR HYPOFUNCTION (UNILATERAL AND BILATERAL). Clinicians may prescribe weekly clinic visits plus an HEP of GSE consisting of a minimum of: (1) 3 times per day for a total of at least 12 minutes daily for individuals with acute/subacute UVH (evidence quality: II; recommendation strength: weak); (2) 3 to 5 times per day for at least 20 minutes daily for 4 to 6 weeks for individuals with chronic UVH (evidence quality: II; recommendation strength: weak); (3) 3 to 5 times per day for a total of 20 to 40 minutes daily for approximately 5 to 7 weeks for individuals with BVH (evidence quality: III; recommendation strength: weak).

Action Statement Profile

Aggregate evidence quality: Indirect evidence due to extrapolation from the available literature. *Acute and subacute UVH*: Grade C: Weak evidence. Based on 3 level I, 4 level II, and 2 level III studies. *Chronic UVH*: Grade C: Weak evidence. Based on 4 level I and 2 level II studies. *BVH*: Grade C: Weak evidence. Based on 1 level I and 2 level III studies.

Benefit:

- Improved outcomes with appropriate exercise dose.

Risk, harm, and cost:

- Risk of nausea and possible emesis when exercises are performed during the most acute stages in some individuals.
- Some physicians may want to delay exercises during the early postoperative stage because of risk of bleeding or cerebrospinal fluid leak.
- Risk of provoking temporary dizziness during and after performance of exercises.
- Increased cost and time spent traveling associated with supervised vestibular rehabilitation.

Benefit-harm assessment:

- Preponderance of benefit over harm.

Value judgments:

- Benefit of GSE in individuals with UVH has been demonstrated in numerous level I and level II studies; however, the frequency and intensity of the exercises are based on extrapolation from research studies rather than based on direct evidence.
- Although recommendations are made as to total duration of exercises, the decision to stop exercises should be based on reaching goals or reaching a plateau in recovery or stopping for another factor.

Intentional vagueness:

- The available literature provides sufficient evidence regarding the frequency, intensity, and duration sufficient for GSE prescription recommendations for individuals with acute, subacute, and chronic UVH and chronic BVH.

Role of individual preferences:

- Availability of an individual's time may play a role.

Exclusions:

- Individuals at risk for bleeding or cerebrospinal fluid leak.
- Individuals who no longer experience dizziness or unsteadiness on the basis of UVH do not need formal VPT.

Quality improvement:

- Clinicians should attempt to consistently document the specific type of GSE prescribed and include dose parameters (frequency, intensity, and duration).
- Clinicians may consider adding/updating specific gaze stabilization dose recommendations on patient education materials and/or exercise handouts for individuals with UVH.

Implementation and audit:

- There is little cost and training associated with GSE.
- The clinical implementation of high-technology computerized visual acuity testing and treatment will need to be justified.

Practice Summary

No new articles examined the role of different exercise doses on outcome for individuals with vestibular hypofunction. From the previous CPG, Cohen and Kimball[75,199] specifically examined the effect of exercise dosage intensity (frequency of head rotation) on recovery in adults with chronic UVH. They found no difference in the 2 groups after 4 weeks of exercise, suggesting that dose intensity was not a factor in recovery. In this action statement, information on exercise dose is supported by comparing and extrapolating the findings from multiple studies on adults with vestibular hypofunction. Most studies used a combination of gaze stabilization, balance, and gait exercises. These data suggest that clinicians may prescribe weekly clinic visits plus an HEP of GSE consisting of a minimum of:

- 3 to 5 times per day for a total of 12 to 20 minutes daily individuals with acute/subacute UVH.
- 3 to 5 times per day for a total of at least 20 minutes daily for 4 to 6 weeks may be sufficient to induce recovery for individuals with chronic UVH.
- 3 to 5 times per day for a total of at least 20 to 40 minutes daily for approximately 5 to 7 weeks may be sufficient to induce recovery for individuals with BVH.

Acute and Subacute UVH

Evidence Update

There have been no additional level I studies since the previous CPG that have examined dosage efficacy in individuals in the acute or subacute stages during the early postoperative period after vestibular schwannoma resection. In a level III study by Millar et al,[200] gaze stabilization and balance exercises were initiated 6 weeks postoperatively during the subacute stage after vestibular schwannoma resection. All individuals performed 6 different exercises (2 gaze stabilization, 2 static balance, and 2 dynamic balance); individuals were divided into 3 groups and the level of challenge of the exercises varied based on their level of impairment on the initial TUG, ABC, DHI, and DGI. They performed horizontal and vertical VORx1 for 1.5 minutes each for 3 repetitions in sitting and standing with near and far targets, once a day for a total of 27 minutes per day over 5 weeks. Individuals improved significantly in DHI, ABC, and TUG scores. Although there was no significant improvement in DGI or gait speed, the posttreatment scores surpassed the minimal clinically important difference.

Several level II and III studies provide support for GSE plus balance exercises on recovery during the acute and subacute stages following vestibular neuritis compared with control groups (level II: Venosa and Bittar[157]; Yoo et al[146]; Navari et al[116]; Lacour et al[131]; level III: Jeong et al[150]). The duration of exercise performance varied from 7 days[146] to 12 weeks.[116] Three of these studies had individuals perform exercises from 2 to 3 times per day for 3 or 4 weeks[150,157] to 4 to 5 times per day for 12 weeks.[116] In the study by Yoo et al[146] with only 7 days of treatment (shortest duration of treatment), individuals performed the VORx1 GSE more frequently than the other studies (10 times per day). The other exception was the study by Lacour et al,[131] in which individuals with vestibular neuritis performed the exercises toward the affected side in 30-minute sessions, twice a week for 4 weeks. Subjects in these studies improved significantly in duration of symptoms,[157] vHIT,[146] DHI,[116] DVA,[131] as well as DHI and composite scores on computerized dynamic posturography[150] over the course of the exercises.

Summary of Prior Supporting Evidence and Clinical Interpretation

In the original CPG, 3 studies examined the effect of GSE during the acute or subacute stages on recovery after vestibular schwannoma resection.[152,154,155] In these level I studies, individuals performed each GSE for 1 minute and a graded walking program, 3 to 5 times per day for a total of 12 to 20 minutes daily while in the hospital. They reported improvement in disequilibrium,[152] DHI scores,[154] and stability while walking with voluntary head movements,[152] compared with the group walking once or twice daily and performing either a placebo exercise or usual activity. Vereeck et al[155] initiated balance exercises and walking by POD 4 and GSEs on POD 7 after discharge from the hospital. Older individuals (older than 50 years) who performed the experimental exercises had normal DGI scores by POD 14 compared with the older individuals in the control group (who performed usual activities).[155]

Chronic Unilateral Vestibular Hypofunction

Evidence Update

The recommendations of the original CPG concerning the dosage effect of GSE on recovery of balance and gait in individuals with chronic UVH are supported by an additional level I study.[113] Meldrum et al[113] compared an exercise program of gaze stabilization, balance exercises, and walking to a VR balance program plus the same gaze stabilization and walking program. The GSE progression followed that outlined by Herdman et al,[170] beginning with VORx1 exercises using near and far targets, progressing to VORx2, eye-head movements, and remembered targets, then adding conflicting backgrounds. Both groups performed GSE for 20 to 35 minutes over 4 to 5 sessions per day for 6 weeks. Both groups improved significantly in DVA but there was no difference between groups. The results suggest that a minimum performance of the GSE 3 times per day for a total of 20 minutes daily for 6 weeks may be sufficient to induce recovery of DVA in individuals with chronic UVH.[170]

Summary of Prior Supporting Evidence and Clinical Interpretation

Three studies (1 level I and 2 level II), each examining the effect of vestibular rehabilitation on outcomes in individuals with chronic UVH, included sufficient details on the type, frequency, and duration of exercise to provide some guidance as to exercise dose. In the level I study, individuals were seen in the clinic once weekly and performed an HEP of a progression of GSE 3 to 5 times per day for a total of 20 to 40 minutes daily over 4 to 6 weeks.[170] The individuals in the exercise group had a significant improvement in DVA compared with the control group who performed eye movement only exercises. A second study by Kao et al[201] (level II) was designed to investigate whether or not supervision of exercises enhanced recovery. Individuals in both the supervised and unsupervised groups performed 10 minutes of gaze stabilization, 10 minutes of eye movement only, and 10 minutes of static balance and walking with head movements 3 times per day for 6 to 8 weeks. Individuals in both groups improved significantly on DHI and Tinetti tests. In a study by Schubert et al[139] (level II), 4 individuals with UVH and 1 with BVH performed an HEP of GSE 4 to 5 times per day for 20 to 30 minutes and also had 5 clinic visits over 6 to 9 weeks. The 4 individuals with UVH improved DVA scores (3 to normal for age) by the end of the study. Finally, in a level III study, individuals with UVH (n = 206) had once a week clinic visits as well as an HEP.[192] Gaze stabilization exercises were performed 3 to 5 times per day; all individuals also performed balance and gait exercises and a daily walking program. Total duration for all exercises was 60 to 70 minutes daily. The sequence of exercises was essentially the same for all individuals; however, the rate of exercise progression differed. Patients performed the exercises until goals were met or recovery plateaued. Typically, individuals were seen for 4 to 6 weeks. These data suggest a minimum performance of the exercises 3 times per day for a total of 20 minutes daily. Two of the studies had individuals perform the exercises over 6 to 9 weeks.[139,201] However, the findings of Herdman et al[170,192]

suggest that 4 to 6 weeks may be sufficient to induce recovery in individuals with chronic UVH.

Bilateral Vestibular Hypofunction

Evidence Update

Two recent level III studies offer evidence that performing GSE results in recovery of DVA in individuals with BVH. In 1 study, individuals with BVH (n = 69) performed GSE 3 to 5 times per day, for a total of 20 to 30 minutes daily and balance and gait exercises for another 30 to 40 minutes daily for a total duration of 5 to 7 weeks.[112] The total duration of treatment (in weeks) was not driven by a predetermined number of treatments based on a research protocol; rather, individuals were discharged once all goals or a plateau in recovery was achieved. Individuals significantly improved on measures of subjective complaints, balance, gait speed, and visual acuity during head movements at discharge.[112] Lehnen et al,[115] in a double-blinded, crossover design study, found that individuals (n = 2) performing GSE for 8 minutes, 5 times per day for 4 weeks, had improved DVA. There was no change in DVA following performance of eye movement only (no head movements) exercises.

Summary of Prior Supporting Evidence and Clinical Interpretation

One level I study of individuals with chronic BVH suggests that a 6-week program of GSE 4 to 5 times per day for a total of 20 to 40 minutes daily plus 20 minutes per day of balance and gait exercises results in significant improvements in visual acuity during head movements compared with a control group, who did not improve.[64]

Overall Summary

Several new studies provide evidence that expands our knowledge concerning dose of GSE in individuals with UVH. For individuals with acute and chronic UVH, these articles provide support for previous recommendations. For individuals with subacute UVH, the data are too variable to make a recommendation on dosage. There are relatively few studies of individuals with BVH; however, based on the available studies, GSE may be beneficial for individuals with BVH.

Research Recommendation 14: Researchers should examine the impact of frequency, intensity, duration, and type of balance and/or GSE on postural control and functional outcomes separately for individuals with acute, subacute, and chronic UVH and BVH. Researchers should clearly document the specific dosage parameters (exercise time per session/day, frequency per day/week, duration, and intensity).

Research Recommendation 15: Researchers should determine methods to rate both the intensity and the difficulty of gaze stabilization and balance exercises and how to progress individuals in a systematic manner.

A. Action Statement 7: EFFECTIVENESS OF SUPERVISED VESTIBULAR REHABILITATION. Clinicians should offer supervised VPT for individuals with UVH and BVH (evidence quality: I; recommendation strength: strong).

Action Statement Profile

Aggregate evidence quality: Grade A: Strong evidence. Based on 4 level I RCTs, 1 level II study, and 3 level III studies.

Benefits:
- Improved outcome with a supervised rehabilitation program.
- Improved adherence with a supervised rehabilitation program.

Risk, harm, and cost:
- There may be an increased cost and time spent traveling associated with in-person, supervised VPT.
- The cost, availability, and ability to use internet-based supervision may be a barrier.
- Without feedback from the supervising physical therapist, individuals may under- or overcomply with the exercise prescription or miss an opportunity to modify the program resulting in either lack of progress/improvement or increased symptoms potentially leading to early withdrawal from VPT.

Benefit-harm assessment:
- Preponderance of benefit for supervision.
- Evidence suggests that individuals drop out at higher rates when unsupervised.
- Evidence suggests individuals older than 50 years may benefit more from supervision.

Value judgments:
- Supervised VPT appears to promote adherence and continued performance of vestibular exercises, which may lead to improved outcomes.
- Individuals with cognitive impairment or moderate-severe mobility dysfunction may need supervision to benefit from VPT.
- Individuals who are fearful of falling may not do well in an unsupervised exercise program.

Intentional vagueness:
- The type and degree/amount of supervision is intentionally vague to allow clinical judgment and patient values to be considered when developing the plan of care.

Role of individual preferences:
- Cost and availability of the individual's time and transportation may play a role.

Exclusions:
- Individuals who live in a rural or underserved area may not be able to participate in face-to-face supervised VPT. Remote monitoring via telehealth may be an option.

Quality improvement:
- Following these guidelines has the potential to improve patient compliance/participation in VPT, which could lead to improved outcomes.

Implementation and audit:
- Clinicians should document the level of supervision provided and the rationale for any changes in supervision.

Practice Summary

Overall, 9 studies have either directly or indirectly examined the impact of supervision on individual outcomes following

VPT. Although conflicting reports are present, a preponderance of evidence suggests that individuals receiving supervised VPT tend to have better outcomes. This may be especially true for individuals with cognitive impairment.

Evidence Update

Exercise supervision in the context of VPT commonly implies that a trained clinician directs performance and participation in a set of custom exercises in person. Recently, this definition of supervised VPT has expanded to include remote monitoring (telephone-, video-, or internet-based) and in some cases exercise progression depends on software algorithms rather than clinical judgment. Moreover, the amount, timing, and type of supervision are additional variables that may impact care and recovery. The effect/benefit of supervision may also vary based on acuity (acute versus chronic vestibular hypofunction), age, musculoskeletal and neuromuscular functioning, and/or cognitive ability. One reason for these differences may be that supervised VPT promotes adherence and continued performance of vestibular exercises, which may lead to improved outcomes (Pavlou et al,[202] level I; Hsu et al,[203] level II).

The degree of supervision may be important. Itani et al,[179] in a retrospective level III study of 32 individuals with various forms of UVH, BVH, and nonvestibular dysfunction, compared a tailored home training group with a supervised clinic group. The subjects self-selected their treatment group. The home training group was loosely monitored (meeting with the physical therapist initially, after 1 week, and then once every 2 weeks for 4 sessions) while the clinic supervised group was closely monitored (3 in-person sessions per week for 5 weeks). It is unclear whether the supervised group also participated in an HEP. Both groups improved on the DGI, but the closely supervised clinic group demonstrated greater improvement.

Although Muller et al's study[204] did not meet the criteria for appraisal (no objective vestibular testing for diagnosis), the information they presented may be useful in the context of supervision. A qualitative investigation of the individual's experiences between unsupervised (booklet only) versus remote supervision (booklet plus telephone call) may provide insight into the benefits of remote monitoring. Muller et al[204] interviewed 33 individuals who completed an RCT investigating the cost-effectiveness of remote monitoring using the booklet-based vestibular rehabilitation.[205] Both groups with chronic dizziness (unsubstantiated by vestibular testing) reported vertigo symptom improvement at the 1-year follow-up compared with unspecified routine care, but the telephone group reported feeling more engaged. Additionally, the authors suggested that additional advice or encouragement might improve adherence to a home-based program.[204]

Monitoring of the exercise program may have value, as worsening symptoms during the first few weeks of a VPT program can occur (Szturm et al,[188] level II; Hondebrink et al,[206] level III). A level IV study by Varriano et al[207] piloted a telephone-supervised home program of VPT for individuals with peripheral vestibular hypofunction plus cognitive impairment. The control group received usual care (no exercise). An important finding of this study was the 71% attrition rate in the experimental group. The high attrition rate occurred despite biweekly telephone calls in which no individuals reported difficulty with the exercises; however, 2 individuals dropped out due to disinterest. The authors recommend that regular in-person monitoring may be more beneficial than a remotely monitored HEP for individuals with UVH/BVH plus cognitive impairment.[207]

There is emerging but insufficient evidence that online-only training incorporating progressions into software algorithms may be of benefit. In a level I study, van Vugt et al[208] randomized adults with chronic vestibular disorders to: (1) stand-alone, internet-based intervention (6 weekly online sessions designed to individualize exercises for the next week plus daily exercises for 10-20 minutes); (2) a blended internet-based intervention (including 2 face-to-face physical therapy sessions in weeks 1 and 3); or (3) usual care (unrestricted, standard care from their doctor). Both intervention groups improved significantly compared with usual care for dizziness handicap and vertigo symptoms and there were no differences between the intervention groups. At-home DVA training using software algorithms to determine optotype size and wearable sensors to track head velocity led to reduction in DHI scores in a small sample of individuals with UVH (Crane and Schubert,[167] level III). Software algorithms have the potential to remotely supervise exercise participation based on predefined objective criteria such as symptom reports, DVA score, or peak head velocity. The limited availability and feasibility of software algorithms capable of monitoring home exercises may currently restrict widespread use of such technology.

