American Academy of Audiology Clinical Consensus Statement: Assessment of Vestibular Function in the Pediatric Population

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Table of Contents

Introduction

In recent years, considerable attention has been given to disorders of the pediatric vestibular system. Perhaps, children with vestibular disorders have gone unnoticed in the past because they do not have the language to accurately describe symptoms of dizziness or imbalance. Children undergo an immense period of development for motor skills from birth through the teenage years, and therefore, require unique assessment and treatment in this area. Today, advances in the niche area of pediatric vestibular testing have allowed clinicians to obtain more data on young children than ever before. Empowered with new technology, techniques, and more readily accessible treatment options, audiologists can offer families more information about a child's emerging balance function and concerns for dizziness.

This document is designed to serve as a guide to approaching vestibular testing in children and allows for expected variations in practice and available equipment. Simply, this document will serve as a practical guide, offering protocols, tips, and tricks for testing children of all ages, specifically children whose developmental age is young. This document focuses on the pediatric approach to test administration and interpretation. See **Table 1** for an overview of vestibular function tests available by age. Each of the following chapters provides additional information on individual tests of vestibular function. Basic, practical knowledge of vestibular testing is required to incorporate the guidance below. As this niche develops, more normative data and test techniques will be included, and this guidance will continue to evolve.

Background

The vestibular system is the first fully myelinated system that is completed in utero. While intact at birth, the vestibular system continues to mature as the child masters control of their movement, ocular motor system and postural stability. Vestibular testing and evaluation are warranted in 2 populations 1) those who present with complaints of dizziness and 2) those with disequilibrium and/or delay in gross motor milestones. Dizziness in children represents a small patient population at around 5.3%[1] of all children. Vestibular disorders in children can be either congenital or acquired and originate in the peripheral and/ or central vestibular system. Specific vestibular tests are helpful in parsing out these distinctive causes.

There is a higher prevalence of peripheral vestibular disorders in children with hearing loss. In many cases, but not all cases, the primary complaint is imbalance or deviation from age-appropriate motor development. It is estimated that nearly half of all children with hearing loss have some degree of vestibular impairment. [2] Children who have greater degrees of hearing loss (>66 dB [3]) or specific etiologies of hearing loss are at an increased risk. Notably, etiologies including structural anomalies (i.e., enlarged vestibular aqueducts, cochlear malformations), congenital cytomegalovirus, certain syndromic hearing loss (i.e., Usher Type I), meningitis, temporal bone fracture and/or exposure to ototoxic medications experience vestibular loss more frequently.[4,5]

Children with normal hearing more often experience symptoms of dizziness, lightheadedness, and vertigo. The most common etiology in this group is pediatric migraine variants and can affect

around 3% of all children under 18 years of age.[6] According to the most recent literature, migraine and migraine variants represent the most common diagnosis for young children with vertigo. Vestibular migraine represents 23.8% of children with vertigo and Recurrent Vertigo of Childhood (previously Benign Paroxysmal Vertigo of Childhood) represents 13.7%.[1] Vestibular migraine may or may not be accompanied by actual head pain. It is hypothesized that perimeningeal vasodilatation and neurogenic inflammation causes pain and other neurologic symptoms.[7]

Children can experience similar etiologies to adults, such as vestibular neuritis, labyrinthitis, postural orthostatic tachycardia syndrome, and persistent postural perceptual dizziness, among others. Etiologies that occur in children, but less frequently compared to adults are benign paroxysmal positional vertigo, Meniere's disease, and superior canal dehiscence syndrome. In addition, teenagers in particular may have autonomic dysfunction, depression, anxiety, psychosomatic, amplified pain syndrome, and other mental health diagnoses as an underlying condition with dizziness.

Significance of Vestibular Testing

Vestibular testing serves to differentiate peripheral from central vestibular disorders, determine the severity of a vestibular loss and parse out any functional effects. Patterns of abnormality can vary by etiology, as well as, by child with abnormalities of the semicircular canals, otolith organs, and functional balance. Often, a normal vestibular test is still helpful in diagnosis by ruling out other issues. In children with suspected vestibular migraine, laboratory findings are varied with the majority of children showing normal tests, followed by abnormal eye movements, abnormal ocular motor findings and abnormal vestibular evoked myogenic potentials. [8,9]

Early intervention and appropriate differential diagnostics are important. The most common manifestation of congenital bilateral vestibular loss is a gross motor delay and often, accompanying muscle hypotonia[10]. For children that are experiencing delays related to congenital vestibular loss, intervention at an early age with qualified vestibular rehabilitation specialists is needed to aid developing milestones. Emerging studies are showing improvements in balance deficits with targeted vestibular rehabilitation in children[11]. In addition, it is helpful for parents to have a clear understanding of their child's diagnosis. In many cases, the role of audiologic testing is part of the "rule out" process. When medication is needed, a good working relationship with physicians including neurologists, otolaryngologists, pediatricians, and psychiatrists helps bridge the diagnostic gap for families.

Table 1: Overview of Vestibular Function Tests Available by Child Age.

	0-2 years	3-7 years	8+ years
Bedsides	Identification of nystagmus Head Impulse Test	Identification of nystagmus Dynamic Visual Acuity Screen Romberg Tandem Gait & Walk mCTSIB Single Leg Stance	Identification of nystagmus Dynamic Visual Acuity Screen-Romberg Tandem Gait & Walk mCTSIB Single Leg Stance
Questionnaires	Ages and Stages Gross Motor (birth-5 yrs.)	Ages and Stages Gross Motor (birth-5 yrs.) DHI-PC (5-12 yrs.) PVIDQ (6-17 yrs.) PVSQ (6-17 yrs.)	DHI-PC (5-12 yrs.) PVIDQ (6-17 yrs.) PVSQ (6-17 yrs.)
Canal	Video Head Impulse Test (remote camera system)	Video Head Impulse Test	Video Head Impulse Test
Canal	Rotary Chair (electrodes, in-room camera, hand held goggles after 2 yrs.)	Rotary Chair	Rotary Chair
Otolith	Cervical VEMP	Cervical VEMP Ocular VEMP	Cervical VEMP Ocular VEMP
VNG	High Frequency Head Shake Skull Vibration Induced Nystagmus Test	High Frequency Head Shake Positional Testing Skull Vibration Induced Nystagmus Test Ocular Motor Test (after 5 yrs.)	All Components of VNG

I. Bedside Examination

1. **Test Names:** Identification of nystagmus**,** Head Impulse Test (HIT), Dynamic Visual Acuity (DVA) test, Tandem and Romberg test, Modified Clinical Test of Sensory Integration of Balance (mCTSIB), and Single Leg Stance (SLS) Test.

2. **Purposes:** To evaluate basic vestibular and balance function in children, aiding clinical diagnosis and management in real time. The results of these bedside examinations can also guide further laboratory testing. Initially used for evaluating adult patients with dizziness and imbalance, these methods are valid and valuable as clinical studies have shown[12], [13],[14], [15], [16]. With minimal modification, these bedside examinations can be implemented in pediatric practice.