Summary of Prior Supporting Evidence and Clinical Interpretation

Several articles referenced in the original CPG and a few recent articles in this update demonstrate the benefits of supervision for VPT. Kao et al[201] (level II) compared supervised and home-based (unsupervised) exercises consisting of seated and standing eye movements and adaptation exercises, as well as walking with head turns. Subjects self-selected their treatment group, with 28 choosing supervised rehabilitation and 13 choosing home-based (unsupervised) rehabilitation. The supervised group attended 3, 30-minute sessions per week with a physical therapist, and the home-based group received instructions to perform the same exercises at home and return for assessment in 2 months. No additional HEPs were documented. More subjects in the supervised group achieved clinically meaningful improvements on the DGI (86% vs 14%) and DHI (74% vs 26%), providing moderate support for improved outcomes with supervision.

Shepard et al[24] (level III) provided an individualized HEP to be completed twice daily with remote supervision by phone calls initiated by the subjects when needed. Shepard et al reported that nausea, emesis, and vertigo provoked by exercises could be managed by stopping the exercise session and resuming the exercises at the next session. In cases where this approach was unsuccessful, individuals initiated remote telephone supervision.

In a level I study of optokinetic training for visual vertigo by Pavlou et al,[202] 60 individuals were randomized into 3 groups: a supervised training group that utilized a full-field

OKS, a supervised training group using a DVD, and an unsupervised training group using a DVD. All subjects received a customized program of gaze and postural stability exercises to perform at home. The SOT and FGA improved significantly for the supervised groups (full-field and DVD groups), and anxiety scores improved for the supervised DVD group. The study had a high dropout rate of 55% in the unsupervised group compared with 10% in the supervised groups. Pavlou et al[202] suggested that supervision promotes greater adherence and improvements in postural stability. Yardley et al[209] (level I) also reported "fair" self-reported adherence to an exercise booklet for persons with vestibular disorders compared with usual care (undefined). Taken together, these studies provide moderate to strong support for improved adherence with supervision.

Not all studies have found additional benefit from supervised VPT. Kammerlind et al,[210] in a level I study of 52 individuals following acute UVH, compared supervised versus unsupervised home training using vestibular exercises that included gaze stabilization, balance with eyes closed, and gait with head turns. All individuals received oral and written instructions for the vestibular exercises including dosage of 15 minutes per day. The VPT started in the hospital, and the supervised group received 3 additional supervised physical therapy sessions. Once discharged home, the supervised group received 12 additional supervised visits over 10 weeks. At 1 week, 10 weeks, and 6 months post-discharge, there were no differences for any balance, gait, or symptom report between the supervised and unsupervised groups. It is unclear how the unsupervised group progressed their individualized program.

Overall Summary

Based on the review of new evidence since 2015, the recommendation increases from moderate to strong. Supervised VPT promotes adherence and continued participation in vestibular rehabilitation exercises and may lead to improved outcomes. Cognitive impairment or moderate to severe mobility dysfunction may lead to attrition if unsupervised, potentially leading to limited improvement.

Research Recommendation 16: Researchers should include measures of adherence and intent-to-treat designs to understand the impact of supervision on exercise compliance and dropout rates.

Research Recommendation 17: Researchers need to investigate whether there are critical dosage or time points for in-person versus telehealth/remote supervision.

Research Recommendation 18: Researchers need to investigate the role of telehealth/remote VPT support on patient compliance/motivation.

B. Action Statement 8: DECISION RULES FOR STOPPING VESTIBULAR REHABILITATION IN INDIVIDUALS WITH PERIPHERAL VESTIBULAR HYPOFUNCTION (UNILATERAL AND BILATERAL). Clinicians may use achievement of primary goals, resolution of symptoms, normalized balance and vestibular function, or plateau in progress as reasons for stopping therapy (evidence quality: II; recommendation strength: moderate).

Action Statement Profile

Aggregate evidence quality: Grade B: Moderate evidence. Based on 3 level I, 10 level II, 9 level III, and 2 level IV studies.

Benefits:

- More efficient management of treatment duration by avoiding cessation of treatment before optimal recovery is achieved or continuing treatment for unreasonably protracted periods.

Risk, harm, and cost:

- Prematurely stopping treatment before maximum gains are achieved.
- Protracted treatment is costly to the payer.
- If individuals are continuing in therapy when the individual and the clinician are not seeing clinically meaningful improvement, other individuals may be waiting to receive intervention because of decreased access to care.

Benefit-harm assessment:

- Preponderance of benefit over harm.

Value judgments:

- No definitive stopping rules have been explored in the literature; however, numerous level I through level IV studies provide comments and findings that can assist in the decision-making process about the cessation of care.

Intentional vagueness:

- Some goals may normalize earlier than others and the action statement is intentionally vague to allow for clinical judgment with regard to the patient's goals, preferences, and values.

Role of individual preferences:

- It is the individual's decision whether to participate in VPT and when to stop.

Exclusions:

- Individuals with moderate to severe cognitive or mobility impairments may need additional treatment sessions. These individuals are often excluded in published research, so stopping rules may not be appropriate for them.

Quality improvement:

- Following these guidelines has the potential to improve discharge planning through clear communication.

Implementation and audit:

- Clinicians may include the specific criteria identified for stopping therapy in the discharge summary.

Practice Summary

The current recommendation, that there is level II evidence supporting decisions to stop therapy, was upgraded from the previous recommendation (level V). This change is based on extrapolation from methodology and results of 24 studies. These studies reported VPT treatment durations that ranged from 5 days to 52 weeks, without specific justifications. One retrospective level III study reported that VPT duration increased with severity of the disorder.[211] Individuals with

UVH including loss of saccular function may need a longer course of treatment (level III).[150] A temporary stop in therapy may be indicated when the individual has a fluctuating or unstable vestibular condition (eg, unstable Meniere's disease) or medical/psychiatric conditions affecting the ability of the individual to participate. Once these health conditions have stabilized, VPT may be appropriate to resume. Finally, based on 1 level II[148] and 1 level III studies[150] and expert opinion, the advisory panel recommends that, before stopping therapy for individuals who remain symptomatic or have not met their goals, consultation with another vestibular physical therapist colleague or physician would be advisable.

Evidence Update

There are no studies that specifically examined decision rules for stopping VPT in those with UVH or BVH. An investigator's a priori decision relative to the research design determines the length of the intervention and criteria for participant withdrawal from the study; thus, the duration and availability of treatment are often protocol-driven and not based on individual characteristics or outcomes. Furthermore, the length of the study intervention may affect an individual's willingness to participate in the study. The only exception identified in this review was a level II study conducted by Ismail et al.[147] Twenty-four out of 60 individuals decided to stop therapy prior to either the 6- or 12-month follow-up visits stating that they felt well and did not wish to continue.

Despite the lack of systematic investigation into decision rules for stopping VPT, several recent studies may provide guidance. Two level III studies used normalization/improvement on objective measures of balance (computerized posturography) or VOR function (rotary chair) as criteria for stopping VPT (Jeong et al,[150] level III; Roller and Hall,[212] level III). In a level III study, Scheltinga et al[149] recommend continuing until balance and gait impairments were normalized. Lorin et al.'s level IV study[213] design included stopping VPT when computerized posturography and rotary chair tests normalized, but the authors suggested that subjective symptom reports should be considered prior to stopping VPT. Others have reported that individuals, in consultation with the therapist, could discontinue the study when it was determined that the intervention was no longer beneficial (Tokle et al,[148] level II). Symptom resolution, lack of symptom provocation with exercises, goal achievement, or a plateau in progress has been reported as criteria for stopping VPT (Herdman et al,[112] level III; Tokle et al,[148] level II; Yoo et al,[146] level II; Roller and Hall,[212] level III). Both objective findings and subjective report should be considered in the decision for stopping therapy. Thus, although we cannot extrapolate from most research studies to create clinical stopping rules, there is evidence to suggest that reduced symptoms, improved balance, and normalized VOR function should be considered in the decision process.

A few studies provided specific criteria for study withdrawal, such as missing at least 3 sessions[136] or noncompliance as reasons to discontinue treatment (Jeong et al,[150] level III; Hondebrink et al,[206] level III; Hsu et al,[203] level II). Research designs dictate intervention duration and withdrawal criteria. Thus, the duration and availability of treatment were protocol-driven and not based on recovery outcomes.

Two level III studies (Patarapak et al[178]; Hondebrink et al[206]) found that individuals experienced an initial increase in dizziness, but their dizziness symptoms later improved compared with preintervention DHI scores. To accommodate the increase in symptoms, Hondebrink et al[206] recommended ceasing exercise for the session when the individual experienced severe nausea based on a MIsery SCore of 5 out of a possible 10.[214] Thus, worsening symptoms during the first several weeks of the VPT program do not necessarily mean VPT should be discontinued, as most individuals progress to symptom improvement.[178,206] A level III study (Jeong et al[150]) reported that moderate to severe pretherapy DHI scores and saccular dysfunction were associated with longer therapy duration and persistent symptoms.

It is worth noting that some individuals with peripheral vestibular loss experiencing chronic worsening of symptoms, at least 3 months after the initial vestibular insult, may have transitioned to PPPD. In cases such as this, it is necessary to make a shift in the approach to patient management.[215-217]

Summary of Prior Supporting Evidence and Clinical Interpretation

Consistent with recent research, the original CPG cited implicit reasons for stopping therapy including being asymptomatic, achievement of goals, or a plateau in progress.[192,218,219] Hall et al's level III study[220] added specificity by indicating discharge from treatment when 75% of goals were met. Deterioration of clinical status was cited in a level II study (Perez et al[221]) as an obvious reason to pause or stop treatment. However, deterioration of clinical status must be clearly distinguished from worsening of subjective complaints. Consistent with more recent literature, a level IV study (Chen et al[222]) reported that nausea, "body shift", dizziness, and stress increased during the first 2 weeks of the exercise intervention but subsided by the end of week 2. Szturm et al's[188] level II RCT found that the adverse effects of moderate to strong dizziness, nausea, and disorientation during exercises subsided within 2 to 5 weeks. Therefore, it is important to educate the individual that a short-term increase in symptoms is likely, but does not seem to affect long-term outcomes and it not necessarily a reason to withdraw from VPT.

Pretreatment disability should be considered when deciding whether or not to discontinue therapy, as individuals with high disability scores may be more challenging to treat and may be less likely to improve based on 2 level II studies (Telian et al[223]; Shepard et al[224]) and 2 level III studies (Shepard et al[24]; Telian et al[129]). We again recommend continuing VPT until there is a plateau in progress and/or the patient and treating clinician agree to discontinue care.

Some studies may have been templates for more recent studies that provided specific criteria for stopping treatment, such as missing at least 3 sessions (Topuz et al,[225] level III) or 30% of therapy sessions (Sparrer et al,[156] level I). Some reasons that individuals report noncompliance with VPT include the following: unrelated health issues, finding the exercises too provocative, difficulty of the exercises, family or work conflicts, litigation, travel, lack of time, loss of interest or motivation, or feeling better (Hsu et al,[203] level II;

Hondebrink et al,[206] level III; Topuz et al,[225] level III). The cost of treatment may be an additional concern for some individuals.

Overall Summary

The current recommendation that there is level II evidence supporting decisions to stop therapy is based on extrapolation from methodology and results of 24 studies. Clinicians should consider the following in the decision to stop treatment: (1) Goals are met, a plateau has been reached, the individual is no longer symptomatic at rest or with activity, or there is agreement between the individual and the clinician to stop. (2) There is evidence of normalized gait, balance, or vestibular function. (3) There is noncompliance with the exercise program, frequent absences, or the individual chooses to stop. (4) The individual is getting worse.

Research Recommendation 19: In the absence of spontaneous recovery, individuals should be encouraged to participate in VPT rather than withdraw. Determining contextual and personal factors leading to withdrawal may reduce barriers to continuation of rehabilitation.

A, B. Action Statement 9: FACTORS THAT MODIFY REHABILITATION OUTCOMES. Clinicians may evaluate factors that could modify rehabilitation outcomes (age: evidence quality: I; recommendation strength: strong; other factors: evidence quality: II; recommendation strength: moderate).

Action Statement Profile

Aggregate evidence quality: *Age*: Grade A: Strong evidence. Based on 4 level I RCTs, 4 level II experimental studies plus 8 level III and IV studies. *Gender*: Grade B: Moderate evidence. Based on 2 level II and 4 level III studies. *Time from onset*: Grade B: Moderate evidence. Based on 2 level I RCTs, 2 level II, and 4 level III studies. *Comorbidities*: Grade B: Moderate evidence. Based on 2 level I RCTs, 4 level II, and 3 level III studies. *Medications:* Grade B: Moderate evidence. Based on 3 level II and 1 level III studies.

Benefits:

- Older individuals obtain similar benefits from VPT as younger individuals.
- Short-term use of low-dose antihistamines in individuals with chronic vestibular disorders may help to control symptoms during VPT.

Risk, harm, and cost:

- Some factors may lead to longer duration of VPT, possibly resulting in increased cost and time spent traveling

Benefit-harm assessment:

- There is new evidence to suggest that earlier intervention may improve outcomes for individuals with acute UVH.
- Studies suggest that in individuals with chronic (unilateral or bilateral) vestibular hypofunction, VPT improves outcomes regardless of time from onset; however, the potential harm of delaying intervention warrants initiating rehabilitation as soon as possible.

Value judgments:

- Evidence is available to make decisions about how to consider factors that may affect outcomes.

Intentional vagueness:

- The available literature provides sufficient evidence regarding some factors that may or may not affect the outcome of VPT. Clinicians should be diligent consumers of the scientific literature in order to remain current about factors that may influence outcomes in VPT.

Role of individual preferences:

- Cost and availability of the individual's time and transportation may play a role, especially with older individuals who may have transportation or technology issues.

Exclusions:

- None

Quality improvement:

- Age and gender: Age and gender do not affect potential for improvement with VPT. Clinicians should offer VPT to older adults with the expectation of good outcomes.
- Time from onset: Participation in vestibular exercises results in improved outcomes regardless of time from onset in individuals with chronic UVH or BVH. Earlier intervention may improve outcomes for individuals with acute UVH.
- Comorbidities: Certain comorbidities may negatively impact rehabilitation outcomes. Clinicians should consider these comorbidities when setting goals for individuals and refer to other health care professionals as needed.
- Medications: Long-term use of vestibular suppressant medication may negatively impact an individual's recovery. Clinicians should consider consulting with the referring physician about continued use of these medications. Short-term, low-dose antihistamines to relieve symptoms may help to control symptoms, allowing participation in VPT.

Implementation and audit:

- Clinicians need to be aware of the potential impact of different factors on the outcome of VPT. Exercise approaches should be designed to take these factors into account.
- Outcomes should be monitored frequently to identify poor progress because of these factors.

Practice Summary

Several modifying factors—including age, gender, time from onset of symptoms until starting VPT, comorbidities, cognitive function, and use of medication—have been evaluated for their impact on VPT outcomes.

- Age: Increased age does not affect potential for improvement with VPT. Clinicians should offer VPT to older adults with the expectation of good outcomes (evidence quality: I; recommendation strength: strong).