3. **Population Intended:** Pediatric patients with balance and/or vestibular complaints. These bedside examination methods are also appropriate for young children who are unable to describe their problems and whose parents or caregivers have balance and/or vestibular concerns.

4. **Expected Outcomes:** Many of these bedside tests have no quantitative outcome, therefore, the outcome is most binary, e.g., normal vs abnormal or present vs absent.

5. **Normative Data:** See individual section for tests with quantitative measures.

6. **Practice Guidance:** These tests are relatively easy to perform and require no or minimal devices. Clinicians can perform the testing at the bedside, in the emergency room, or for ambulatory services. For detailed description of each test, see individual section.

7. **Test Interpretation and Reporting:** Clinician must have a good understanding of vestibular anatomy, physiology, and pathology to conduct these tests and interpret them accurately. Abnormal findings usually suggest possible vestibular pathologies; however, vestibular dysfunction can't be ruled out based on normal/negative finding of any individual test.

Identification of Nystagmus: Nystagmus is involuntary rhythmic eye movement with fast and slow phases. The direction of nystagmus is named for the direction of the fast phase. While horizontal (left or right-beating) and vertical (up or down-beating) nystagmus can be easily recognized, torsional nystagmus may be difficult to observe without goggles[17]. It should be pointed out that abnormal eye movements are common in young children, and may consist of ocular oscillation, opsoclonus, and flutter among others, which are not vestibular in origin[18],[19],[20].

A. **Spontaneous Nystagmus:** Since spontaneous nystagmus of vestibular origin can be suppressed by fixation, Frenzel goggles (**Figure 1**) are recommended. If Frenzel goggles are not available, then the light in the exam room should be dimmed for better observation. Spontaneous nystagmus often exists in cases of peripheral vestibular lesion or uncompensated vestibular loss and can be suppressed by visual fixation. In contrast,

central lesions are indicated if not suppressed by fixation. Most of the time, spontaneous nystagmus is horizontal, and the direction of the nystagmus is opposite to the side of lesion, i.e., right-beating nystagmus indicating left vestibular lesion/loss. Spontaneous nystagmus in the vertical plane, especially down-beating, is uncommon and central vestibular pathology may be suspected if present. Any nystagmus with direction and/or velocity changing also raises the concern of central involvement.

Figure 1. Examples of Frenzel goggles/lenses

B. **Evoked Nystagmus:** Gaze-evoked nystagmus is commonly used for examining a patient with suspected vestibular impairment. Both horizontal gaze (looking to the left or right) and vertical gaze (looking up or down) can be performed. An attractive toy with flashing light (**Figure 2**) can be very helpful to get the attention of a young child. A parent can hold the child's head during the exam. The toy should not be placed too far away from the center in any direction (i.e., less than 30 degrees) to avoid eliciting end-gaze nystagmus. Gazed-evoked nystagmus is often most evident or only seen with gaze in the direction of the fast phase (Alexander's law). With proper tools, sound or pressure-evoked nystagmus can also be performed to rule out certain type of vestibular conditions.

Figure 2. Examples of toys

C. **Non-vestibular Nystagmus:** It should be noted that not all observed nystagmus is vestibular in origin. For example, congenital nystagmus may be found in children without vestibular impairment. Although the pathophysiology of congenital nystagmus is not entirely clear, its characteristics (e.g., presence in infancy, being purely horizontal, diminishing with convergence, causing vison loss, etc.) make congenital nystagmus distinguishable from vestibular nystagmus.

Assessment of Vestibulo-Ocular Reflex (VOR): The VOR is present at birth. Although its function may not be fully matured, even infants have nystagmus in response to angular acceleration. The main role of the VOR is to maintain clear vision when the head is in motion. By observing the reflexive eye movement responding to head motion, apparent vestibular loss, i.e., loss in semicircular canal function, can be identified.

A. **Head Impulse/Thrust:** Introduced by Halmagyi and Curthoys in 1998, the head impulse test (HIT) has been proved to be a reliable tool to identify unilateral or bilateral loss of semicircular canal function[21]. Performing HIT sounds easy to describe but mastering the technique requires proper training and practice, particularly in children. Starting with instruction to the patient looking at the clinician's eyes or nose, the clinician then performs a brief, but quick head thrust which turns the head no more than 15 degrees. Impulses can be completed either away from or toward the midline. For infants or toddlers, toys or stickers can be used as a fixation point. Testing should be completed with an otherwise blank wall, free of visual distractions. If a child has intact VOR, his/her gaze will hold steady during the head impulse. A corrective/catch-up saccade at the end of head movement (see **Figure 3**) implies an impaired VOR/semicircular canal function[22]. Several impulses should be completed. Children with impaired VOR should demonstrate a repeatable catch-up saccade. Although HIT can be done for all six semicircular canals, it's mostly performed for the horizontal semicircular canals without goggles. In contrast to caloric or rotary testing, the HIT evaluates high-frequency VOR function.

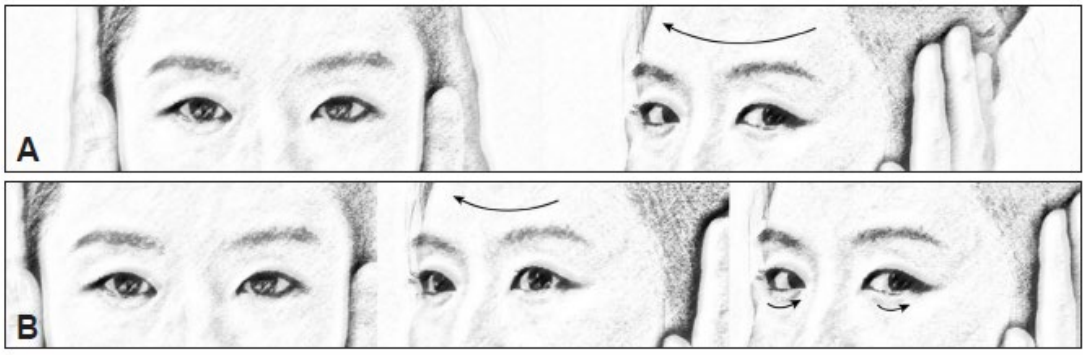

Figure 3. Reprinted from Huh and Kim (2013)[14]. A: normal HIT. B: Corrective saccades noted in response to rightward head impulse

B. **Post-rotary Nystagmus:** Rotating a child at a constant velocity on a swivel chair for about 30 seconds with eyes closed will elicit nystagmus when the VOR is intact. This post-rotary

nystagmus can be seen when the chair is stopped, and the eyes are open. Lack of post-rotary nystagmus to clockwise and counterclockwise rotations indicates bilateral vestibular loss[23]. Nystagmus that decays before 15 seconds in room light and 29 seconds with Frenzel lenses was recommended to predict vestibular loss[24].

C. **Dynamic Visual Acuity (DVA):** Impaired VOR can also affect visual acuity during head movement. To perform DVA testing, a certain type of eye chart (Snellen, Sloan, or E) is needed. For testing at bedside or in a small exam room, a pocket Sloan letter chart can be used (**Figure 4**). First, the patient is told to read optotypes (letters or symbols) in the eye chart with head still in a specific distance, e.g., 16 inches, establishing static visual acuity. Then, the examiner moves the patient's head horizontally at a frequency of 2 Hz while viewing the eye chart again to obtain DVA. A drop of two lines or more from static visual acuity suggests an impaired VOR or bilateral vestibular loss. For example, DVA testing is often used at bedside to screen for ototoxicity.