- Gender: Gender does not impact rehabilitation outcomes and clinicians may offer VPT to individuals regardless of gender with expectation of similar outcomes (evidence quality: ii; recommendation strength: moderate).
- Time from onset: In individuals with chronic (unilateral or bilateral) vestibular hypofunction, studies suggest that participation in vestibular exercises results in improved outcomes regardless of time from onset. Based on one study, earlier intervention may improve outcomes for individuals with acute UVH (evidence quality: II; recommendation strength: moderate).
- Comorbidities: Anxiety, depression, peripheral neuropathy, migraine, abnormal binocular vision, and abnormal cognition may negatively impact rehabilitation outcomes (evidence quality: II; recommendation strength: moderate).
- Medications: Long-term use of vestibular suppressant medication may negatively impact an individual's recovery; however, short-term, low-dose antihistamines may help to control symptoms allowing participation in VPT (evidence quality: ii; recommendation strength: moderate).

Evidence Update and Clinical Interpretation

Several modifying factors have been evaluated in various studies. These factors include age, gender, time from onset of symptoms until starting VPT, comorbidities, cognitive function, and use of medication.

Age

Five recent studies evaluated the effect of age on the efficacy of traditional VPT in adults with UVH and BVH. One of these studies evaluated the efficacy of VPT in individuals with BVH and found that age did not negatively impact rehabilitation outcomes (Herdman et al,[112] level III). For some measures, older individuals improved more than younger individuals. For example, in this study, age was negatively correlated with head motion-provoked dizziness, such that older individuals reported less head motion-provoked dizziness at discharge than younger individuals. Herdman et al[112] also reported a positive correlation between age and a meaningful change in percent of time symptoms interfered with life (self-report measure), such that older individuals were more likely to report a meaningful improvement at discharge.

Two studies (Ertugrul and Emre Soylemez,[173] level II; Itani et al,[179] level III) did not find an effect of age on rehabilitation outcomes for individuals with various peripheral vestibular disorders. Lorin et al[213] (level IV) reported that increasing age was not associated with functional outcomes after VPT. However, they also reported that increasing age was associated with lower activity levels and lower activity levels negatively affected VPT outcomes. In contrast, another study evaluated individuals with acute UVH and found that improvement of balance in individuals 60 years and older occurred more slowly (Scheltinga et al,[150] level III). The findings of this study may indicate a need for more sessions of VPT for older individuals.

Gender

Three studies evaluated the effect of gender on the efficacy of VPT, and none demonstrated a significant effect of gender on recovery. One level III study found no effect of gender on multiple vestibular rehabilitation outcomes in individuals with BVH[112] and 2 other level III studies found no effect of gender on DGI (Itani et al[179]) or DHI (Ertugrul and Emre Soylemez[173]) scores in individuals with various peripheral vestibular disorders.

Symptom Onset

Two new studies evaluated the effect of time from onset until starting VPT. These studies provide conflicting results. In individuals with acute UVH, 1 level II study indicated that earlier intervention (within 2 weeks of onset of symptoms) produced better results in terms of DVA and DHI compared with later intervention.[131] Additionally, Lacour et al[131] found evidence that the mechanisms of recovery may be different between groups, with the individuals initiating VPT sooner showing increased VOR gain and the later groups (those initiating 2-4 weeks and greater than 1 month after onset of symptoms) demonstrating increased percentage of compensatory saccades.

For individuals with chronic BVH, a level III study found no effect of time since onset of symptoms on the efficacy of VPT.[112] This study included individuals with chronic symptoms of BVH (a median of 12 months since onset of symptoms) suggesting that, for individuals with chronic BVH, vestibular exercises improve rehabilitation outcomes regardless of time from onset.[112]

Comorbidities

Six recent studies have examined the role of comorbidities on VPT outcomes in individuals with vestibular hypofunction.

Psychosocial Comorbidities

In a level III study of individuals with BVH, no effect was found for anxiety or depression, separately or in combination, on outcome.[112] In contrast, in a level III study of individuals with various peripheral and central vestibular abnormalities, abnormal affect (anxiety and/or depression) was correlated with a longer course of rehabilitation.[211]

Medical Comorbidities

In a level I study of individuals older than 65 years with vestibular dysfunction for more than 2 months, those with a greater number of comorbid diseases were less likely to have a 4-point change on the DGI following 16 sessions of VPT.[136] Additionally, a level II study of individuals with various vestibular symptoms and diagnoses found that individuals with abnormal binocular vision had a less favorable outcome regarding visual vertigo and anxiety and/or depression than individuals with normal binocular vision following VPT.[226] To date, there is no other evidence about the effects of binocular visual deficits on the results of VPT.

Cognitive Function

A recent level III study evaluated the influence of cognitive function on VPT outcomes in older individuals (55 years

and older) with UVH.[227] Individuals with UVH plus MCI (n = 12) improved in measures of self-reported balance confidence and handicap plus postural stability during stance and gait; however, they did not have as favorable an outcome as individuals with UVH with normal cognition (n = 12). Furthermore, Micarelli et al[183] (level II) demonstrated that older individuals with UVH plus MCI (n = 12) benefitted from VPT that included VR via a head-mounted display, although not to the same extent as those with UVH with normal cognition (n = 11). Individuals with UVH plus MCI who received VR improved to a greater extent than individuals with UVH plus MCI in standard VPT, suggesting that the additional VR treatment enhanced the benefits of VPT for individuals with UVH plus MCI.[183]

Medication

Three recent studies examined the effect of medication on the outcomes and ability to participate in VPT. Basta et al[133] (level II) demonstrated that short-term use of low-dose antihistamines in individuals with chronic vestibular disorders did not adversely affect rehabilitation outcomes and had the potential to control symptoms. Two level II studies of individuals with acute onset of vestibular neuritis (Yoo et al[146]; Ismail et al[147]) found no benefit of steroid therapy on long-term recovery (1 year and 6 months, respectively) beyond that obtained with an HEP of VPT. A potential limitation of the Yoo et al study[145] was that their steroid administration within the first 7 days of onset of symptoms may have been outside the critical 24-hour window for maximum benefit.[228]

Summary of Prior Supporting Evidence and Clinical Interpretation

Age

Six studies evaluated the influence of age on VPT in individuals with UVH; of these, 3 studies were level I (Herdman et al[170]; Vereeck et al[155]; Cohen et al[163]), 1 study was level II (Topuz et al[225]), and 2 were level III studies (Herdman et al[192]; Hall et al[220]). Four studies evaluated the influence of age on VPT in individuals with various diagnoses including both peripheral and central vestibular deficits; of these, 2 were level II studies (Kao et al[201]; Telian et al[223]) and 2 were level III studies (Patatas et al[230]; Whitney et al[231]). One level I study (Herdman et al[64]) evaluated the influence of age on VPT in individuals with BVH. Overall, these studies included in the original CPG found no effect of age on rehabilitation outcomes for individuals with various peripheral vestibular disorders.

Gender

Two studies, a level II (Topuz et al[225]) and a level III (Herdman et al[192]), found no influence of gender on the outcome of VPT in individuals with UVH. One level II study evaluated the influence of gender on VPT in individuals with various diagnoses including both peripheral and central vestibular deficits and found no effect (Kao et al[201])

Time From Onset

One level III study (Bamiou et al[231]) indicated that earlier intervention (within 6 months of onset) produced better results in terms of DVA and DHI scores. In contrast, 3 studies of individuals with UVH, 1 level I (Herdman et al[170]) and 2 level III (Herdman et al[192]; Hall et al[220]), showed no effect of time from onset to initiation of VPT on outcome. In all 3 of these studies, data were skewed toward more chronic individuals, which may explain the different result from the Bamiou et al study.[231]

Comorbidities

Individuals with chronic BVH and more than 4 medical comorbidities demonstrated less improvement with VPT compared with individuals with fewer comorbidities (Gillespie and Minor,[197] level III). A single study (Aranda et al,[232] level II) reported a negative impact of peripheral neuropathy on VPT outcomes in individuals with peripheral vestibular disorders.

Three studies investigated the impact of migraine on vestibular rehabilitation outcomes. Vitkovic et al (level I)[234] and Wrisley et al (level II)[234] found that individuals with vestibular dysfunction and migraine had poorer outcomes in terms of quality of life as measured by the DHI. A level II study (Pavlou et al[202]) reported that, after a course of VPT, individuals with migraine improved in symptoms of visual vertigo more than individuals without migraine. In this study, OKS was combined with VPT. It is unclear whether the individuals with migraine improved because of the VPT or because of the OKS or both.

Medications

A level II study (Horak et al[132]) found that patients with vestibular hypofunction who were treated with valium or meclizine daily had no improvement in postural sway over a 6-week treatment period. These patients did report a decrease in dizziness and in symptomatic complaints over time with these medications. A level III study (Shepard et al[24]) reported that individuals with various peripheral and central vestibular disorders, who were using centrally active medications such as vestibular suppressants, antidepressants, tranquilizers, and anticonvulsants, required a longer duration of therapy to achieve the same benefit as compared with individuals who were not using medications.

Overall Summary

Although there is a preponderance of evidence that there is no effect of age on outcomes, at least one study suggests that it may take longer to get better with advanced age. Gender appears to have no effect on outcomes. Most evidence suggests that time from onset of symptoms to initiation of VPT does not affect outcome in individuals with chronic vestibular hypofunction. However, there is 1 level III study on individuals 6 months post-onset who found that time from onset did affect outcome.[231] In individuals with acute UVH, a recent level II study indicates that starting intervention earlier (within the first 2 weeks) is better than delaying intervention.[131] There is contradictory evidence about the effects of anxiety and depression on outcomes. There is a preponderance of evidence that certain medical comorbidities complicate care. There is a benefit to treating individuals with MCI, although client management may need to be

modified for these individuals. The effects of medications on VPT are not clear.

Research Recommendation 20: Researchers should determine the factors that positively and negatively impact functional recovery during VPT, including anxiety and depression, cognitive impairment, and use of medications.

Research Recommendation 21: Researchers should examine whether the inclusion of psychological support (eg, cognitive behavioral therapy, counseling, and antidepressant/anxiety medications) as an adjunct to VPT for individuals with anxiety/depression or who have developed PPPD is effective.

A. Action Statement 10: **THE HARM/BENEFIT RATIO FOR VESTIBULAR REHABILITATION IN TERMS OF QUALITY OF LIFE**. Clinicians should offer VPT to persons with peripheral vestibular hypofunction with the intention of improving quality of life (evidence quality: level I; recommendation strength: strong).

Action Statement Profile

Aggregate evidence quality: Grade A: Strong evidence. Based on 7 level I, 17 level II, 9 level III, and 2 level IV studies.

Benefits:

- There are improved quality of life and psychological outcomes of individuals undergoing VPT when compared with controls who receive sham or no exercise interventions.

Risk, harm, and cost:

- Neck pain, motion sickness, and nausea have been reported as side effects of rehabilitation and these can affect quality of life.
- Dizziness and imbalance as side effects of the exercises could increase psychological distress in some individuals.

Benefit-harm assessment:

- Preponderance of benefit, although not all individuals improve with VPT.

Value judgments:

- There is sufficient evidence of improved quality of life and reduced psychological distress with VPT.

Intentional vagueness:

- None.

Role of individual preferences:

- Cost and availability of the individual's time and travel may play a role.
- Exclusions: None.

Quality improvement:

- Clinicians following these guidelines may measure quality of life and psychological outcomes for individuals with UVH or BVH who are undergoing VPT.

Implementation and audit:

- Use of evidence-based, PRO measures of quality of life should be systematically utilized and monitored to ensure consistent examination and care for individuals with vestibular hypofunction who may be experiencing psychological distress and anxiety.
- Standardizing reporting of patient-related factors and treatment protocols, including exercise type and dose, within and across clinical settings, will enable comparative outcome research.
- Clinics and organizations should collect data with respect to patient outcomes and therapeutic approaches used, including adjunct therapies such as cognitive behavioral therapy, for individuals with vestibular hypofunction who are experiencing psychological distress and anxiety.

Practice Summary

Literature prior to 2015 included in the original CPG provides strong evidence that VPT offers a clinically significant benefit for improving functional abilities and quality of life. The literature since 2015 supports the assertion that VPT leads to improved quality of life but does not provide evidence in support of any particular therapeutic approach to optimize quality of life.

Evidence Update

Loss of vestibular function can result in postural instability, visual blurring with head movement, and subjective complaints of dizziness and/or imbalance. Sun et al[84] examined quality of life (QoL) in individuals with UVH and BVH via survey and reported reduced QoL plus loss of workdays as a result of dizziness; QoL was especially reduced for individuals with BVH.

The DHI was designed to quantify the disabling effects of dizziness and to document change over time,[52] and is the most commonly used PRO and has been used as a primary measure of QoL related to dizziness.[235] Several studies since 2015 have addressed QoL as measured by the DHI and other PROs. Long-term benefits (up to 1 year) on QoL have been shown in individuals with acute onset of vestibular neuritis who received VPT compared with standard of care (steroids plus general information) (Tokle et al,[148] level II). In this level II RCT, the VPT program started within 1 week of onset of symptoms and resulted in significantly greater improvements in perceived disability (DHI), anxiety/depression (HADS), and overall perceived dizziness compared with the standard of care.

Several RCTs used vestibular exercises in both experimental and control groups and found improved QoL in both groups regardless of the additional investigational approach. For example, Meldrum et al[113] (level I) compared a VR-based treatment using the Wii Fit Plus to low-technology balance exercises. Both groups performed similar HEPs including GSE and a progressive walking program. The balance exercises were different between the groups and performed either using the Wii Fit Plus system fitted with a rocker board (Frii Board, Swiit Game Gear) or a foam cushion. This level I RCT study showed no superiority of the VR-based balance treatment on 2 measures of QoL, the VRBQ and the HADS. The Wii Fit Plus group reported significantly greater enjoyment and less fatigue during the exercises. Aratani et al[168] (level I) reported that older individuals improved significantly on the DHI and other PRO after receiving either of 2

different forms of VPT (Cawthorne-Cooksey and multimodal Cawthorne-Cooksey), although there were no differences between the groups. Additional PROs in this study included the Vestibular Disorder Activities of Daily Living Scale,[61] the Geriatric Depression scale,[236] and the ABC.[49] Two additional level II studies (Basta et al[133]; Yoo et al[146]) found significant improvements on the DHI from pre- to posttest following a course of VPT that included balance exercises with vibrotactile feedback or GSE and balance and gait. In the Basta et al[133] study, the additional investigational approach included antivertiginous medications, whereas Yoo et al[146] investigated the addition of steroid therapy.

A single level II study found greater improvement in the experimental group compared with the control group. Micarelli et al[164] examined the impact of an immersive VR game using an HMD for individuals with chronic UVH. Both groups performed VPT, including GSE and balance and gait training, and the experimental group also received 20 minutes of immersive VR training. Both groups improved their DHI and ABC scores significantly from pre- to posttest; however, the gaming group demonstrated a significantly greater improvement suggesting that the VR game involving visual-vestibular interaction may result in greater quality of life improvements.

Two level III studies suggest that the extent of vestibular deficit (UVH vs BVH) may negatively impact the amount of improvement following vestibular exercises.[112,192] Herdman et al[112] examined individuals with BVH (n = 69), all of whom participated in a VPT program consisting of daily GSE (adaptation and substitution), balance and gait exercises, and a walking program. The general sequence of exercises was the same for all individuals, but the rate of exercise progression differed. As a group, individuals with BVH improved significantly in most outcome measures including ABC and percent of time symptoms interfere with life. The exception was in the disability rating scores, which showed no improvement as a group. In contrast, the group of individuals with UVH improved significantly in disability rating scores.[192] A comparison of individuals with UVH to those with BVH showed that at discharge the UVH group had significantly higher balance-related confidence, walked faster, and had higher DGI scores than the BVH group. In individuals with BVH, poorer DGI scores at baseline were related to poorer disability rating scale scores at discharge.[192] Compared with individuals with UVH, a smaller percentage of individuals with BVH improve and to a lesser extent.

Quality of Life: Harm/Benefits Ratio

None of the recent studies on VPT reports any significant harm to individuals. The most commonly reported side effects of VPT treatment include vertigo, dizziness, and nausea, which may be experienced when not performing exercises and these symptoms typically dissipate within minutes to a day after exercise participation is finished for that session.