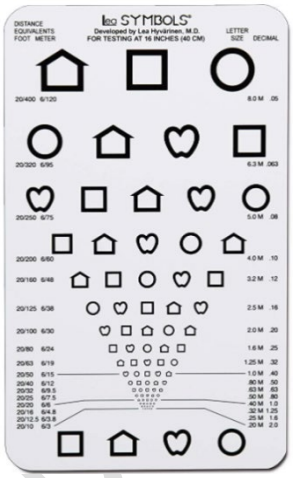

Figure 4. Example of pocket Sloan letter chart and LEA card for kids

Assessment of Vestibulo-Spinal Reflex (VSR): The VSR helps to stabilize the body and maintain postural control. In a normally developing child, the maturation of postural control grows in a cephalocaudal fashion, i.e., first controlling the head, then the trunk, and finally postural stability with standing. Specifically, the earliest development starts around 6 weeks of age with head holding up, 16 weeks of age with head control/ turning. Sitting without help normally occurs by 9 months of age, standing around 12 months and walking independently by 15 months[25],[26]. Any vestibular loss during this process will have a negative impact on postural stability.

A. **Romberg Test:** This test can assess a child's ability to control balance while standing still. In standard Romberg, the patient is instructed to stand with feet together and hands on the sides/hips; eyes open and closed, for 30 seconds. Positive findings include excessive sway or fall, indicating acute unilateral vestibulopathy or severe bilateral vestibular impairment[14]. A failed Romberg test may be a sign of cerebellar lesion also. There are limitations to this test, such as being insensitive for detecting chronic unilateral vestibular loss.

B. **Tandem Gait/Stance and Walk:** This test is sensitive to an acute vestibular loss. The patient is instructed to stand one foot in front of the other with eyes open and closed, then walk heel to toe along a straight line on the floor with stop and turn. Children can put their hands on their hips if helpful. Positive findings include excessive sway during walking or inability to maintain balance within a certain time frame (e.g., 10–30 seconds). For age specific norms in tandem stance, **Table 2** can serve as a reference. It should be noted that children with ataxia/gait problems or cerebellar lesions can also have difficulties in this test[27],[28] . Young children can also be provided practice trials.

Table 2. Age Specific Norms for Tandem Stance

Age	Duration in Seconds (eyes open/closed)
4- 5 years	>7/4
6-7 years	>13/6
8-9 years	>51/12
10-11 years	>68/17
≥ 12 years	>120/18

Modified with permission from Condon & Cremin[29]

Screening Tests for Balance Function: Assessment of balance function is important for accurate diagnosis of vestibular impairment, identifying fall risk, and treatment planning. There are a variety of tests that can serve as screeners, and many have been used primarily by Physical Therapists[30]. Two popular and most-commonly used tests are listed below, which are easy for audiologists to adopt in clinics.

A. **Modified Clinical Test of Sensory Integration of Balance (mCTSIB):** To complete this test, the patient first stands still on a hard surface with eyes open and closed (Romberg). Then the patient is asked to stand on a soft surface/foam with eyes open and closed[31],[32],[33], [34] (see **Figure 5**). If a patient can't finish the task on the first try, an additional trial may be given. Normally, one can stand for 30 seconds in each condition without difficulty. This test is reliable for children ages 6 and up.

Figure 5. Clinical Test of Sensory Interaction for Balance.

B. **Single Leg Stance (SLS) Test:** During this test, the patient is instructed to stand on one leg (left or right, whichever is dominant) with arms on the sides/hips (see **Figure 6**). Record the time that a patient can stand still with eyes open and closed. Excessive sways or falls are abnormal finding. In fact, failing to stand for 10 seconds would raise a flag for vestibular impairment, and a cut of 4 or 5 seconds has been found to be sensitive for vestibular loss[28], [29], [36], [37], [35]. For age specific norms, **Table 3** can serve as a reference.[38]

Table 3. Age Specific Norms for Single Leg Stance (SLS)

Age	Duration in Seconds (eyes open/closed)
30-36 months	1-2
4 years	5
5 years	10/<5
7 years	15/5
9 years	30/15
11 years	30+/30

Modified with permission from Cushing et al. [35]

Figure 6. Depiction of Single Leg Stance. Modified from Kakebeeke et al. (2018).[33]

Cervicogenic Screening: Cervicogenic dizziness can be screened at the bedside by placing the child on a swivel chair; keeping the head still, the child is rotated side-to-side and assessed for the presence of dizziness. Additionally, deep palpation of the neck that triggers dizziness can also be a clinical indicator for cervicogenic dizziness.

Summary: The evaluation of children with dizziness, vertigo and/or balance problems is a challenging task. Contemporary vestibular laboratories normally implement sophisticated testing equipment; however, this computerized equipment is not readily available in most clinical settings. Therefore, audiologists who may encounter these children need to be familiar with the tests described in this document.

II. Vestibular Evoked Myogenic Potential (VEMP)

1. **Test Name:** Vestibular evoked myogenic potential (VEMP). There are two kinds of VEMP responses used clinically: Cervical VEMP (cVEMP) and ocular VEMP (oVEMP).

2. **Purposes:** cVEMP are ipsilateral, inhibitory responses measured from the contracted sternocleidomastoid muscle and represent function of the descending reflex pathway extending from the saccule and inferior portion of the vestibular nerve to the sternocleidomastoid muscle[39,40] while oVEMP are excitatory responses measured from the inferior oblique muscle and represent function of the ascending, crossed reflex pathway extending from the utricle and superior portion of the vestibular nerve to the contralateral inferior oblique muscle[41,42]. VEMP responses have gained particular interest in children as they do not elicit dizziness, can be completed in 15 – 30 minutes, and collectively provide information about otolith and vestibular nerve function.

3. **Populations Intended:** cVEMP can be completed across the lifespan from newborn through adulthood[43], with cVEMP responses more likely to occur in full-term versus pre-term infants[44]. oVEMP responses undergo maturation in early childhood and can be measured in 100% of children by age 4[45]; therefore, oVEMP responses are routinely completed in children starting at age 4 through adulthood. oVEMPs can be attempted in children younger than 4; however, it may be difficult to differentiate whether absent responses are related to maturation or pathology.

4. **Expected Outcome:** cVEMP outcome parameters are the p13/n23 latency, peak-to-peak amplitude, corrected amplitude (raw peak-to-peak amplitude/raw EMG), and threshold. An example cVEMP waveform is shown in **Figure 7A**; cVEMPs are measured in the ipsilateral channel. oVEMP outcome parameters are the n10/p16 latency, peak to peak amplitude, and threshold. An example oVEMP waveform is shown in **Figure 7B**; oVEMPs are measured in the contralateral channel.