Summary of Prior Supporting Evidence and Clinical Interpretation

Based on improvements in the DHI measure over time, there is substantial evidence that QoL improves following VPT for individuals with UVH (level I: Enticott et al[154]; Johansson et al[237]; Rossi-Isquierdo et al[194]; Winkler and Esses[195]; level II: Clendaniel[187]; Badaracco et al[238]; Giray et al[74]; Gottshall et al[239]; Meli et al[240]; Mantello et al[241]; Morozetti et al[242]; Murray et al[243]; Perez et al[221]; Schubert et al[139]; Tee et al[244]; Teggi et al[158]; Tokle et al[148]; Topuz et al[226]; level III: Cowand et al[245]; Patatas et al[230]; level IV: Bittar et al[246]; Koganemaru et al[185]) and BVH (level I: Krebs et al[127]; level III: Gillespie and Minor[197]; Brown et al[198]). Others have utilized the ABC to record changes over time in perceived balance confidence (level I: Enticott et al[154]; level II: Badaracco et al[238]; Gottshall et al[239]; Meli et al[240]; level III: Brown et al[199]; Herdman et al[192]). The improvements in the DHI and the ABC scale suggest that individuals have improved QoL based on their perceptions of being less dizzy and having improved balance confidence after a course of VPT.

Quality of Life: Anxiety and Depression

There is emerging evidence that psychological distress and anxiety decrease with vestibular exercises in individuals with vestibular hypofunction. Two level I RCTs reported that autonomic/somatic anxiety scores decreased (improved anxiety) with VPT (Pavlou et al[190,202]). Pavlou et al also reported positive changes on the HADS plus the State Trait Anxiety Inventory,[247] suggesting that after rehabilitation their subjects were less anxious. A level II study reported improvements following VPT using a VAS of anxiety when compared with control subjects at 25 days post-hospitalization for acute vertigo.[158] The VPT group participated in 10 sessions that included dynamic posturography training and GSE. A level III study found that anxiety and/or depression were associated with less balance confidence and greater frequency of symptom interference with activities at discharge in individuals with UVH.[192]

Quality of Life: Harm/Benefits Ratio

Harm to the individual was not specifically noted in any of the literature reviewed related to QoL and psychological distress. Occasional mention was made about negative side effects of the VPT program and that not all individuals improved. Herdman et al[192] (level III) reported that anxiety and depression were associated with lower balance confidence scores in individuals with UVH, suggesting that coexisting anxiety and depression might diminish the beneficial effects of an exercise program. Cohen and Kimball[75] (level II) reported nausea as a side effect of the exercise program, which could affect QoL. Although nausea is a common side effect of exercise, it has not been routinely reported in the literature as being "harmful" nor as causing individuals to drop out of a VPT program.

Not all individuals benefit from vestibular exercises. Studies involving VPT suggest that most, but not all, participants improve. Telian et al[223] (level II) reported that a majority of individuals with UVH (82% of the participants, n = 65) indicated that they had improved, whereas 12% reported feeling worse. Almost half of their subjects had central vestibular disorders. Of the 12% who were worse after VPT, it is not reported whether these people had central or peripheral vestibular diagnoses. Herdman et al[192] (level III) found that 12% to 25% of individuals with UVH and 14% to 56% of

individuals with BVH (level III)[112] do not improve, depending on which outcome measure is used.

Return to work is an important measure of the benefit of any VPT program; however, few researchers have incorporated a measure of return to work. In 4 level II studies[223,224,248,249] and 4 level III studies,[24,112,129,192] individuals' perceived disability has been reported to positively change after rehabilitation. Although the disability rating scale includes ability to work as a portion of the instrument, no studies specifically report how frequently people with peripheral vestibular hypofunction are able to return to work in the same occupation and capacity after VPT.

Two reports (level III) have examined disability scores in individuals with UVH and BVH.[112,192] Only 44% of individuals with BVH experienced a clinically meaningful improvement or returned to normal in disability rating scores compared with 75% of individuals with UVH.[192] Chen et al[222] (level IV) reported that 3 out of 3 of their subjects were able to return to work and drive. Improvements in return to work and driving have also been noted in others with chronic UVH after a VPT program (level II).[249] There is the possibility that people will complete a VPT program and experience no change in their work-related QoL.

Quality of Life: Effect of Age

Meli et al[240] (level II) studied 42 people prospectively and followed up at 6 months to determine whether they had improved after a course of VPT. The Medical Outcomes Study 36-item Short Form (SF-36) improved in the study participants, except bodily pain and vitality. Younger participants had worse SF-36 scores, suggesting that dizziness may have more effect on their lives with respect to work and possibly a busier schedule than the older adults studied.

Overall Summary

There is substantial evidence that a program of VPT improves quality of life for individuals with UVH and BVH as measured by the DHI, ABC, and other PROs. There is some evidence that quality of life for individuals with BVH does not improve to the same extent as for individuals with UVH.

Research Recommendation 22: Researchers should examine the concept of return to work. Areas for study include job requirements that may be difficult for individuals with vestibular hypofunction, job modification or assistive technology to allow return to work, criteria for return to work or disability assignment, and indicators for return to safe driving.

Research Recommendation 23: Future studies of VPT should measure quality of life and examine whether or not harm occurred to the participants.

Limitations: The focus of the guideline was on peripheral vestibular hypofunction; thus, the recommendations of the guideline may not apply to individuals with central vestibular disorders. Only articles published in English were included. One criterion for study inclusion was that vestibular hypofunction was determined based on objective vestibular function tests. This guideline may not apply to individuals who report symptoms of dizziness, imbalance, and/or oscillopsia without a diagnosis of vestibular hypofunction.

FUTURE DIRECTIONS

There is a paucity of research on the effectiveness of vestibular rehabilitation in children, which is especially important given the significant number of young children who receive cochlear implants and that the surgical procedure may affect vestibular function. In the original 2016 CPG, the action statement on BVH referenced the only study by Rine et al[80] that included children. Rine et al[80] (level I) utilized a combination of GSE and balance exercises adapted for children during 12 weeks of thrice weekly supervised sessions and demonstrated improved postural control and gross motor skills in children (aged 3-8.5 years) with BVH. Since 2016, 1 additional level II study by Ebrahimi et al[250] also demonstrated improved sensory integration and limits of stability following 8 weeks of thrice weekly supervised sessions of GSE and balance exercises in children (aged 7-12 years) with BVH. A single level IV study provides support for VPT in children with UVH due to vestibular neuritis. Four of the 6 children (≤19 years) who received VPT experienced resolution of their symptoms of dizziness and imbalance. Most children with BVH lost vestibular function before birth or early in development, which may reduce the effectiveness of visual and somatosensory cues for postural control.[80] It is not clear whether interventions need to be different for children with congenital versus acquired vestibular hypofunction. This emerging evidence that children with BVH or UVH may benefit from VPT underscores the need for additional high-quality research to examine rehabilitation outcomes in children with vestibular hypofunction.

Augmenting traditional VPT for peripheral vestibular hypofunction with emerging technologies may be the next clinical evolution. Currently, these technologies are primarily available for research, but early studies suggest promise for these techniques. Incremental VOR adaptation, first described by Migliaccio and Schubert,[251] involves a head-worn device that projects a laser target that adaptively moves as a percentage of head velocity to achieve a specific VOR gain demand. The velocity of the target is incrementally increased starting at a level based on the actual VOR gain of the individual and then incremented; for example, for a VOR gain of 1.5, the target velocity would be in the opposite direction of head velocity and one and half times as fast. Two recent level IV case studies of individuals with chronic UVH (Rinaudo et al[252]) and BVH (Gimmon et al[175]) demonstrated that incremental VOR training improved passive VOR gain as well as balance and gait measures.

Computerized gaze stability training based on adaptable visual acuity demand may also prove to be beneficial. Crane and Schubert[167] (level III) examined whether internet-based adaptive vestibular rehabilitation training would reduce dizziness symptoms. The optotype size was adaptive such that the visual acuity demand could gradually increase across sessions and peak head rotation velocity triggered the optotype appearance. Four individuals with UVH reported a reduction in dizziness after completing a month of home training. This small study lends support to remote monitoring and progression based on performance metrics, which has implications for telehealth. van Vugt et al[208] (level I) reported a comparison of internet-based vestibular rehabilitation to internet-based plus in-person vestibular rehabilitation. The online training program had exercise progressions built into the software algorithms. This method of remote progression may benefit individuals who have limited access to therapists trained in VPT. Whether internet-based rehabilitation will facilitate improvements in balance and gait remains to be determined, and larger prospective studies are needed to determine the effectiveness of this treatment mode.

VR and sensory augmentation may also have a role in the future of VPT for peripheral vestibular hypofunction. Emerging evidence suggests a beneficial role for both of these technologies, but the optimal exposure parameters remain to be determined.[145,193,253] Some have demonstrated long-term improvements in balance after electrotactile sensory substitution therapy,[254] but this balance enhancement is not universal, and the mechanism of improvement remains unknown.

Neural modulation via electrical or magnetic stimulation has been shown to enhance motor performance and may have a role in treating UVH/BVH. Transcranial direct current stimulation of the cerebellum led to improved DHI scores reported by individuals with UVH.[185] Enhancing cerebellar neuroplasticity through direct stimulation may have the potential to improve many aspects of life for individuals with peripheral vestibular hypofunction, but more studies are needed.

The environment within which VPT is performed may prove to be important. An aquatic environment has the potential to reduce overall injury risk while participating in higher-risk balance activities. A recent level IV case series reported that performing vestibular rehabilitation in an aquatic environment was feasible.[255] This supports a previous study indicating improved balance (measured by computerized posturography) and dizziness for individuals with UVH after VPT provided in an aquatic setting.[256] Traditional land-based protocols may limit participation in VPT for individuals with UVH/BVH with comorbid severe arthritis or other weight-bearing restrictions.[257]

Several investigators have proposed using lenses to stabilize oscillopsia,[258,259] a primary complaint for individuals with BVH.[55,56] Although promising, image stabilizing lenses have not been adequately investigated.

Many individuals with peripheral vestibular hypofunction who undergo VPT recover successfully; however, there is a small percentage of individuals with poor rehabilitation outcomes who report long-term symptoms. In 2017, the Bárány Society published diagnostic criteria for PPPD, which is classified as a chronic functional vestibular disorder.[215] Limited data are available that have examined rehabilitation outcomes of individuals with peripheral vestibular hypofunction who meet the diagnostic criteria for PPPD; thus, this subpopulation was not included in these practice guidelines. Future work is needed to better understand rehabilitation outcomes of individuals with peripheral vestibular hypofunction who develop PPPD and use of adjunct

therapies (eg, cognitive behavioral therapy, counseling, and antidepressant/anxiety medications) to optimize outcomes.

GUIDELINE IMPLEMENTATION RECOMMENDATIONS

The following strategies are provided as suggestions for clinicians to implement the action statements of this CPG but are not an exhaustive list. Many variables affect the successful translation of evidence into practice, and clinicians need to assess their own practice environment, clinical expertise, and patient values and goals to determine the best approach to implement these action statements. Implementation adjustments should be based on clinical judgment of the patient's presentation, examination results, and response to interventions.

Strategies for implementation:

- Keep a copy of the CPG in a convenient clinic location.
- Use patient educational materials that align with the recommendations of the CPG.
- Seek training in the use of the recommended intervention approaches.
- Build relationships with referral sources to encourage early referral of individuals with peripheral vestibular hypofunction.
- Build a multidisciplinary clinic or network of health care providers who can work together to help manage patients who have peripheral vestibular hypofunction.
- Measure outcomes of care using recommended outcome measures across the ICF domains.
- Share the *Journal of Neurologic Physical Therapy* (*JNPT*) Perspectives for Patients that accompanies this article with patients and others who are interested in learning about the management of dizziness and imbalance related to vestibular disorders.

In addition to the these strategies, the Practice Committee of the ANPT has assembled a task force that will work on specific knowledge translation and implementation initiatives for this CPG and will collaborate with members of the GDG.

SUMMARY OF RESEARCH RECOMMENDATIONS

Research Recommendation 1: The timing of initiation of VPT after acute or subacute onset of UVH should be further examined with respect to optimizing rehabilitation outcomes.

Research Recommendation 2: Researchers should explore delivery of VPT using technology, telehealth, or self-teaching methods as an alternative for some individuals and identify individual-level factors that impact the use of technology on rehabilitation outcomes and patient satisfaction.

Research Recommendation 3: Researchers should identify factors that predict which individuals will need VPT to optimize outcomes and which individuals will recover spontaneously.

Research Recommendation 4: Level I studies are needed to determine the effect of VPT in individuals with BVH on various aspects of vestibular function across ICF domains, including at the level of participation (eg, reading and learning, participation in recreation, work, and driving).

Research Recommendation 5: All future studies that include individuals with BVH should consistently confirm the diagnosis of BVH using the Bárány Society diagnostic criteria.

Research Recommendation 6: Studies that use a mixture of individuals with UVH and BVH should analyze the 2 groups separately so that clinical judgments can be made for each group.

Research Recommendation 7: Randomized controlled studies are needed to determine the effect of GSE on gaze stability, gross motor abilities, and postural control in children with UVH and BVH.

Research Recommendation 8: Research is needed to determine whether the effective dose of GSE and balance training is dependent on the type (congenital vs acquired) and severity (UVH vs BVH) of the lesion in children.

Research Recommendation 9: Epidemiological studies are needed to confirm the prevalence of UVH and BVH in children.

Research Recommendation 10: There is sufficient evidence that vestibular exercises compared with no or placebo exercises are effective; thus, future research efforts should be directed to comparative effectiveness research.

Research Recommendation 11: Research in large-scale trials is needed to determine what types of technology-augmented VPT exercises (eg, VR for gaze or postural stability or vibratory stimulus) are most effective for improving specific symptoms and/or minimizing activity limitations and participation restrictions.

Research Recommendation 12: Research is needed to determine the most effective components of VPT (eg, gaze stability, balance, or habituation) and methods of delivering VR (eg, immersive vs nonimmersive devices).

Research Recommendation 13: Randomized controlled studies of longer-term impact on VPT outcomes are needed for emerging and novel treatment options like transcranial direct current stimulation or other forms of neuromodulation.

Research Recommendation 14: Researchers should examine the impact of frequency, intensity, duration, and type of balance and/or GSE on postural control and functional outcomes separately for individuals with acute, subacute, and chronic UVH and BVH. Researchers should clearly document the specific dosage parameters (exercise time per session/day, frequency per day/week, duration, and intensity).

Research Recommendation 15: Researchers should determine methods to rate both the intensity and the difficulty of gaze stabilization and balance exercises and how to progress individuals in a systematic manner.

Research Recommendation 16: Researchers should include measures of adherence and intent-to-treat designs to understand the impact of supervision on exercise compliance and dropout rates.

Research Recommendation 17: Researchers need to investigate whether there are critical dosages or time points for in-person versus telehealth/remote supervision.

Research Recommendation 18: Researchers need to investigate the role of telehealth/remote VPT support on patient compliance/motivation.

Research Recommendation 19: In the absence of spontaneous recovery, individuals should be encouraged to participate in VPT rather than withdraw. Determining contextual and personal factors leading to withdrawal may reduce barriers to continuation of rehabilitation.

Research Recommendation 20: Researchers should determine the factors that positively and negatively impact functional recovery during VPT, including anxiety and depression, cognitive impairment, and use of medications.

Research Recommendation 21: Researchers should examine whether the inclusion of psychological support (eg, cognitive behavioral therapy, counseling, and

antidepressant/anxiety medications) as an adjunct to VPT for individuals with anxiety/depression or who have developed PPPD is effective.

Research Recommendation 22: Researchers should examine the concept of return to work. Areas for study include job requirements that may be difficult for individuals with vestibular hypofunction, job modification or assistive technology to allow return to work, criteria for return to work or disability assignment, and indicators for return to safe driving.

Research Recommendation 23: Future studies of VPT should measure quality of life and examine whether or not harm occurred to the participants.

In summary, updated evidence supports the original recommendations from the 2016 CPG.[1] Vestibular physical therapy provides a clear and substantial benefit to individuals with vestibular hypofunction and it should be offered to individuals of all ages who present with impairments, activity limitations, and participation restrictions related to the vestibular deficit. Additional research is needed to answer or further clarify outstanding questions regarding: the use of technology and neuromodulation, the incorporation of telehealth; the effectiveness of different types and/or combinations of exercises as well as specific exercise dose and guidelines for exercise progression; and factors that positively and negatively impact functional recovery including the individual's ability to return to work. Large clinical trials across multiple settings, which include pediatric and adult populations, are encouraged. This CPG addressing VPT for peripheral vestibular hypofunction will be revised every 5 years incorporating updated research, which supports or refutes existing action statements. With additional knowledge, new action statements may be forthcoming.