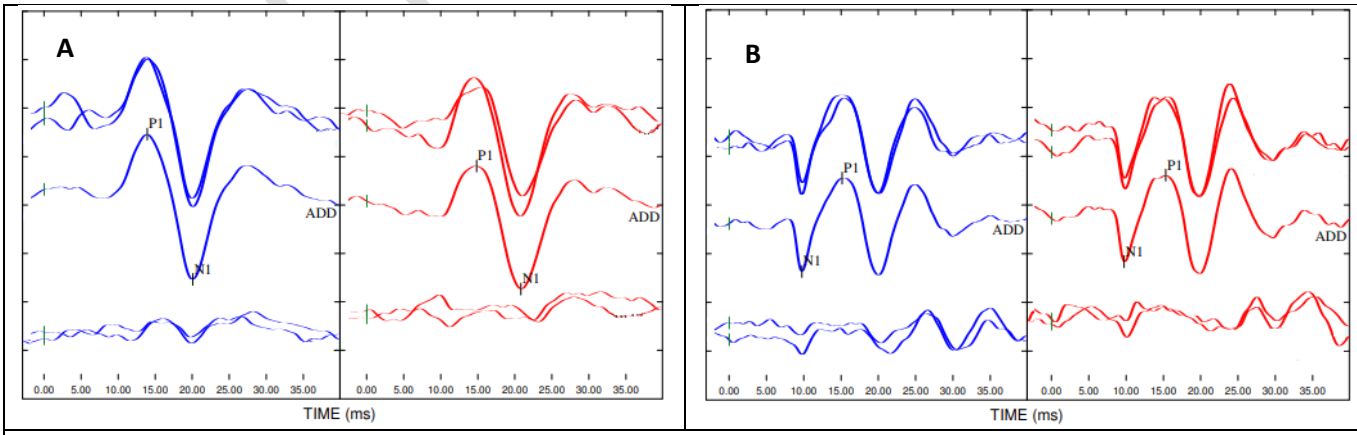

Figure 7A: Sample cVEMP waveforms: left cVEMP in blue and right cVEMP in red; cVEMP are ipsilateral responses, thus, measured in the ipsilateral channel (top waveform). Contralateral responses are shown in bottom waveform. **7B**: Sample oVEMP waveforms: left oVEMP in blue and right oVEMP in red; oVEMP are contralateral responses, thus, measured in the contralateral channel (top waveform). Ipsilateral responses are shown in the bottom waveform.

5. **Normative Data:** One of the biggest downfalls with VEMP testing in both children and adults is the lack of standardization[46]. While several normative datasets have been published, there is no uniformity in stimuli, electrode placement and overall test settings. If using any of these datasets for reference values, note stimuli, electrode placement and test setting used. Sample normative data in children are outlined in **Table 4** and demonstrate the wide variability in reported age ranges and stimuli[43,45,47–55]. In summary, cVEMP latencies are shorter in infants and children compared to adults[43,49,53] which has been attributed to neck length[56,57]. There is no difference in oVEMP parameters between children and adults[54,55]. Most studies have used either 500 Hz or click stimuli. 500 Hz tone bursts yield later latencies and larger amplitudes compared to click stimuli[53]. Both c- and oVEMP responses have been recorded in nearly 100% of normal control ears, demonstrating their feasibility.

Table 4. VEMP Normative Data

Author	Stimuli	N (age)	Cervical VEMP					
			RR	P13 (ms)	N23 (ms)	Amp (µv)	AR (%)	Threshold
Brix (2019)	500 Hz, 100 dB nHL	N = 30 (13 – 16 years)	85%	15.52 (1.74)	25.66 (2.29)	1.65 (0.65)	15.25 (11)	---
Erbek (2007)	500 Hz, 100 dB nHL	N = 24 (4 weeks)	100%	13.7 (1.1)	20.5 (1.6)	22.6 (18.4)	31.3 (23.1)	---
Kelsch (2006)	Click, 90 dB nHL	N = 30 (3 to 11 years)	100%	11.3 (1.3)	17.6 (1.4)	122 (68)	17.7 (12.8)	---
Lee (2008)	Clicks, 95 dB nHL	N = 97 (12 – 77 years)	100%	13.79 (2.35)	19.46 (2.55)	16.96 (7.26)	.1 (10.8)	---
Maes (2014)	500 Hz, 95 dB nHL (130 dB SPL)	N = 48 (4 – 12 years)	100%	13.19 (0.82)	20.78 (1.47)	208.38 (61.53)	1.76 (7.96)	72.17 (6.18)
Rodriguez (2018)	500 Hz, 120 dB SPL	N = 15 (4 – 12 years)	100%	13.23 (0.87)	20.94 (1.77)	268.85 (210.12)	---	---
Sheykholeslami (2005)	500 Hz, 95 dB nHL	N = 24 (1 – 12 months)	100%	---	---	---	---	---
Valente (2007)	Click, 95 dB nHL, 500 Hz, 120 dB SPL	N = 60 (3 – 6, 9 – 11 years)	100%	---	---	---	---	---
Author	**Stimuli**	**N (age)**	**Ocular VEMP**					
			RR	**N10 (ms)**	**P16 (ms)**	**Amp (µv)**	**AR (%)**	**Threshold**
Brix (2019)	70 dB nHL (B-81)	N = 31 (13 – 16 years)	100%	10.61 (0.78)	16.58 1.17)	23.26 (11.51)	16.1 (13.6)	---

Chou (2012)	500 Hz, 128 dB FL (V201 Shaker)	N = 15 (3 – 14 years)	100%	8.0 (0.7)	12.2 (1.5)	16.1 (9.0)	12 (14)	---
Kuhn (2018)	500 Hz, 105 dB nHL	N = 22 (3.5 – 8.9 years)	100%	10.9 (1.1)	15.0 (1.3)	15.3 (13.4)	18.9 (14)	92.4 (7.2)
Rodriguez (2018)	500 Hz, 120 dB SPL	N = 15 (4 – 12 years)	100%	10.2 (.72)	14.52 (1.82)	6.62 (2.51)	---	---
Wang (2013)	500 Hz, 95 dB nHL	N = 15 (4 – 13 years)	100%	11.1 (0.9)	16.1 (1.0)	7.3 (3.0)	---	---
RR = Response Rate; Amp = Amplitude; AR = asymmetry ratio								

6. **Practice Guidance (method):** For cVEMP, the most common electrode montage is to place the active (noninverting) electrode on the sternocleidomastoid (SCM) belly (located midway between the mastoid and sternum, roughly at the level of the chin), the reference (inverting) electrode on the manubrium of the sternum and a ground electrode on the forehead, **Figure 8A**. Depending on the manufacturer, EMG monitoring electrodes may be placed just below each active electrode. Of note, some centers use the clavicle as a reference. To contract the SCM, children $\geq$ 3 years lay in the supine position, elevated 30 degrees (often propped on their forearms), and are instructed to lift their heads and turn away from the ear receiving the air-conducted stimulus, **Figure 9A**. Toddlers can sit on a parent's lap and contract the SCM by turning the head, which can be reinforced with toys or a short video, **Figure 9B**. Infants can either lay supine and turn the head or be held in a declined position, facing the parent/caregiver, during acoustic stimulation. cVEMP amplitudes increase as SCM contraction increases up to 400 µV where cVEMP amplitudes either asymptote or decline[58]. Thus, EMG monitoring is recommended to ensure that a minimum amount of EMG is obtained (> 50 µV) and that EMG does not exceed 400 µV. Children often have a difficult time sustaining SCM contraction; therefore, frequent breaks may be needed. If a child cannot meet minimum EMG requirements, cVEMP can be attempted with EMG monitoring turned off. **Figure 9B** demonstrates that even with our best efforts, VEMP testing is not favorable for some children; therefore, care is taken to complete testing as fast and efficiently as possible to minimize the burden on children. For this reason, a second, or team tester, is often used for pediatric vestibular testing.

   For oVEMP, the most common electrode montage is to place the active (noninverting) electrode mediolaterally below the eye, over the contralateral inferior oblique muscle with a reference (inverting) electrode on the inner canthus and a ground electrode on the sternoclavicular notch, **Figure 8B**[59,60]. Previously, active electrodes were centered under the pupil with reference electrodes placed directly below the active electrode or on the chin; however, this is not current practice. Children can lay in the supine position or be seated upright and are instructed to gaze upward at a visual target. oVEMP amplitudes increase with increasing upward gaze[61]; therefore, the gaze angle during testing is standardized by placing a visual target at 30 degrees above eye level. To help maintain a constant upward gaze, fun stickers or short video recordings can be

placed at 30 degrees upward gaze which are helpful with young children. For children who cannot sustain upward gaze, oVEMP can be completed with the eyes closed[62]; however, it should be noted that response rates are lower and oVEMP amplitudes are smaller and less reliable[62,63].

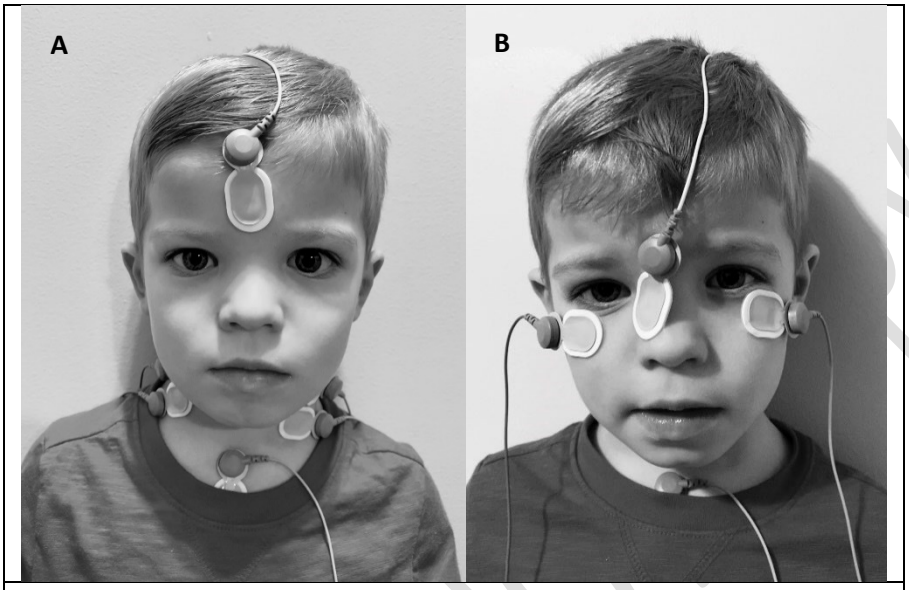

Figure 8A) cVEMP electrode montage with the active (noninverting) electrode on the SCM belly, EMG electrodes below the active electrodes, the reference (inverting) electrode on the manubrium of the sternum and a ground electrode on the forehead; **B)** oVEMP electrode montage with the active (noninverting) electrode mediolaterally below the eye, over the contralateral inferior oblique muscle with a reference (inverting) electrode on the inner canthus and a ground electrode on the sternoclavicular notch

Figure 9A) in children > 3 years, SCM contraction can be achieved by laying propped up on forearms with the head turned away from the

stimulated ear; **B)** in toddlers, SCM contraction can be achieved by sitting on a parent lap with the head turned toward a reinforcing toy (toy not shown).

Stimuli and Recording Parameters: Air-conducted, 500 Hz tone bursts presented at a rate of 5.1 Hz are commonly used to elicit both c- and oVEMP responses; however, click and tone burst stimuli ranging from 500 to 1000 Hz can be used to elicit responses. VEMP responses are deemed morphologically acceptable if they meet latency criteria (p13/n23 for cVEMP and n10/p16 for oVEMP) and are larger in amplitude than surrounding noise. Two trials are completed to ensure replicability. Responses are considered absent if not replicated over at least two trials. Artifact rejection is turned off. EMG signals are amplified 5000x and band-pass filtered from 5 to 500 Hz. Because VEMP protocols are not standardized, there is variability among labs in terms of stimuli and recording parameters. Example stimulus settings are: 125 dB SPL; Blackman gated; 2 ms rise/fall time, 0 ms plateau, condensation polarity. For an overview of VEMP testing, see Rosengren (2019)[46].

To minimize the amount of acoustic energy reaching the cochlea, care should be taken to minimize the overall the number of sweeps, stimulus duration and stimulus intensity, particularly with children whose ear canals are smaller, which results in higher peak equivalent sound pressure levels (peSPL) in the ear[52,64]. In children, the number of sweeps can be limited to 75 per trial, stimulus duration to 2 ms, and stimulus intensity to 120 dB SPL. Limiting the stimulus duration to 2 ms also reduces potential contributions from the acoustic reflex[65] and reduces artifact from obscuring portions of the response[46].

Testing Considerations:

- **Tympanometry**: Air-conducted VEMP responses can be abolished with 9 dB of conductive hearing loss[66]. Thus, completing tympanometry prior to VEMP testing is recommended to rule out the presence of middle ear disorder (i.e., perforation, effusion, negative pressure, etc). If conductive hearing loss is present, or tympanometry is abnormal, bone-conduction stimulation can be used. If using air-conduction stimuli, tympanometry can be used to measure the ear canal volume, which in turn can be used to determine the air-conduction stimulus level. Children with ear canal volumes < 0.8 ml have significantly higher peSPL compared to adults[52,64]. Thus, if ECVs are > 0.8 ml, 125 dB SPL (97 dB nHL) stimuli can be used; however, if ECVs are ≤ 0.8 ml, 120 dB pSPL (92 dBnHL) should be used to insure safe levels[52,67].

- **Bone Conduction:** VEMPs can be elicited in response to bone conduction stimulation. While evoked potential units display stimulus levels in dB nHL, bone conduction stimuli are typically reported in dB force level (FL) which is measured using an artificial mastoid. The following are types of bone conduction stimulation and their approximate dB FL, which can vary by equipment: B-71 (132 dB FL), B-81 (138 dB FL), tendon reflex hammer (145 dB FL), and mini-shaker device (149 dB FL), among others[68,69]. Bone conduction stimulation is typically delivered at the midline when using a tendon reflex hammer or mini-shaker. When doing cVEMP testing, bilateral SCM contraction can be achieved by having patients

lift their head straight up, nose toward the ceiling. While most commercial evoked potential units are equipped with a B-71 or B-81 device, VEMP testing is less reliable[68] and is not felt to be an adequate stimulus for use in adults[70]; however, the B-71 is reliable in children[68]. It is the author's experience that when using the B-71, optimal responses are achieved by placing the bone oscillator on the mastoid of the stimulated ear. Bone conduction is the stimulation method of choice in children where otitis media is prevalent.