ACKNOWLEDGMENTS

We are grateful to Maria Kirby, BS, DPT, and Jacqueline Butch, BS, DPT, for countless hours of research and assistance with data management, especially the Qualtrics platform, throughout this project. We gratefully acknowledge the assistance of University of Pittsburgh academic librarian Rose Turner, MLIS, with the systematic literature search.

We are grateful to members of the Neurology Section and Vestibular Special Interest Group who volunteered their time and efforts to perform critical appraisals of the literature. The physical therapist critical appraisal team included Carmen Abbott, Nicole Blitz, Jessica Cammarata, Jonna Carroll, Katie Chae, Pam Cornwell, Claudia Costa, Rene Crumley, Daniel Dettman, Megan Dial, Pamela Dunlap, Cheryl Ford-Smith, Melissa Grzesiak, Cory Hall, Teresa Hunter, Ryan Jensen, Brooke Klatt, Anne Knox, Andrew Littmann, Joann Moriarty-Baron, Laura Morris, Faisal al Mubarak, Nora Riley, Monica Ross, Ana Sanchez Junkin, Abby Manzo, Matthew Manzo, Zachary Robbins, Jazmine Shaw, Jason Sheehan, Debbie Struiksma, Zachary Sutton, Marie Timm, Lenny Vasanthan, Rachel Wellons, Kacee Windsor, Joseph Wise, Rachel Woods, Amanda Wu, and Karen Zacharewicz.

REFERENCES

1. Hall CD, Herdman SJ, Whitney SL, et al. Vestibular rehabilitation for peripheral vestibular hypofunction: an evidence-based clinical practice guideline: from the American Physical Therapy Association Neurology Section. *J Neurol Phys Ther*. 2016;40(2):124-155. doi:10.1097/NPT.0000000000000120.
2. Institute of Medicine (US) Committee on Standards for Developing Trustworthy Clinical Practice Guidelines, Graham R, Mancher M, Miller Wolman D, et al. eds. *Clinical practice guidelines we can trust*. Washington, DC: National Academies Press (US); 2011. doi:10.17226/13058.
3. American Physical Therapy Association. *APTA Clinical Practice Guideline Process Manual*. Alexandria, VA: American Physical Therapy Association; 2018.
4. Phillips B, Ball C, Sackett D, et al. Oxford Centre for Evidence-based Medicine—Levels of Evidence. https://www.cebm.net/2009/06/oxford-centre-evidence-based-medicine-levels-evidence-march-2009.apta. Published 2009.
5. Herdman SJ, Tusa RJ, Blatt PJ, Suzuki A, Venuto PJ, Roberts D. Computerized dynamic visual acuity test in the assessment of vestibular deficits. *Am J Otol.* 1998;19(6):790-796.
6. Li C, Beaumont JL, Rine RM, Slotkin J, Schubert MC. Normative scores for the NIH Toolbox Dynamic Visual Acuity Test from 3 to 85 years. *Front Neurol*. 2014;5:223. doi:10.3389/fneur.2014.00223.
7. Longridge NS, Mallinson AI. A discussion of the dynamic illegible "E" test: a new method of screening for aminoglycoside vestibulotoxicity. *Otolaryngol Head Neck Surg*. 1984;92(6):671-677. doi:10.1177/019459988409200614.
8. Herdman SJ. Computerized dynamic visual acuity test in the assessment of vestibular disorders. In: Eggers SDZ Zee DS, eds. *Vertigo and Imbalance: Clinical Neurophysiology of the Vestibular System, Handbook of Clinical Neurophysiology*. Vol 9. Amsterdam, the Netherlands: Elsevier; 2010:181-190.
9. Ward BK, Mohammad MT, Whitney SL, Marchetti GF, Furman JM. The reliability, stability, and concurrent validity of a test of gaze stabilization. *J Vestib Res*. 2010;20(5):363-372. doi:10.3233/VES-2010-0371.
10. Weber KP, MacDougall HG, Halmagyi GM, Curthoys IS. Impulsive testing of semicircular-canal function using video-oculography. *Ann N Y Acad Sci.* 2009;1164:486-491. doi:10.1111/j.1749-6632.2008.03730.x.
11. Kamei T. Two types of head-shaking tests in vestibular examination. *Acta Otolaryngol Suppl*. 1988;458:108-112. doi:10.3109/00016488809125112.
12. Thyssen HH, Brynskov J, Jansen EC, Münster-Swendsen J. Normal ranges and reproducibility for the quantitative Romberg's test. *Acta Neurol Scand*. 1982;66(1):100-104. doi:10.1111/j.1600-0404.1982.tb03133.x.
13. Ekdahl C, Jarnlo GB, Andersson SI. Standing balance in healthy subjects. Evaluation of a quantitative test battery on a force platform. *Scand J Rehabil Med*. 1989;21(4):187-195.
14. Nashner LM, Black FO, Wall C 3rd. Adaptation to altered support and visual conditions during stance: patients with vestibular deficits. *J Neurosci.* 1982;2(5):536-544. doi:10.1523/JNEUROSCI.02-05-00536.1982.
15. Di Fabio RP. Sensitivity and specificity of platform posturography for identifying patients with vestibular dysfunction. *Phys Ther*. 1995;75(4):290-305. doi:10.1093/ptj/75.4.290.
16. Honaker JA, Janky KL, Patterson JN, Shepard NT. Modified head shake sensory organization test: sensitivity and specificity. *Gait Posture*. 2016;49:67-72. doi:10.1016/j.gaitpost.2016.06.024.
17. Zwergal A, Rettinger N, Frenzel C, Dieterich M, Brandt T, Strupp M. A bucket of static vestibular function. *Neurol*. 2009;72(19):1689-1692. doi:10.1212/WNL.0b013e3181a55ecf.
18. Shumway-Cook A, Horak FB. Assessing the influence of sensory interaction of balance. Suggestion from the field. *Phys Ther*. 1986;66(10):1548-1550. doi:10.1093/ptj/66.10.1548.
19. Anacker SL, Di Fabio RP. Influence of sensory inputs on standing balance in community-dwelling elders with a recent history of falling. *Phys Ther*. 1992;72(8):575-581 doi:10.1093/ptj/72.8.575.
20. Cohen H, Blatchly AC, Gombash LL. A study of the clinical test of sensory interaction and balance. *Phys Ther*. 1993;73(6):346-354. doi:10.1093/ptj/73.6.346.
21. Hall CD, Herdman SJ. Reliability of clinical measures used to assess patients with peripheral vestibular disorders. *J Neurol Phys Ther*. 2006;30(2):74-81. doi:10.1097/01.npt.0000282571.55673.ed.
22. Toupet M, Ferrary E, Grayeli AB. Visual analog scale to assess vertigo and dizziness after repositioning maneuvers for benign paroxysmal positional vertigo. *J Vestib Res.* 2011;21(4):235-241. doi:10.3233/VES-2011-0420.
23. Dannenbaum E, Chilingaryan G, Fung J. Visual vertigo analogue scale: an assessment questionnaire for visual vertigo. *J Vestib Res*. 2011;21(3):153-159. doi:10.3233/VES-2011-0412.
24. Shepard NT, Telian SA, Smith-Wheelock M. Habituation and balance retraining therapy. A retrospective review. *Neurol Clin*. 1990;8(2):459-475.
25. Yardley L, Masson E, Verschuur C, Haacke N, Luxon L. Symptoms, anxiety and handicap in dizzy patients: development of the vertigo symptom scale. *J Psychosom Res.* 1992;36(8):731-741. doi:10.1016/0022-3999(92)90131-k.
26. Guralnik JM, Ferrucci L, Simonsick EM, Salive M, Wallace RB. Lower extremity function in persons over the age of 70 years as a predictor of subsequent disability. *N Engl J Med*. 1995;332(9):556-561. doi:10.1056/NEJM199503023320902.
27. Whitney SL, Wrisley DM, Marchetti GF, Gee MA, Redfern MS, Furman JM. Clinical measurement of sit-to-stand performance in people with balance disorders: validity of data for the Five-times-sit-to-stand test. *Phys Ther.* 2005;85(10):1034-1045.
28. Meretta BM, Whitney SL, Marchetti GF, Sparto PJ, Muirhead RJ. The five times sit to stand test: responsiveness to change and concurrent validity in adults undergoing vestibular rehabilitation. *J Vestib Res*. 2006;16(4/5):233-243.
29. Rikli RE, Jones CJ. *Senior Fitness Test Manual.* Champaign, IL: Human Kinetics; 2001.
30. Duncan PW, Studenski S, Chandler J, Prescott B. Functional reach: predictive validity in a sample of elderly male veterans. *J Gerontol*. 1992;47(3):M93-M98. doi:10.1093/geronj/47.3.m93.

31. Mann GC, Whitney SL, Redfern MS, Borello-France DF, Furman JM. Functional reach and single leg stance in patients with peripheral vestibular disorders. *J Vestib Res.* 1996;6(5):343-353.
32. Bohannon RW. Comfortable and maximum walking speed of adults aged 20-79 years: reference values and determinants. *Age Ageing.* 1997;26(1):15-19. doi:10.1093/ageing/26.1.15.
33. Perera S, Mody SH, Woodman RC, Studenski SA. Meaningful change and responsiveness in common physical performance measures in older adults. *J Am Geriatr Soc*. 2006;54(5):743-749. doi:10.1111/j.1532-5415.2006.00701.x.
34. Studenski S, Perera S, Patel K, et al. Gait speed and survival in older adults. *JAMA.* 2011;305(1):50-58. doi:10.1001/jama.2010.1923.
35. Horak FB, Wrisley DM, Frank J. The Balance Evaluation Systems Test (BESTest) to differentiate balance deficits. *Phys Ther*. 2009;89(5):484-498. doi:10.2522/ptj.20080071.
36. Franchignoni F, Horak F, Godi M, Nardone A, Giordano A. Using psychometric techniques to improve the balance evaluation systems test: the mini-BESTest. *J Rehabil Med*. 2010;42(4):323-331. doi:10.2340/16501977-0537.
37. Godi M, Franchignoni F, Caligari M, Giordano A, Turcato AM, Nardone A. Comparison of reliability, validity, and responsiveness of the mini-BESTest and Berg Balance Scale in patients with balance disorders. *Phys Ther*. 2013;93(2):158-167. doi:10.2522/ptj.20120171.
38. Berg KO, Wood-Dauphinee SL, Williams JI, Maki B. Measuring balance in the elderly: validation of an instrument. *Can J Public Health.* 1992;83(suppl 2):S7-S11.
39. Whitney SL, Wrisley DM, Furman JM. Concurrent validity of the Berg Balance Scale and the Dynamic Gait Index in people with vestibular dysfunction. *Physiother Res Int*. 2003;8(4):178-186. doi:10.1002/pri.288.
40. Shumway-Cook A, Gruber W, Baldwin M, Liao S. The effect of multidimensional exercises on balance, mobility, and fall risk in community-dwelling older adults. *Phys Ther*. 1997;77(1):46-57. doi:10.1093/ptj/77.1.46.
41. Whitney SL, Hudak MK, Marchetti GF. The Dynamic Gait Index related to self-reported fall history in individuals with vestibular dysfunction. *J Vestib Res.* 2000;10(2):99-105.
42. Wrisley DM, Marchetti GF, Kuharsky DK, Whitney SW. Reliability, internal consistency, and validity of data obtained with the functional gait assessment. *Phys Ther.* 2004;84(10):906-918.
43. Whitney SL, Marchetti GF, Morris LO, Sparto PJ. The reliability and validity of the Four Square Step Test for people with balance deficits secondary to a vestibular disorder. *Arch Phys Med Rehabil*. 2007;88(1):99-104. doi:10.1016/j.apmr.2006.10.027.
44. Bohannon RW, Larkin PA, Cook AC, Gear J, Singer J. Decrease in timed balance test scores with aging. *Phys Ther*. 1984;64(7):1067-1070. doi:10.1093/ptj/64.7.1067.
45. Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc*. 1991;39(2):142-148. doi:10.1111/j.1532-5415.1991.tb01616.x.
46. Whitney SL, Marchetti GF, Schade A, Wrisley DM. The sensitivity and specificity of the timed "Up & Go" and the Dynamic Gait Index for self-reported falls in persons with vestibular disorders. *J Vestib Res.* 2004;14(5):397-409.
47. Shumway-Cook A, Brauer S, Woollacott M. Predicting the probability for falls in community-dwelling older adults using the timed up & go test. *Phys Ther*. 2000;80(9):896-903.
48. Caixeta GC, Doná F, Gazzola JM. Cognitive processing and body balance in elderly subjects with vestibular dysfunction. *Braz J Otorhinolaryngol*. 2012;78(2):87-95.
49. Powell LE, Myers AM. The Activities-specific Balance Confidence (ABC) scale. *J Gerontol A Biol Sci Med Sci.* 1995;50A(1):M28-M34. doi:10.1093/gerona/50a.1.m28.
50. Myers AM, Powell LE, Maki BE, Holliday PJ, Brawley LR, Sherk W. Psychological indicators of balance confidence: relationship to actual and perceived abilities. *J Gerontol A Biol Sci Med Sci.* 1996;51(1):M37-M43. doi:10.1093/gerona/51a.1.m37.
51. Alsubaie SF, Whitney SL, Furman JM, et al. Reliability and validity of ratings of perceived difficulty during performance of static standing balance exercises. *Phys Ther*. 2019;99(10):1381-1393. doi:10.1093/ptj/pzz091.
52. Jacobson GP, Newman CW. The development of the dizziness handicap inventory. *Arch Otolaryngol Head Neck Surg*. 1990;116(4):424-427. doi:10.1001/archotol.1990.01870040046011.
53. Zigmond AS, Snaith RP. The Hospital Anxiety and Depression Scale. *Acta Psychiatr Scand*. 1983;67(6):361-370. doi:10.1111/j.1600-0447.1983.tb09716.x.
54. Herrmann C. International experiences with the Hospital Anxiety and Depression Scale—a review of validation data and clinical results. *J Psychosom Res.* 1997;42(1):17-41. doi:10.1016/s0022-3999(96)00216-4.
55. Anson ER, Gimmon Y, Kiemel T, Jeka JJ, Carey JP. A tool to quantify the functional impact of oscillopsia. *Front Neurol.* 2018;9:142. doi:10.3389/fneur.2018.00142.
56. Guinand N, Pijnenburg M, Janssen M, Kingma H. Visual acuity while walking and oscillopsia severity in healthy subjects and patients with unilateral and bilateral vestibular function loss. *Arch Otolaryngol Head Neck Surg*. 2012;138(3):301-306. doi:10.1001/archoto.2012.4.
57. Hazlett RL, Tusa RJ, Waranch HR. Development of an inventory for dizziness and related factors. *J Behav Med*. 1996;19(1):73-85. doi:10.1007/BF01858175.
58. Honrubia V, Bell TS, Harris MR, Baloh RW, Fisher LM. Quantitative evaluation of dizziness characteristics and impact on quality of life. *Am J Otol.* 1996;17(4):595-602.
59. Duracinsky M, Mosnier I, Bouccar D, Sterkers O, Chassany O; Working Group of the Société Française d'Oto-Rhino-Laryngologie (ORL). Literature review of questionnaires assessing vertigo and dizziness, and their impact on patients' quality of life. *Value Health*. 2007;10(4):273-284. doi:10.1111/j.1524-4733.2007.00182.x.
60. Alghwiri AA, Whitney SL, Baker CE, et al. The development and validation of the vestibular activities and participation measure. *Arch Phys Med Rehabil.* 2012;93(10):1822-1831. doi:10.1016/j.apmr.2012.03.017.
61. Cohen HS, Kimball KT. Development of the vestibular disorders activities of daily living scale. *Arch Otolaryngol Head Neck Surg.* 2000;126(7):881-887. doi:10.1001/archotol.126.7.881.
62. Morris AE, Lutman ME, Yardley L. Measuring outcome from vestibular rehabilitation, part I: qualitative development of a new self-report measure. *Int J Audiol.* 2008;47(4):169-177. doi:10.1080/14992020701843129.
63. Morris AE, Lutman ME, Yardley L. Measuring outcome from vestibular rehabilitation, part II: refinement and validation of a new self-report measure. *Int J Audiol*. 2009;48(1):24-37. doi:10.1080/14992020802314905.
64. Herdman SJ, Hall CD, Schubert MC, Das VE, Tusa RJ. Recovery of dynamic visual acuity in bilateral vestibular hypofunction. *Arch Otolaryngol Head Neck Surg*. 2007;133(4):383-389. doi: 10.1001/archotol.133.4.383.
65. McDonnell MN, Hillier SL. Vestibular rehabilitation for unilateral peripheral vestibular dysfunction. *Cochrane Database Syst Rev.* 2015;1:CD005397. doi:10.1002/14651858.CD005397.pub4.
66. Grill E, Heuberger M, Strobl R, et al. Prevalence, determinants, and consequences of vestibular hypofunction. Results from the KORA-FF4 survey. *Front Neurol.* 2018;9:1076. doi:10.3389/fneur.2018.01076.
67. Lee SU, Park SH, Kim HJ, Koo JW, Kim JS. Normal caloric responses during acute phase of vestibular neuritis. *J Clin Neurol*. 2016;12(3):301-307. doi:10.3988/jcn.2016.12.3.301.
68. Zingler VC, Weintz E, Jahn K, et al. Causative factors, epidemiology, and follow-up of bilateral vestibulopathy. *Ann N Y Acad Sci.* 2009;1164:505-508. doi:10.1111/j.1749-6632.2009.03765.x.