- **Reliability**: C- and oVEMP responses are reliable in children[63,68]. Bone conduction VEMPs can be reliably completed using a B-71 bone oscillator (Radioear Corporation, New Eagle, PA, USA), 4810 Mini-shaker (Bruel & Kjaer, Denmark), or Piezotronics impulse hammer (Model 086C01, sensitivity of 11.2 millivolts/Newton; PCB Corporation, Depew, NY, USA)[68,71].

- **cVEMP Amplitude Normalization**: Amplitude of the cVEMP response is contingent on degree of sternocleidomastoid muscle tension; larger contractions of the sternocleidomastoid muscle result in larger cVEMP amplitudes.[72, 73] While this relationship is neither completely linear nor proportionate, amplitude normalization can be helpful for controlling for differences in muscle contraction[72, 73]. One common way of doing this is to measure EMG in the pre-stimulus window and then divide the raw amplitude by the EMG level, which yields a corrected amplitude. Amplitude normalization can be helpful in young children who often have a difficult time with sustained head holding.

Interpretation:

VEMP parameters are latency, amplitude, and threshold. The parameters used to interpret VEMP vary based on the population. However, most etiologies use presence/absence of VEMP responses as the primary outcome parameter. VEMP interpretation by etiology is outlined in **Table 5**. This is not an all-inclusive list and is limited to populations comprised primarily of children. Short summary descriptions of each etiology and the VEMP parameter used for interpretation are listed below.

- *Cochlear Implantation*: Several studies have examined VEMP changes following cochlear implantation. A large percentage (> 50%) of individuals have absent VEMP responses pre-implantation[74–78] with additional absent responses post-implantation[74–79]. In total, as many as 50 to 100% of children have VEMP abnormalities post-implantation [74–78,80,81]. While the majority of studies have focused on cVEMP, oVEMPs follow similar trends[78,79]. It should be noted that cochlear implantation can result in air-bone gaps[82,83]. While air-bone gaps do not affect children's use of their cochlear implant (CI), the air-bone gaps can affect VEMP responses[84]. Higher VEMP response rates have been reported in children using bone conduction versus air-conduction, suggesting the degree of cVEMP abnormalities may be inflated if air-conduction stimuli are used[84]. In a cohort of 50 patients (100 ears) post implantation, only 3 ears showed a decline in VEMP following implantation – all of which had CMV[85]. Thus, pre- and post CI VEMP testing should incorporate bone-conduction stimuli. Additionally, VEMP response rates can increase when completed with the implant on rather than off[75,79]. Lastly, children with CIs who have vestibular loss are more likely to

evidence CI failure[86]. The primary outcome parameter is presence or absence of VEMP responses pre- and post-implantation, with the recommendation to use bone-conduction stimuli.

- *Sensorineural Hearing Loss (SNHL):* Vestibular loss is associated with SNHL; however, not all children with SNHL will have vestibular loss[87–90]. The large percentage of children with absent VEMP responses prior to receiving a CI highlights the relationship between vestibular loss and hearing loss severity. Vestibular loss is more likely to occur as hearing loss severity increases, with specific etiologies and with sudden SNHL[80,90,91]. The primary outcome parameter is presence or absence of VEMP responses. Due to the high association between hearing loss and vestibular loss[92,93] and because cervical VEMP responses can be completed in newborns, cervical VEMPs are beginning to be used to screen for vestibular loss in children with hearing loss[94]. Bone-conduction cervical VEMPs are used due to the high incidence of middle ear disease.
- *Large Vestibular Aqueduct Syndrome (LVAS)*: LVAS occurs when the vestibular aqueduct is greater than 1.5 mm, which often leads to congenital hearing loss[95]. LVAS has been considered one type of third window disorder[96]. VEMP findings in LVAS vary considerably. While many reports note reduced thresholds and increased amplitudes[97–102], normal thresholds, normal amplitudes and reduced amplitudes in LVAS have also been reported[97,103–106]. Longer bone-conduction and shorter air-conduction latencies have also been noted[97,100]. Outcomes with LVAS consist of analyzing ocular VEMP amplitude, cervical VEMP threshold, and latency differences.
- *Meniere's Disease (MD):* MD is rare in children; Pediatric MD is estimated to comprise 2.3% of all MD cases[107]. While rare, MD is 3rd to vestibular migraine and recurrent vertigo of childhood for causes of dizziness in children[107]. Thus, there are few publications in pediatric MD. Of those, most children with pediatric MD have normal cervical and ocular VEMP responses[107]. The primary outcome parameter is presence or absence of VEMP responses.
- *Conductive Hearing Loss (CHL):* The presence of a CHL reduces the amount of acoustic energy reaching the vestibular system when using air-conduction stimuli. In adults with CHL, cervical VEMP responses are diminished with CHL of 9 dB, yet remain in some ears with as much as 24 dB of CHL[66]. In children with otitis media, cervical VEMP responses have been recorded with reduced amplitude and delayed latencies that normalize 3 months following medical treatment[108]. In a case of CHL, use of bone-conduction stimuli has been helpful for diagnosing underlying vestibular loss[109]. The primary outcome parameter is presence or absence of VEMP responses, with the recommendation to use bone conduction.
- *Auditory Neuropathy Spectrum Disorder (ANSD):* Many children with ANSD demonstrate abnormal VEMP responses[110–114]. Children with ANSD and abnormal VEMP responses are more likely to have ANSD onset post-lingually[111], more severe hearing loss[111], worse speech discrimination[111], and evidence vestibular involvement on the MRI (e.g., vestibular dysplasia)[113]; although these associations have not been uniform across studies. The primary outcome parameter is presence or absence of VEMP responses.

- *Superior Canal Dehiscence Syndrome (SCDS):* In children, the prevalence of dehiscence is estimated to be 1.7% in the superior canal and 1.2% in the posterior canal[115]. Few papers have been published on VEMP outcomes in children with SCDS. One published case study demonstrated abnormally large ocular VEMP amplitudes. In adults, high amplitude ocular VEMPs, low threshold cervical VEMPs and altered tuning are typically used to diagnose SCDS[116–119]. Thus, the primary outcome parameters would be ocular VEMP amplitude, cervical VEMP threshold and presence or absence of VEMP responses for high frequency stimuli (e.g, 4k Hz).
- *Recurrent Vertigo of Childhood (previously Benign Paroxysmal Vertigo of Childhood):* Recurrent vertigo of childhood is common in children and considered a variant of migraine. Absent and/or delayed cervical VEMP responses and normal ocular VEMP responses have been reported[120–122]. Due to normal ocular VEMP responses and abnormal cervical VEMP responses, the lower brainstem is thought to be affected [120,121]. The primary outcome parameters are cervical and ocular VEMP amplitude and latency.

Table 5. VEMP interpretation by etiology

Group	Author	N (age)	Cervical VEMP	Ocular VEMP
Cochlear Implant (CI)	Cushing (2013)	N = 153 children (3 – 20 years)	135 children completed cVEMP; 72/135 (53%) had abnormal cVEMP (32/72 (44%) bilateral; 40/72 (56%) unilateral)	Not completed
	Devroede (2016)	N = 24 children (1 – 13 years)	Post-unilateral CI, 19/24 (79%) had present cVEMP. Post-contralateral CI, 15/24 (62%) had present cVEMP.	Not completed
	Dhondt (2016)	N = 50 (< 17 years)	Pre-CI, 82/100 (82%) had present cVEMP. Post-CI, 1 had cVEMP return while 3/82 had reduced cVEMP (1 ipsi, 2 contra).	Not completed
	Imai (2019)	N = 12 (7 – 82 years)	Pre-CI, 9/12 (75%) had present cVEMP. Of those, 5/9 had reduced cVEMP post-CI.	Pre-CI, 11/12 (92%) had present oVEMP. Of those, 10/11 had reduced oVEMP post-CI.
	Jin (2006)	N = 12 children (2 - 7 years)	Pre-CI, 6/12 (50%) had present cVEMP. Of those, 1/6 had reduced cVEMP and 5/6 had absent cVEMP post-CI.	Not completed
	Katsiari (2012)	N = 20 (10 - 77 years)	Pre-CI, 10/20 (50%) had present VEMP, bilaterally. Of those, 6/10 had absent cVEMP post-CI.	Not completed
	Li (2020)	N = 35 (3 – 18 years)	Pre-CI, 64/70 (91.4%) had present cVEMP, bilaterally. Post-CI (1 month), 72% had present cVEMP.	Pre-CI, 57/70 (81.4%) had present VEMP, bilaterally. Post-CI (1 month), 34.6% had present VEMP.
	Licameli (2009)	N = 42 post-CI (5 – 22 years)	Post-CI, 15 completed cVEMP, 3/15 (20%) had present cVEMP.	Not completed
		N = 19 pre/post-CI (2 – 23 years)	Pre-CI, 17/19 (89%) had present cVEMP. Of those, 3.17 had no change and 14/17 had reduced VEMP post-CI.	
	Merchant (2020)	N = 27 ears with CI (7 - 31 years)	Response rates increased from 41% (11/27) with ACS to 67% (18/27) with BCV	Response rates increased from 15% (4/27) with ACS to 52% (14/27) with BCV

	Wagner (2010)	N = 20 (40 ears) (11 – 58 years)	Pre-CI, 22/40 (55%) had present cVEMP. Of those, 5 (23%) had absent cVEMP post-CI	Not completed
	Wolter (2015)	N = 187 children (22 with CI failure, 165 without failure)	A higher proportion of abnormal cVEMP in children with CI failure (81%) compared to those without CI failure (46%).	Not completed
Sensorineural Hearing Loss (SNHL)	Birdane (2016)	N = 33 Unilateral SNHL (5 – 18 years)	ACS click: Absent in 3/33 (9%)	Not completed
	Chen (2016)	N = 16 Bilateral sudden SNHL (5 – 79 years)	Abnormal responses: 100% (12/12)	Abnormal responses: 100% (4/4)
	Shinjo (2007)	N = 20 Severe HL (31 – 97 months)	ACS Clicks: present bilaterally in 10/20 (50%), asymmetrical in 6/20 (30%), and absent in 4/20 (20%)	Not completed
	Singh (2012)	N = 15 children (4 – 12 years)	2/15 had bilaterally absent responses; children with SNHL had significantly smaller amplitudes compared to controls	Not completed
	Verbecque (2017)	N = 828 children Systematic Review	Abnormal responses in 46.7 – 100% of children with SNHL; abnormal responses more likely with greater severity of SNHL	63.5% of children with SNHL had normal oVEMP
Large Vestibular Aqueduct Syndrome (LVAS)	Liu (2020)	N = 44 bilateral LVAS, 10 controls (< 14 years)	500 Hz ACS: No difference in latency or threshold. LVAS had significantly larger amplitudes. 500 Hz BCV: No difference in amplitude or threshold. LVAS had longer P1 latency and shorter P1-N1 interval.	500 Hz ACS: No difference in latency, threshold, or amplitude. 500 Hz BCV: No difference in amplitude. LVAS had longer P1 and N1 latency and higher threshold.
	Manzari (2008)	N = 15 (21 – 68 years)	Normal amplitude in all patients (stimulus not described)	Not completed
	Sheykholeslami (2004)	N = 3 (31, 9, and 6 years)	500 Hz ACS: In 2 patients, ears with LVAS had lower thresholds and higher amplitudes compared to normal ears. In 1 patient with mixed hearing loss from tympanoplasty, VEMP responses present despite air-bone gap	Not completed
	Taylor (2012)	N = 1 (42 years)	250, 500, 1k, and 2k Hz ACS: Amplitudes and thresholds in normal range for all frequencies.	250, 500, 1k, and 2k Hz ACS: Large amplitudes and low thresholds in the right ear at 250, 500, and 1k and large amplitudes in the left ear at 1k Hz.
	Taylor (2020)	N = 1	Not completed	Click ACS: Enlarged amplitude
	Zalewski (2015)	N = 9	500 Hz ACS: 1 ear did not elicit a VEMP response. No significant difference in	Not completed