69. Smith PF, Curthoys IS. Mechanisms of recovery following unilateral labyrinthectomy: a review. *Brain Res Brain Res Rev*. 1989;14(2):155-80. doi:10.1016/0165-0173(89)90013-1.
70. Fetter M. Vestibular system disorders. In: Herdman SJ Clendaniel RA. *Vestibular Rehabilitation.* 4th ed. Philadelphia, PA: F. A. Davis Co; 2014:50-58.
71. Schubert MC. Compensatory strategies for vestibulo-ocular hypofunction. In: Herdman SJ, Clendaniel RA, eds. *Vestibular Rehabilitation.* 4th ed. Philadelphia, PA: F. A. Davis Co; 2014:151-157.
72. Brandt T, Zwergal A, Glasauer S. 3-D spatial memory and navigation: functions and disorders. *Curr Opin Neurol.* 2017;30(1):90-97. doi:10.1097/WCO.0000000000000415.
73. Agrawal Y, Smith PF, Rosenberg PB. Vestibular impairment, cognitive decline and Alzheimer's disease: balancing the evidence. *Aging Ment Heal.* 2020;24:705-708.
74. Giray M, Kirazli Y, Karapolat H, Celebisoy N, Bilgen C, Kirazli T. Short-term effects of vestibular rehabilitation in patients with chronic unilateral vestibular dysfunction: a randomized controlled study. *Arch Phys Med Rehabil.* 2009;90(8):1325-1331. doi:10.1016/j.apmr.2009.01.032.
75. Cohen HS, Kimball KT. Increased independence and decreased vertigo after vestibular rehabilitation. *Otolaryngol Head Neck Surg*. 2003;128(1):60-70. doi:10.1067/mhn.2003.23.
76. Yardley L, Owen N, Nazareth I, Luxon L. Prevalence and presentation of dizziness in a general practice community sample of working age people. *Br J Gen Pract.* 1998;48(429):1131-1135.
77. Lahmann C, Henningsen P, Brandt T, et al. Psychiatric comorbidity and psychosocial impairment among patients with vertigo and dizziness. *J Neurol Neurosurg Psychiatry.* 2015;86(3):302-308. doi:10.1136/jnnp-2014-307601.
78. Staab JP. Persistent postural-perceptual dizziness. *Semin Neurol.* 2020;40(1):130-137. doi:10.1055/s-0039-3402736.
79. Lucieer F, Vonk P, Guinand N, Stokroos R, Kingma H, van de Berg R. Bilateral vestibular hypofunction: insights in etiologies, clinical subtypes, and diagnostics. *Front Neurol*. 2016;7:26. doi:10.3389/fneur.2016.00026.
80. Rine RM, Braswell J, Fisher D, Joyce K, Kalar K, Shaffer M. Improvement of motor development and postural control following intervention in children with sensorineural hearing loss and vestibular impairment. *Int J Pediatr Otorhinolaryngol*. 2004;68(9):1141-1148. doi:10.1016/j.ijporl.2004.04.007.
81. Hain TC, Cherchi M, Yacovino DA. Bilateral vestibular loss. *Semin Neurol.* 2013;33(3):195-203. doi:10.1055/s-0033-1354597.
82. Herdman SJ, Blatt P, Schubert MC, Tusa RJ. Falls in patients with vestibular deficits. *Am J Otol*. 2000;21(6):847-851.
83. Guinand N, Boselie F, Guyot JP, Kingma H. Quality of life of patients with bilateral vestibulopathy. *Ann Otol Rhinol Laryngol.* 2012;121(7):471-477. doi:10.1177/000348941212100708.
84. Sun DQ, Ward BK, Semenov YR, Carey JP, Della Santina CC. Bilateral vestibular deficiency: quality of life and economic implications. *JAMA Otolaryngol Head Neck Surg.* 2014;140(6):527-534. doi:10.1001/jamaoto.2014.490.
85. Dobbels B, Peetermans O, Boon B, Mertens G, Van de Heyning P, Van Rompaey V. Impact of bilateral vestibulopathy on spatial and nonspatial cognition: a systematic review. *Ear Hear.* 2019;40(4):757-765. doi:10.1097/AUD.0000000000000679.
86. Agrawal Y, Carey JP, Della Santina CC, Schubert MC, Minor LB. Disorders of balance and vestibular function in US adults: data from the National Health and Nutrition Examination Survey, 2001-2004. *Arch Intern Med.* 2009;169(10):938-944. doi:10.1001/archinternmed.2009.66.
87. Kovacs E, Wang X, Grill E. Economic burden of vertigo: a systematic review. *Health Econ Rev.* 2019;9(1):37. doi:10.1186/s13561-019-0258-2.
88. Wang X, Strobl R, Holle R, Seidl H, Peters A, Grill E. Vertigo and dizziness cause considerable more health care resource use and costs: results from the KORA FF4 study. *J Neurol*. 2019;266(9):2120-2128. doi:10.1007/s00415-019-09386-x.
89. Schlick C, Schniepp R, Loidl V, Wuehr M, Hesselbarth K, Jahn K. Falls and fear of falling in vertigo and balance disorders: a controlled cross-sectional study. *J Vestib Res.* 2016;25(5/6):241-251. doi:10.3233/VES-150564.
90. Burns ER, Stevens JA, Lee R. The direct costs of fatal and non-fatal falls among older adults—United States. *J Safety Res.* 2016;58:99-103. doi:10.1016/j.jsr.2016.05.001.
91. Florence CS, Bergen G, Atherly A, Burns E, Stevens J, Drake C. Medical costs of fatal and nonfatal falls in older adults. *J Am Geriatr Soc.* 2018;66(4):693-698. doi:10.1111/jgs.15304.
92. Parry SW, Deary V, Finch T, et al. The STRIDE (Strategies to Increase confidence, InDependence and Energy) study: cognitive behavioural therapy-based intervention to reduce fear of falling in older fallers living in the community—study protocol for a randomised controlled trial. *Trials*. 2014;15:210. doi:10.1186/1745-6215-15-210.
93. Kim H, Lee S, Kim J. Risk of injury after emergency department visit for acute peripheral vertigo: a matched-cohort study. *Clin Exp Emerg Med*. 2020;7(3):176-182. doi:10.15441/ceem.19.064.
94. Neuhauser HK, Radtke A, von Brevern M, Lezius F, Feldmann M, Lempert T. Burden of dizziness and vertigo in the community. *Arch Intern Med*. 2008;168(19):2118-2124. doi:10.1001/archinte.168.19.2118.
95. Adamec I, Skorić MK, Handžić J, Habek M. Incidence, seasonality and comorbidity in vestibular neuritis. *Neurol Sci.* 2015;36(1):91-95.
96. Hülse R, Biesdorf A, Hörmann K, et al. Peripheral vestibular disorders: an epidemiologic survey in 70 million individuals. *Otol Neurotol.* 2019;40(1):88-95. doi:10.1097/MAO.0000000000002013.
97. Kroenke K, Hoffman RM, Einstadter D. How common are various causes of dizziness? A critical review. *South Med J.* 2000;93(2):160-168.
98. Brodsky JR, Lipson S, Bhattacharyya N. Prevalence of pediatric dizziness and imbalance in the United States. *Otolaryngol Head Neck Surg*. 2020;162(2):241-247. doi:10.1177/0194599819887375.
99. Ward BK, Agrawal Y, Hoffman HJ, Carey JP, Della Santina CC. Prevalence and impact of bilateral vestibular hypofunction: results from the 2008 US National Health Interview Survey. *JAMA Otolaryngol Head Neck Surg*. 2013;139(8):803-810. doi:10.1001/jamaoto.2013.3913.
100. Paige GD. Senescence of human visual-vestibular interactions: smooth pursuit, optokinetic, and vestibular control of eye movements with aging. *Exp Brain Res.* 1994;98(2):355-372. doi:10.1007/BF00228423.
101. Peterka RJ, Black FO. Age-related changes in human posture control: sensory organization tests. *J Vestib Res.* 1990;1(1):73-85.
102. Li C, Layman AJ, Carey JP, Agrawal Y. Epidemiology of vestibular evoked myogenic potentials: data from the Baltimore Longitudinal Study of Aging. *Clin Neurophysiol*. 2015;126(11):2207-2215. doi:10.1016/j.clinph.2015.01.008.
103. Li C, Layman AJ, Geary R, et al. Epidemiology of vestibulo-ocular reflex function: data from the Baltimore Longitudinal Study of Aging. *Otol Neurotol*. 2015;36(2):267-272. doi:10.1097/MAO.0000000000000610.
104. Dillon CF, Gu Q, Hoffman HJ, Ko C-W. Vision, hearing, balance, and sensory impairment in Americans aged 70 years and over: United States, 1999-2006. *NCHS Data Brief.* 2010(31):1-8.
105. Agrawal Y, Van de Berg R, Wuyts F, et al. Presbyvestibulopathy: diagnostic criteria consensus document of the classification committee of the Bárány Society. *J Vestib Res*. 2019;29(4):161-170. doi:10.3233/VES-190672.
106. Gadkaree SK, Sun DQ, Li C, et al. Does sensory function decline independently or concomitantly with Age? Data from the Baltimore Longitudinal Study of Aging. *J Aging Res.* 2016;2016:1865038. doi:10.1155/2016/1865038.
107. O'Reilly RC, Morlet T, Nicholas BD, et al. Prevalence of vestibular and balance disorders in children. *Otol Neurotol.* 2010;31(9):1441-1444. doi:10.1097/MAO.0b013e3181f20673.

108. Tribukait A, Brantberg K, Bergenius J. Function of semicircular canals, utricles and saccules in deaf children. *Acta Oto-Laryngol*. 2004;124(1):41-48. doi:10.1080/00016480310002113.
109. Jacot E, Van Den Abbeele T, Debre HR, Wiener-Vacher SR. Vestibular impairments pre- and post-cochlear implant in children. *Int J Pediatr Otorhinolaryngol.* 2009;73(2):209-217. doi:10.1016/j.ijporl.2008.10.024.
110. Wiener-Vacher SR, Quarez J, Priol AL. Epidemiology of vestibular impairments in a pediatric population. *Semin Hear.* 2018;39(3):229-242. doi:10.1055/s-0038-1666815.
111. Martens S, Dhooge I, Dhondt C, et al. Vestibular infant screening—Flanders: the implementation of a standard vestibular screening protocol for hearing-impaired children in Flanders. *Int J Pediatr Otorhinolaryngol.* 2019;120:196-201. doi:10.1016/j.ijporl.2019.02.033.
112. Herdman SJ, Hall CD, Maloney B, Knight S, Ebert M, Lowe J. Variables associated with outcome in patients with bilateral vestibular hypofunction: preliminary study. *J Vestib Res*. 2015;25(3/4):185-194. doi:10.3233/VES-150556.
113. Meldrum D, Herdman S, Vance R, et al. Effectiveness of conventional versus virtual reality-based balance exercises in vestibular rehabilitation for unilateral peripheral vestibular loss: results of a randomized controlled trial. *Arch Phys Med Rehabil*. 2015;96(7):1319-1328.e1. doi:10.1016/j.apmr.2015.02.032.
114. Allum JHJ, Cleworth T, Honegger F. Recovery of vestibulo-ocular reflex symmetry after an acute unilateral peripheral vestibular deficit: time course and correlation with canal paresis. *Otol Neurotol.* 2016;37(6):772-780. doi:10.1097/MAO.0000000000001054.
115. Lehnen N, Kellerer S, Knorr AG, et al. Head-movement-emphasized rehabilitation in bilateral vestibulopathy. *Front Neurol*. 2018;9:562. doi:10.3389/fneur.00562.
116. Navari E, Cerchiai N, Casani AP. Assessment of vestibulo-ocular reflex gain and catch-up saccades during vestibular rehabilitation. *Otol Neurotol*. 2018;39(10):e1111-e1117. doi:10.1097/MAO.0000000000002032.
117. Smółka W, Smółka K, Markowski J, Pilch J, Piotrowska-Seweryn A, Zwierzchowska A. The efficacy of vestibular rehabilitation in patients with chronic unilateral vestibular dysfunction. *Int J Occup Med Environ Health*. 2020;33(3):273-282. doi:10.13075/ijomeh.1896.01330.
118. Porciuncula F, Johnson CC, Glickman LB. The effect of vestibular rehabilitation on adults with bilateral vestibular hypofunction: a systematic review. *J Vestib Res.* 2012;22(5/6):283-298. doi:10.3233/VES-120464.
119. Guidetti G, Guidetti R, Mandredi M, Mafredi M. Vestibular pathology and spatial working memory. *Acta Otorhinolaryngol Ital*. 2020;40(1):72-78. doi:10.14639/0392-100X-2189.
120. Bhattacharyya N, Gubbels SP, Schwartz SR, et al. Clinical practice guideline: benign paroxysmal positional vertigo (update). *Otolaryngol Head Neck Surg.* 2017;156(3_suppl):S1-S47. doi:10.1177/0194599816689667.
121. Basura GJ, Adams ME, Monfared A, et al. Clinical practice guideline: Ménière's disease. *Otolaryngol Head Neck Surg.* 2020;162(2_suppl):S1-S55. doi:10.1177/0194599820909438.
122. Quatman-Yates CC, Hunter-Giordano A, Shimamura KK, et al. Physical therapy evaluation and treatment after concussion/mild traumatic brain injury. *J Orthop Sports Phys Ther.* 2020;50(4):CPG1-CPG73. doi:10.2519/jospt.2020.0301.
123. Gandolfi MM, Reilly EK, Galatioto J, Judson RB, Kim AH. Cost-effective analysis of unilateral vestibular weakness investigation. *Otol Neurotol*. 2015;36(2):277-281. doi:10.1097/MAO.0000000000000649.
124. Voelker CC, Lucisano A, Kallogjeri D, Sinks BC, Goebel JA. Comparison of the gaze stabilization test and the dynamic visual acuity test in unilateral vestibular loss patients and controls. *Otol Neurotol*. 2015;36(4):746-753. doi:10.1097/MAO.0000000000000689.
125. Yeh SC, Huang MC, Wang PC, et al. Machine learning-based assessment tool for imbalance and vestibular dysfunction with virtual reality rehabilitation system. *Comput Methods Programs Biomed.* 2014;116(3):311-318.
126. Jongkees LB. Thermic test and electronystagmography. *Acta Otorhinolaryngol Belg.* 1965;19(2):455-464.
127. Krebs DE, Gill-Body KM, Riley PO, Parker SW. Double-blind, placebo-controlled trial of rehabilitation for bilateral vestibular hypofunction: preliminary report. *Otolaryngol Head Neck Surg.* 1993;109(4):735-741. doi:10.1177/019459989310900417.
128. Shepard NT, Jacobson GP. The caloric irrigation test. *Handb Clin Neurol*. 2016;137:119-131. doi:10.1016/B978-0-444-63437-5.00009-1.
129. Telian SA, Shepard NT, Smith-Wheelock M, Hoberg M. Bilateral vestibular paresis: diagnosis and treatment. *Otolaryngol Head Neck Surg*. 1991;104(1):67-71. doi:10.1177/019459989110400113.
130. Yip CW, Glaser M, Frenzel C, Bayer O, Strupp M. Comparison of the bedside head-impulse test with the video head-impulse test in a clinical practice setting: a prospective study of 500 outpatients. *Front Neurol*. 2016;7:58. doi:10.3389/fneur.2016.00058.
131. Lacour M, Laurent T, Alain T. Rehabilitation of dynamic visual acuity in patients with unilateral vestibular hypofunction: earlier is better. *Eur Arch Otorhinolaryngol*. 2020;277(1):103-113. doi:10.1007/s00405-019-05690-4.
132. Horak FB, Jones-Rycewicz C, Black FO, Shumway-Cook A. Effects of vestibular rehabilitation on dizziness and imbalance. *Otolaryngol Head Neck Surg*. 1992;106(2):175-180.
133. Basta D, Borsellino L, Ernst A. Antivertiginous drug therapy does not hinder the efficacy of individualized vibrotactile neurofeedback training for vestibular rehabilitation—a randomized trial. *Int J Rehabil Res*. 2017;40(4):333-338. doi:10.1097/MRR.0000000000000245.
134. Berryhill W, Graham M. Chemical and physical labyrinthectomy for Meniere's disease. *Otolaryngol Clin North Am.* 2002;35(3):675-682. doi:10.1016/s0030-6665(02)00025-7.
135. Cawthorne T. Vestibular injuries. *Proc R Soc Lond B Biol Sci*. 1946;39(5):270-273.
136. Ricci NA, Aratani MC, Caovilla HH, Ganança FF. Effects of vestibular rehabilitation on balance control in older people with chronic dizziness: a randomized clinical trial. *Am J Phys Med Rehabil*. 2016;95(4):256-269.
137. Jáuregui-Renaud K, Villanueva Padrón LA, Cruz Gómez NS. The effect of vestibular rehabilitation supplemented by training of the breathing rhythm or proprioception exercises, in patients with chronic peripheral vestibular disease. *J Vestib Res*. 2007;17(1):63-72.
138. Gauthier GM, Robinson DA. Adaptation of the human vestibuloocular reflex to magnifying lenses. *Brain Res.*1975;92(2):331-335. doi:10.1016/0006-8993(75)90279-6.
139. Schubert MC, Migliaccio AA, Clendaniel RA, Allak A, Carey JP. Mechanism of dynamic visual acuity recovery with vestibular rehabilitation. *Arch Phys Med Rehabil.* 2008;89(3):500-507. doi:10.1016/j.apmr.2007.11.010.
140. Schubert MC, Hall CD, Das V, Tusa RJ, Herdman SJ. Oculomotor strategies and their effect on reducing gaze position error. *Otol Neurotol.* 2010;31(2):228-231. doi:10.1097/MAO.0b013e3181c2dbae.
141. Strupp M, Arbusow V, Maag KP, Gall C, Brandt T. Vestibular exercises improve central vestibulospinal compensation after vestibular neuritis. *Neurology.* 1998;51(3):838-844. doi:10.1212/wnl.51.3.838.
142. Levac D, Glegg SM, Sveistrup H, et al. A knowledge translation intervention to enhance clinical application of a virtual reality system in stroke rehabilitation. *BMC Health Serv Res.* 2016;16(1):557. doi:10.1186/s12913-016-1807-6.
143. Klatt BN, Carender WJ, Lin CC, et al. A conceptual framework for the progression of balance exercises in persons with balance and vestibular disorders. *Phys Med Rehabil Int.* 2015;2(4):1044.
144. Espy D, Reinthal A, Kuchta N, Casey N, Wiland T. Development of a rating scale for perceived stability during balance training. Paper presented at: Combined Sections Meeting. February 4-7, 2015; Indianapolis, IN.

145. Sienko KH, Whitney SL, Carender WJ, Wall C. The role of sensory augmentation for people with vestibular deficits: real-time balance aid and/or rehabilitation device? *J Vestib Res*. 2017;27(1):63-76. doi:10.3233/VES-170606.
146. Yoo MH, Yang CJ, Kim SA, et al. Efficacy of steroid therapy based on symptomatic and functional improvement in patients with vestibular neuritis: a prospective randomized controlled trial. *Eur Arch Otorhinolaryngol*. 2017;274(6):2443-2451. doi:10.1007/s00405-017-4556-1.
147. Ismail EI, Morgan AE, Abdel Rahman AM. Corticosteroids versus vestibular rehabilitation in long-term outcomes in vestibular neuritis. *J Vestib Res*. 2018;28(5/6):417-424. doi:10.3233/VES-180645.
148. Tokle G, Mørkved S, Bråthen G, et al. Efficacy of vestibular rehabilitation following acute vestibular neuritis: a randomized controlled trial. *Otol Neurotol.* 2020;41(1):78-85. doi:10.1097/MAO.0000000000002443.
149. Scheltinga A, Honegger F, Timmermans DP, Allum JH. The effect of age on improvements in vestibulo-ocular reflexes and balance control after acute unilateral peripheral vestibular loss. *Front Neurol*. 2016;7:18. doi:10.3389/fneur.2016.00018.
150. Jeong J, Jung J, Lee JM, Suh MJ, Kwak SH, Kim SH. Effects of saccular function on recovery of subjective dizziness after vestibular rehabilitation. *Otol Neurotol*. 2017;38(7):1017-1023. doi:10.1097/MAO.0000000000001467.
151. Büki B, Hanschek M, Jünger H. Vestibular neuritis: involvement and long-term recovery of individual semicircular canals. *Auris Nasus Larynx*. 2017;44(3):288-293. doi:10.1016/j.anl.2016.07.020.
152. Herdman SJ, Clendaniel RA, Mattox DE, Holliday MJ, Niparko JK. Vestibular adaptation exercises and recovery: acute stage after acoustic neuroma resection. *Otolaryngol Head Neck Surg.* 1995;113(1):77-87. doi:10.1016/s0194-5998(95)70148-6.
153. Mruzek M, Barin K, Nichols DS, Burnett CN, Welling DB. Effects of vestibular rehabilitation and social reinforcement on recovery following ablative vestibular surgery. *Laryngoscope*. 1995;105 (7, pt 1):686-692. doi:10.1288/00005537-199507000-00004.
154. Enticott JC, O'Leary SJ, Briggs RJ. Effects of vestibulo-ocular reflex exercises on vestibular compensation after vestibular schwannoma surgery. *Otol Neurotol.* 2005;26(2):265-269. doi:10.1097/00129492-200503000-00024.
155. Vereeck L, Wuyts FL, Truijen S, De Valck C, Van de Heyning PH. The effect of early customized vestibular rehabilitation on balance after acoustic neuroma resection. *Clin Rehabil*. 2008;22(8):698-713.
156. Sparrer I, Duong Dinh TA, Ilgner J, Westhofen M. Vestibular rehabilitation using the Nintendo® Wii Balance Board—a user-friendly alternative for central nervous compensation. *Acta Otolaryngol*. 2013;133(3):239-245. doi:10.3109/00016489.2012.732707.
157. Venosa AR, Bittar RS. Vestibular rehabilitation exercises in acute vertigo. *Laryngoscope*. 2007;117(8):1482-1487. doi:10.1097/MLG.0b013e318068b54f.
158. Teggi R, Caldirola D, Fabiano B, Recanati P, Bussi M. Rehabilitation after acute vestibular disorders. *J Laryngol Otol*. 2009;123(4):397-402. doi:10.1017/S0022215108002983.
159. Marioni G, Fermo S, Zanon D, Broi N, Staffieri A. Early rehabilitation for unilateral peripheral vestibular disorders: a prospective, randomized investigation using computerized posturography. *Eur Arch Otorhinolaryngol*. 2013;270(2):425-435. doi:10.1007/s00405-012-1944-4.
160. Magnusson M, Kahlon B, Karlberg M, Lindberg S, Siesjö P. Preoperative vestibular ablation with gentamicin and vestibular "prehab" enhance postoperative recovery after surgery for pontine angle tumours—first report. *Acta Otolaryngol*. 2007;127(12):1236-1240. doi:10.1080/00016480701663433.
161. Tjernström F, Fransson PA, Kahlon B, et al. Vestibular PREHAB and gentamicin before schwannoma surgery may improve long-term postural function. *J Neurol Neurosurg Psychiatry*. 2009;80(11):1254-1260. doi:10.1136/jnnp.2008.170878.
162. Magnusson M, Karlberg M, Tjernström F. "PREHAB": vestibular prehabilitation to ameliorate the effect of a sudden vestibular loss. *NeuroRehabilitation*. 2011;29(2):153-156. doi:10.3233/NRE-2011-0689.
163. Cohen HS, Kimball KT, Jenkins HA. Factors affecting recovery after acoustic neuroma resection. *Acta Otolaryngol*. 2002;122(8):841-850.
164. Micarelli A, Viziano A, Augimen I, Micarelli D, Alessandrini M. Three-dimensional head-mounted gaming task procedure maximizes effects of vestibular rehabilitation in unilateral vestibular hypofunction: a randomized controlled pilot trial. *Int J Rehabil Res*.2017;40(4):325-332. doi:10.1097/MRR.0000000000000244.
165. Bao T, Klatt BN, Carender WJ, et al. Effects of long-term vestibular rehabilitation therapy with vibrotactile sensory augmentation for people with unilateral vestibular disorders—a randomized preliminary study. *J Vestib Res*. 2019;29(6):323-334. doi:10.3233/VES-190683.
166. Bayat A, Saki N. Effects of vestibular rehabilitation interventions in the elderly with chronic unilateral vestibular hypofunction. *Iran J Otorhinolaryngol*. 2017;29(3):183-188.
167. Crane BT, Schubert MC. An adaptive vestibular rehabilitation technique. *Laryngoscope*. 2018;128(3):713-718. doi:10.1002/lary.26661.
168. Aratani MC, Ricci NA, Caovilla HH, Ganança FF. Benefits of vestibular rehabilitation on patient-reported outcomes in older adults with vestibular disorders: a randomized clinical trial. *Braz J Phys Ther*. 2020;24(6):550-559. doi:10.1016/j.bjpt.2019.12.003.
169. Viziano A, Micarelli A, Augimeri I, Micarelli D, Alessandrini M. Long-term effects of vestibular rehabilitation and head-mounted gaming task procedure in unilateral vestibular hypofunction: a 12-month follow-up of a randomized controlled trial. *Clin Rehabil*. 2019;33(1):24-33. doi:10.1177/0269215518788598.
170. Herdman SJ, Schubert MC, Das VE, Tusa RJ. Recovery of dynamic visual acuity in unilateral vestibular hypofunction. *Arch Otolaryngol Head Neck Surg*. 2003;129(8):819-824. doi:10.1001/archotol.129.8.819.
171. Loader B, Gruther W, Mueller CA, et al. Improved postural control after computerized optokinetic therapy based on stochastic visual stimulation in patients with vestibular dysfunction. *J Vestib Res.* 2007;17(2/3):131-136.
172. Shepard NT, Telian SA. Programmatic vestibular rehabilitation. *Otolaryngol Head Neck Surg.* 1995;112(1):173-182. doi:10.1016/S0194-59989570317-9.
173. Ertugrul S, Emre Soylemez E. Investigation of the factors affecting the success of vestibular rehabilitation therapy in patients with idiopathic unilateral vestibular hypofunction and idiopathic bilateral vestibular hypofunction. *ENT Updates*. 2019;9(2):150-158. doi:10.32448/entupdates.570136.
174. Strupp M, Kim JS, Murofushi T, et al. Bilateral vestibulopathy: diagnostic criteria consensus document of the classification committee of the Bárány Society. *J Vestib Res*. 2017;27(4):177-189. doi:10.3233/VES-170619 .
175. Gimmon Y, Migliaccio AA, Kim KJ, Schubert MC. VOR adaptation training and retention in a patient with profound bilateral vestibular hypofunction. *Laryngoscope*. 2019;129(11):2568-2573. doi:10.1002/lary.27838.
176. Allum JHJ, Rust HM, Honegger F. Functional testing of vestibulo-spinal contributions to balance control: insights from tracking improvement following acute bilateral peripheral vestibular loss. *Front Neurol*. 2019;10:550. doi:10.3389/fneur.2019.00550.
177. Brugnera C, Bittar RS, Greters ME, Basta D. Effects of vibrotactile vestibular substitution on vestibular rehabilitation—preliminary study. *Braz J Otorhinolaryngol*. 2015;81(6):616-621. doi:10.1016/j.bjorl.2015.08.013.
178. Patarapak S, Jarusripan P, Isipradit P. Chulalongkorn vestibular balance exercise for rehabilitation in persons with various types of vestibular disorders. *J Med Assoc Thai*. 2015;98(suppl 1):S77-S84.
179. Itani M, Koaik Y, Sabri A. The value of close monitoring in vestibular rehabilitation therapy. *J Laryngol Otol*. 2017;131(3):227-231. doi:10.1017/S0022215116009750.

180. Szturm T, Reimer KM, Hochman J. Home-based computer gaming in vestibular rehabilitation of gaze and balance impairment. *Games Health J*. 2015;4(3):211-220. doi:10.1089/g4h.2014.0093.
181. Krebs DE, Gill-Body KM, Parker SW, Ramirez JV, Wernick Robinson M. Vestibular rehabilitation: useful but not universally so. *Otolaryngol Head Neck Surg*. 2003;128(2):240-250. doi:10.1067/mhn.2003.72.
182. Rosiak O, Krajewski K, Woszczak M, Jozefowicz-Korczynska M. Evaluation of the effectiveness of a virtual reality-based exercise program for unilateral peripheral vestibular deficit. *J Vestib Res*. 2018;28(5/6):409-415. doi:10.3233/VES-180647.
183. Micarelli A, Viziano A, Micarelli B, Augimeri I, Alessandrini M. Vestibular rehabilitation in older adults with and without mild cognitive impairment: effects of virtual reality using a head-mounted display. *Arch Gerontol Geriatr*. 2019;83:246-256. doi:10.1016/j.archger.2019.05.008.
184. Coelho AR, Fontes RC, Moraes R, Barros CGC, de Abreu DCC. Effects of the use of anchor systems in the rehabilitation of dynamic balance and gait in individuals with chronic dizziness of peripheral vestibular origin: a single-blinded, randomized, controlled clinical trial. *Arch Phys Med Rehabil*. 2020;101(2):249-257. doi:10.1016/j.apmr.2019.07.012.
185. Koganemaru S, Goto F, Arai M, et al. Effects of vestibular rehabilitation combined with transcranial cerebellar direct current stimulation in patients with chronic dizziness: an exploratory study. *Brain Stimul*. 2017;10(3):576-578. doi:10.1016/j.brs.2017.02.005.
186. Pavlou M, Lingeswaran A, Davies RA, Gresty MA, Bronstein AM. Simulator based rehabilitation in refractory dizziness. *J Neurol*. 2004;251(8):983-95. doi:10.1007/s00415-004-0476-2.
187. Clendaniel RA. The effects of habituation and gaze stability exercises in the treatment of unilateral vestibular hypofunction: preliminary results. *J Neurol Phys Ther*. 2010;34(2):111-116. doi:10.1097/NPT.0b013e3181deca01.
188. Szturm T, Ireland DJ, Lessing-Turner M. Comparison of different exercise programs in the rehabilitation of patients with chronic peripheral vestibular dysfunction. *J Vestib Res.* 1994;4(6):461-479.
189. McGibbon CA, Krebs DE, Wolf SL, Wayne PM, Scarborough DM, Parker SW. Tai chi and vestibular rehabilitation effects on gaze and whole-body stability. *J Vestib Res*. 2004;14(6):467-478.
190. Pavlou M, Kanegaonkar RG, Swapp D, Bamiou DE, Slater M, Luxon LM. The effect of virtual reality on visual vertigo symptoms in patients with peripheral vestibular dysfunction: a pilot study. *J Vestib Res*. 2012;22(5/6):273-281. doi:10.3233/VES-120462.
191. Cakrt O, Chovanec M, Funda T, Kalitová P, Betka J, Zverina E, Kolár P, Jerábek J. Exercise with visual feedback improves postural stability after vestibular schwannoma surgery. *Eur Arch Otorhinolaryngol*. 2010;267(9):1355-1360. doi:10.1007/s00405-010-1227-x.
192. Herdman SJ, Hall CD, Delaune W. Variables associated with outcome in patients with unilateral vestibular hypofunction. *Neurorehabil Neural Repair*. 2012;26(2):151-162. doi:10.1177/1545968311407514.
193. Bergeron M, Lortie CL, Guitton MJ. Use of virtual reality tools for vestibular disorders rehabilitation: a comprehensive analysis. *Adv Med.* 2015;2015:916735. doi:10.1155/2015/916735.
194. Rossi-Izquierdo M, Santos-Pérez S, Soto-Varela A. What is the most effective vestibular rehabilitation technique in patients with unilateral peripheral vestibular disorders? *Eur Arch Otorhinolaryngol*. 2011;268(11):1569-1574. doi:10.1007/s00405-011-1532-z.
195. Winkler PA, Esses B. Platform tilt perturbation as an intervention for people with chronic vestibular dysfunction. *J Neurol Phys Ther*. 2011;35(3):105-115. doi:10.1097/NPT.0b013e31822a2af9.
196. Nardone A, Godi M, Artuso A, Schieppati M. Balance rehabilitation by moving platform and exercises in patients with neuropathy or vestibular deficit. *Arch Phys Med Rehabil*. 2010;91(12):1869-1877. doi:10.1016/j.apmr.2010.09.011.
197. Gillespie MB, Minor LB. Prognosis in bilateral vestibular hypofunction. *Laryngoscope.* 1999;109(1):35-41. doi:10.1097/00005537-199901000-00008.
198. Brown KE, Whitney SL, Wrisley DM, Furman JM. Physical therapy outcomes for persons with bilateral vestibular loss. *Laryngoscope.* 2001;111(10):1812-1817. doi:10.1097/00005537-200110000-00027.
199. Cohen HS, Kimball KT. Changes in a repetitive head movement task after vestibular rehabilitation. *Clin Rehabil*. 2004;18(2):125-131. doi:10.1191/0269215504cr707oa.
200. Millar JL, Gimmon Y, Roberts D, Schubert MC. Improvement after vestibular rehabilitation not explained by improved passive VOR gain. *Front Neurol*. 2020;11:79. doi:10.3389/fneur.00079.
201. Kao CL, Chen LK, Chern CM, Hsu LC, Chen CC, Hwang SJ. Rehabilitation outcome in home-based versus supervised exercise programs for chronically dizzy patients. *Arch Gerontol Geriatr.* 2010;51(3):264-267. doi:10.1016/j.archger.2009.11.014.
202. Pavlou M, Bronstein AM, Davies RA. Randomized trial of supervised versus unsupervised optokinetic exercise in persons with peripheral vestibular disorders. *Neurorehabil Neural Repair*. 2013;27(3):208-218. doi:10.1177/1545968312461715.
203. Hsu SY, Fang TY, Yeh SC, Su MC, Wang PC, Wang VY. Three-dimensional, virtual reality vestibular rehabilitation for chronic imbalance problem caused by Ménière's disease: a pilot study. *Disabil Rehabil*. 2017;39(16):1601-1606. doi:10.1080/09638288.2016.1203027.
204. Muller I, Kirby S, Yardley L. Understanding patient experiences of self-managing chronic dizziness: a qualitative study of booklet-based vestibular rehabilitation, with or without remote support. *BMJ Open*. 2015;5(5):e007680. doi:10.1136/bmjopen-2015-007680.
205. Yardley L, Barker F, Muller I, et al. Clinical and cost effectiveness of booklet based vestibular rehabilitation for chronic dizziness in primary care: Single blind, parallel group, pragmatic, randomised controlled trial. *BMJ*. 2012;344:e2237. doi:10.1136/bmj.e2237.
206. Hondebrink MS, Mert A, van der Lint R, de Ru JA, van der Wurff P. Motion-based equilibrium reprocessing therapy a novel treatment method for chronic peripheral vestibulopathies: a pilot study. *Medicine (Baltimore)*. 2017;96(24):e7128. doi:10.1097/MD.0000000000007128.
207. Varriano B, Sulway S, Wetmore C, et al. Vestibular exercises as a fall prevention strategy in patients with cognitive impairment. *Can J Neurol Sci*. 2020;47(1):126-130. doi:10.1017/cjn.2019.309.
208. van Vugt VA, van der Wouden JC, Essery R, et al. Internet based vestibular rehabilitation with and without physiotherapy support for adults aged 50 and older with a chronic vestibular syndrome in general practice: three armed randomised controlled trial. *BMJ*. 2019;367:l5922. doi:10.1136/bmj.l5922.
209. Yardley L, Donovan-Hall M, Smith HE, Walsh BM, Mullee M, Bronstein AM. Effectiveness of primary care-based vestibular rehabilitation for chronic dizziness. *Ann Intern Med.* 2004;141(8):598-605. doi:10.7326/0003-4819-141-8-200410190-00007.
210. Kammerlind ASC, Ledin TRE, Odkvist LM, Skargren EIB. Effects of home training and additional physical therapy on recovery after acute unilateral vestibular loss—a randomized study. *Clin Rehabil.* 2005;19(1):54-62. doi:10.1191/0269215505cr830oa.
211. MacDowell SG, Wellons R, Bissell A, Knecht L, Naquin C, Karpinski A. The impact of symptoms of anxiety and depression on subjective and objective outcome measures in individuals with vestibular disorders. *J Vestib Res*. 2018;27(5-6):295-303. doi:10.3233/VES-170627.
212. Roller RA, Hall CD. A speed-based approach to vestibular rehabilitation for peripheral vestibular hypofunction: a retrospective chart review. *J Vestib Res*. 2018;28(3/4):349-357. doi:10.3233/VES-180633.
213. Lorin P, Donnard M, Foubert F. Vestibular neuritis: evaluation and effect of vestibular rehabilitation. *Rev Laryngol Otol Rhinol (Bord)*. 2015;136(1):21-27.
214. Bos JE, MacKinnon SN, Patterson A. Motion sickness symptoms in a ship motion simulator: effects of inside, outside, and no view. *Aviat Space Environ Med.* 2005;76(12):1111-1118.

215. Staab JP, Eckhardt-Henn A, Horii A, et al. Diagnostic criteria for persistent postural-perceptual dizziness (PPPD): consensus document of the committee for the classification of vestibular disorders of the Bárány Society. *J Vestib Res*. 2017;27(4):191-208. doi:10.3233/VES-170622.
216. Holmberg JM. Pathophysiology, differential diagnosis, and management of persistent postural- perceptual dizziness: a review. *Perspectives*. 2020;5(1):181-191. doi:10.1044/2019_PERSP-19-00105.
217. Popkirov S, Stone J, Holle-Lee D. Treatment of persistent postural-perceptual dizziness (PPPD) and related disorders. *Curr Treat Options Neurol*. 2018;20(12):50. doi:10.1007/s11940-018-0535-0.
218. Krueger WW. Controlling motion sickness and spatial disorientation and enhancing vestibular rehabilitation with a user-worn see-through display. *Laryngoscope*. 2011;121(suppl 2, 0 2):S17-S35. doi:10.1002/lary.21373.
219. Keim RJ, Cook M, Martini D. Balance rehabilitation therapy. *Laryngoscope*. 1992;102(11):1302-1307. doi:10.1288/00005537-199211000-00019.
220. Hall CD, Schubert MC, Herdman SJ. Prediction of fall risk reduction as measured by Dynamic Gait Index in individuals with unilateral vestibular hypofunction. *Otol Neurotol*. 2004;25(5):746-751. doi:10.1097/00129492-200409000-00017.
221. Perez N, Santandreu E, Benitez J, Rey-Martinez J. Improvement of postural control in patients with peripheral vestibulopathy. *Eur Arch Otorhinolaryngol*. 2006;263(5):414-420. doi:10.1007/s00405-005-1027-x.
222. Chen PY, Hsieh WL, Wei SH, Kao CL. Interactive wiimote gaze stabilization exercise training system for patients with vestibular hypofunction. *J Neuroeng Rehabil.* 2012;9:77. doi:10.1186/1743-0003-9-77.
223. Telian S, Shepard N, Smith-Wheelock M, Kemink J. Habituation therapy for chronic vestibular dysfunction: preliminary results. *Otolaryngol Head Neck Surg.* 1990;103(1):89-95. doi:10.1177/019459989010300113.
224. Shepard NT, Smith-Wheelock M, Telian SA, Raj A. Vestibular and balance rehabilitation therapy. *Ann Otol Rhinol Laryngol.* 1993;102(3, pt 1):198-205. doi:10.1177/000348949310200306.
225. Topuz O, Topuz B, Ardiç FN, Sarhus M, Ögmen G, Ardiç F. Efficacy of vestibular rehabilitation on chronic unilateral vestibular dysfunction. *Clin Rehabil.* 2004;18(1):76-83. doi:10.1191/0269215504cr704oa.
226. Pavlou M, Acheson J, Nicolaou D, Fraser CL, Bronstein AM, Davies RA. Effect of developmental binocular vision abnormalities on visual vertigo symptoms and treatment outcome. *J Neurol Phys Ther*. 2015;39(4):215-224. doi:10.1097/NPT.0000000000000105.
227. Micarelli A, Viziano A, Della-Morte D, Augimeri I, Alessandrini M. Degree of functional impairment associated with vestibular hypofunction among older adults with cognitive decline. *Otol Neurotol*. 2018;39(5):e392-e400. doi:10.1097/MAO.0000000000001746.
228. Sjögren J, Magnusson M, Tjernström F, Karlberg M. Steroids for acute vestibular neuronitis—the earlier the treatment, the better the outcome? *Otol Neurotol*. 2019;40(3):372-374. doi:10.1097/MAO.0000000000002106.
229. Patatas OH, Ganança CF, Ganança FF. Quality of life of individuals submitted to vestibular rehabilitation. *Braz J Otorhinolaryngol*. 2009;75(3):387-394.
230. Whitney SL, Wrisley DM, Marchetti GF, Furman JM. The effect of age on vestibular rehabilitation outcomes. *Laryngoscope*. 2002;112(10):1785-1790. doi:10.1097/00005537-200210000-00015.
231. Bamiou DE, Davies RA, McKee M, Luxon LM. Symptoms, disability and handicap in unilateral peripheral vestibular disorders. Effects of early presentation and initiation of balance exercises. *Scand Audiol*. 2000;29(4):238-244. doi:10.1080/010503900750022862.
232. Aranda C, Meza A, Rodríguez R, Mantilla MT, Jáuregui-Renaud K. Diabetic polyneuropathy may increase the handicap related to vestibular disease. *Arch Med Res*. 2009;40(3):180-185. doi:10.1016/j.arcmed.2009.02.011.
233. Vitkovic J, Winoto A, Rance G, Dowell R, Paine M. Vestibular rehabilitation outcomes in patients with and without vestibular migraine. *J Neurol*. 2013;260(12):3039-3048. doi:10.1007/s00415-013-7116-7.
234. Wrisley DM, Whitney SL, Furman JM. Vestibular rehabilitation outcomes in patients with a history of migraine. *Otol Neurotol*. 2002;23(4):483-487. doi:10.1097/00129492-200207000-00016.
235. Fong E, Li C, Aslakson R, Agrawal Y. Systematic review of patient-reported outcome measures in clinical vestibular research. *Arch Phys Med Rehabil*. 2015;96(2):357-365. doi:10.1016/j.apmr.2014.09.017.
236. Sheikh JI, Yesavage JA. *Geriatric Depression Scale (GDS). Recent Evidence and Development of a Shorter Version in Clinical Gerontology*. Brink TL, ed. Binghamton, NY: Haworth Press; 1986.
237. Johansson M, Akerlund D, Larsen HC, Andersson G. Randomized controlled trial of vestibular rehabilitation combined with cognitive-behavioral therapy for dizziness in older people. *Otolaryngol Head Neck Surg*. 2001;125(3):151-156.
238. Badaracco C, Labini FS, Meli A, De Angelis E, Tufarelli D. Vestibular rehabilitation outcomes in chronic vertiginous patients through computerized dynamic visual acuity and Gaze stabilization test. *Otol Neurotol*. 2007;28(6):809-813.
239. Gottshall KR, Hoffer ME, Moore RJ, Balough BJ. The role of vestibular rehabilitation in the treatment of Meniere's disease. *Otolaryngol Head Neck Surg*. 2005;133(3):326-328.
240. Meli A, Zimatore G, Badaracco C, De Angelis E, Tufarelli D. Vestibular rehabilitation and 6-month follow-up using objective and subjective measures. *Acta Otolaryngol*. 2006;126(3):259-266.
241. Mantello EB, Moriguti JC, Rodrigues-Junior AL, Ferrioli E. Vestibular rehabilitation's effect over the quality of life of geriatric patients with labyrinth disease. *Braz J Otorhinolaryngol*. 2008;74(2):172-180.
242. Morozetti PG, Ganança CF, Chiari BM. Comparison of different protocols for vestibular rehabilitation in patients with peripheral vestibular disorders. *J Soc Bras Fonoaudiol*. 2011;23(1):44-50.
243. Murray K, Carroll S, Hill K. Relationship between change in balance and self-reported handicap after vestibular rehabilitation therapy. *Physiother Res Int*. 2001;6(4):251-263.
244. Tee LH, Chee NWC, Zhu M, Jin J. Functional outcomes after customized vestibular rehabilitation in subjects with chronic vestibular dysfunction. *Physiother Sing*. 2010;13(2):4-7.
245. Cowand JL, Wrisley DM, Walker M, Strasnick B, Jacobson JT. Efficacy of vestibular rehabilitation. *Otolaryngol Head Neck Surg*. 1998;118(1):49-54.
246. Bittar RSM, Pedalini MEB, Lorenzi MC, Formigoni LG. Treating vertigo with vestibular rehabilitation: results in 155 patients. *Rev Laryngol Otol Rhinol*. 2002;123(1):61-65.
247. Spielberger CD, Gorsuch RL, Lushene RD. *STAI: Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologists Press; 1970.
248. Cass SP, Borello-France D, Furman JM. Functional outcome of vestibular rehabilitation in patients with abnormal sensory-organization testing. *Am J Otol*. 1996;17(4):581-594.
249. Murray KJ, Hill K, Phillips B, Waterston J. Does otolith organ dysfunction influence outcomes after a customized program of vestibular rehabilitation? *J Neurol Phys Ther*. 2010;34(2):70-75. doi:10.1097/NPT.0b013e3181dde5dd.
250. Ebrahimi AA, Jamshidi AA, Movallali G, Rahgozar M, Haghgoo HA. The effect of vestibular rehabilitation therapy program on sensory organization of deaf children with bilateral vestibular dysfunction. *Acta Med Iran*. 2017;55(11):683-689.
251. Migliaccio AA, Schubert MC. Pilot study of a new rehabilitation tool: improved unilateral short-term adaptation of the human angular vestibulo-ocular reflex. *Otol Neurotol*. 2014;35(10):e310-e316. doi:10.1097/MAO.0000000000000539.
252. Rinaudo CN, Schubert MC, Cremer PD, Figtree WVC, Todd CJ, Migliaccio AA. Improved oculomotor physiology and behavior after unilateral incremental adaptation training in a person with chronic vestibular hypofunction: a case report. *Phys Ther*. 2019;99(10):1326-1333. doi:10.1093/ptj/pzz083.

253. Bechly KE, Carender WJ, Myles JD, Sienko KH. Determining the preferred modality for real-time biofeedback during balance training. *Gait Posture*. 2013;37(3):391-396. doi:10.1016/j.gaitpost.2012.08.007.
254. Yamanaka T, Sawai Y, Murai T, Nishimura T, Kitahara T. Long-term effects of electrotactile sensory substitution therapy on balance disorders. *Neuroreport*. 2016;27(10):744-748. doi:10.1097/WNR.0000000000000606.
255. Pereira CMM, Pinheiro do Vale JS, de Oliveira WP, et al. Aquatic physiotherapy: a vestibular rehabilitation option [published online ahead of print January 13, 2020]. *Braz J Otorhinolaryngol*. doi:10.1016/j.bjorl.2019.12.003.
256. Gabilan YP, Perracini MR, Munhoz MS, Gananç FF. Aquatic physiotherapy for vestibular rehabilitation in patients with unilateral vestibular hypofunction: exploratory prospective study. *J Vestib Res*. 2008;18(2/3):139-146.
257. Kutzner I, Richter A, Gordt K, et al. Does aquatic exercise reduce hip and knee joint loading? In vivo load measurements with instrumented implants. *PLoS One*. 2017;12(3):e0171972. doi:10.1371/journal.pone.0171972.
258. Rushton D, Cox N. A new optical treatment for oscillopsia. *J Neurol Neurosurg Psychiatry*. 1987;50(4):411-415. doi:10.1136/jnnp.50.4.411.
259. Pothier DD, Hughes C, Dillon W, Ranalli PJ, Rutka JA. The use of real-time image stabilization and augmented reality eyewear in the treatment of oscillopsia. *Otolaryngol Head Neck Surg*. 2012;146(6):966-971. doi:10.1177/0194599811434708.