		(4.6 – 17.3 years)	cVEMP amplitude between ears with and without LVAS.	
	Zhang (2020)	N = 29 (23 children [3 – 12 years], 6 adults [15 – 33 years])	500 Hz ACS: Absent in 6/46 child ears (13%) and 3/12 adult ears (25%). Compared to controls, LVAS adults had significantly smaller cVEMP amplitudes; there were no differences for LVAS children.	500 Hz ACS: Absent in 3/46 child ears (6.5%) and 2/12 adult ears (16.7%). Compared to controls, LVAS adults had significantly higher amplitudes; there were no differences for LVAS children.
	Zhou (2008)	N = 54 (82 ears) (2 – 16 years)	500 Hz ACS: cVEMP completed in 14. VEMP thresholds were significantly lower in ears with EVA.	Not completed
	Zhou (2011)	N = 25 (37 ears) (3 to 20 years)	500 Hz ACS: Thresholds were abnormally low in 34/37 (92%) of LVAS ears. VEMP were absent in 3 patients with vestibular complaints. No differences in latencies.	Not completed
	Zhou (2017)	N = 18 (7 – 27 years)	500 Hz ACS: Lower thresholds, shorter latencies, and larger amplitudes	500 Hz ACS: Lower thresholds and larger amplitudes
MD	Wang (2018)	N = 15	12/15 (80%) had normal cVEMP	13/15 (86.7%) ears had normal oVEMP
Conductive Hearing Loss (CHL)	Monobe (2004)	N = 1 (3 years)	Bilateral OME present. BCV VEMP were used to diagnose vestibular neuritis. Absent VEMP on right side and present on left with right caloric weakness and spontaneous left beat nystagmus	Not completed
	Yildiz (2012)	N = 40 (4 – 16 years)	Prolonged latency and reduced amplitude in ears with OME. Latencies shortened and amplitudes increased following treatment	Not completed
	Zhou (2012)	N = 120 with ABG (3 – 76 years)	Responses used to differentiate types of air-bone gaps (middle vs inner ear). Middle ear pathologies resulted in absent VEMP, inner ear anomalies (SCDS and LVAS) had abnormal low VEMP thresholds.	Not completed
Auditory Neuropathy Spectrum Disorder (ANSD)	Akdogan (2008)	N = 3 (4 – 5 years)	ACS 500 Hz: Absent in 2/3 (66.7%)	Not completed
	El-Badry (2018)	N = 54 28 pre-lingual onset, 16 post-lingual onset (3.7 – 10.2 years)	ACS 500 Hz: Absent in 3/38 (8%) of the pre-lingual onset group and absent in 11/16 (69%) in the post-lingual onset group	Not completed
	Emami (2015)	N = 13 (15 ears)	ACS 500 Hz: 4/15 (27%) ears had absent responses	Not completed
	Laurent (2021)	N = 9 Unilateral ANSD (0 to 95 months)	500 Hz BCV: abnormal responses in 4/9 (44.4%)	Not completed
	Sinha (2013)	N = 11 (15 - 28 years)	500 Hz ACS: Absent in responses in 20/22 ears (90.9%)	500 Hz ACS: Absent responses in 22/22 ears (100%)
BPVC	Chang (2007)	N = 20 (5 – 15 years)	ACS 500 Hz: 10/20 (50%) children had abnormal responses: 6 children had	Not completed

			absent responses and 5 had delayed responses (1 child had both absent and delayed)	
	Lin (2010)	N = 15 (4 – 14 years)	ACS 500 Hz: 11/15 (73%) children had delayed responses	ACS 500 Hz: Normal responses in 15/15 (100%)
	Zhang (2011)	N = 56 (3 – 12 years)	ACS 500 Hz: 18/56 (32.1% had abnormal responses: 16 had amplitude and 2 had latency abnormalities	Not completed
SCDS	Wenzel (2015)	N – 1 (11 years)	Not completed	Enlarged amplitude for affected ear

ACS = air-conducted sound; BCV = bone-conducted vibration; BPVC = benign paroxysmal vertigo of childhood; CHL = conductive hearing loss; CI = cochlear implant; LVAS = large vestibular aqueduct syndrome; MD = meniere's disease; OME = otitis media with effusion; SCDS = superior canal dehiscence syndrome; SNHL = sensorineural hearing loss

Summary: Air- or bone-conducted stimulation can be used for VEMP testing. If using air-conducted stimuli, tympanometry is recommended prior to VEMP testing to assess middle ear status. If tympanometry is normal, VEMP using air-conducted stimuli can be used; however, should not exceed 120 dB SPL (92 dB nHL) if ECVs are < 0.8 ml. If tympanometry is abnormal, VEMP using bone-conducted stimuli is recommended (e.g., B-71). Bone-conducted stimuli is recommended in children pre- and post-implantation and for newborn screening due to the high rate of otitis media. Most etiologies use presence/absence of VEMP responses as the primary outcome parameter; however, abnormal latencies can be seen in BPV of Childhood (using ACS) and LVAS (using either ACS or BCV) and abnormally high ocular VEMP amplitudes, low cervical VEMP thresholds and high frequency responses can be noted in SCDS and LVAS. Cervical VEMP can be completed in newborns, while ocular VEMP are initiated around age 3 – 4.

III. Video Head Impulse Test (vHIT)

1. **Test Name**: Video Head Impulse Test

2. **Purpose:** The purpose of vHIT is to evaluate the vestibulo-ocular reflex (VOR) associated with each of the 6 semicircular canals. The VOR allows for stable gaze and clear vision while the head is in motion. During vHIT, children wear tight fitting goggles, and the clinician administers high acceleration head impulses in the plane of each semicircular canal (horizontal, superior, and posterior) of each ear. Stimulation of the semicircular canal via a head thrust in the plane of that canal drives the neural response to the cranial nerves that innervate the eye muscles, turning the eyes equal and opposite to the movement of the head. This allows the patient to maintain stable gaze on a focal point. Ear-specific and canal-specific information may be obtained.

3. **Populations intended:** Children, age 4 and older. Of note, approved outside of the US and for research purposes inside the US, a remote camera system is available. This remote camera stands alone and measures the pupil without goggles while facing the child. Normative data is available for children as young as 3 months of age. [7]

4. **Expected outcomes:** The main outcome parameter is gain, which is calculated by dividing eye velocity (measured by a camera within the goggles) by head velocity (measured by a gyroscope within the goggles).

    a. **Normal Results:** In children with normal vestibular function, head impulses in the plane of each semicircular canal result in an equal and opposite eye movement, generating gain values near 1.0. Normal gain values for children and adults are listed in **Table 6**. For quick reference, 0.80 – 1.2 is considered normal gain for lateral canal vHIT. Gain cutoff values for LARP and RALP (Left Anterior/ Right Posterior Semicircular Canal Plane and Right Anterior/ Left Posterior Semicircular Canal Plane) in children are lower, however, on the order of 0.60 – 1.2.[124, 126] Normal neural input from the canals drives the VOR, allowing the patient to maintain focus on a visual focal point on the wall. The computer recordings of the patient's eye movement and the patient's head movement are viewed as either superimposed (**Figure 10A**), or 180 degrees out of phase (**Figure 10B**)

Table 6. VOR Gain for Each Semicircular Canal for Children and Adults (Mean + Std Dev (5th, 95th confidence intervals)) from Bachman et al. (2018)[124] and Curthoys et al. (2016) [125].

Age Group	Semicircular Canal Tested					
	Left Lateral	Right Lateral	Left Anterior	Right Anterior	Left Posterior	Right Posterior
Children 4-12 years[124]	0.96 ± 0.09 (0.79 - 1.14)	1.04 ± 0.09 (0.87 - 1.23)	0.80 ± 0.11 (0.58 - 1.02)	0.90 ± 0.19 (0.53 - 1.27)	0.91 ± 0.14 (0.65 - 1.18)	0.83 ± 0.09 (0.65 - 1.01)
Adults[124]	0.91 ± 0.06 (0.79 - 1.04)	1.03 ± 0.06 (0.91 - 1.14)	0.93 ± 0.07 (0.78 - 1.07)	0.95 ± 0.18 (0.60 - 1.30)	0.95 ± 0.09 (0.77 - 1.12)	0.89 ± 0.08 (0.73 - 1.05)
Adults [125]	0.92 ± 0.06 (lower cutoff = 0.80)	1.00 ± 0.07 (lower cutoff = 0.86)	0.96 ± 0.12 (lower cutoff = 0.71)	0.95 ± 0.12 (lower cutoff = 0.70)	0.92 ± 0.17 (lower cutoff = 0.58)	0.98 ± 0.15 (lower cutoff = 0.68)

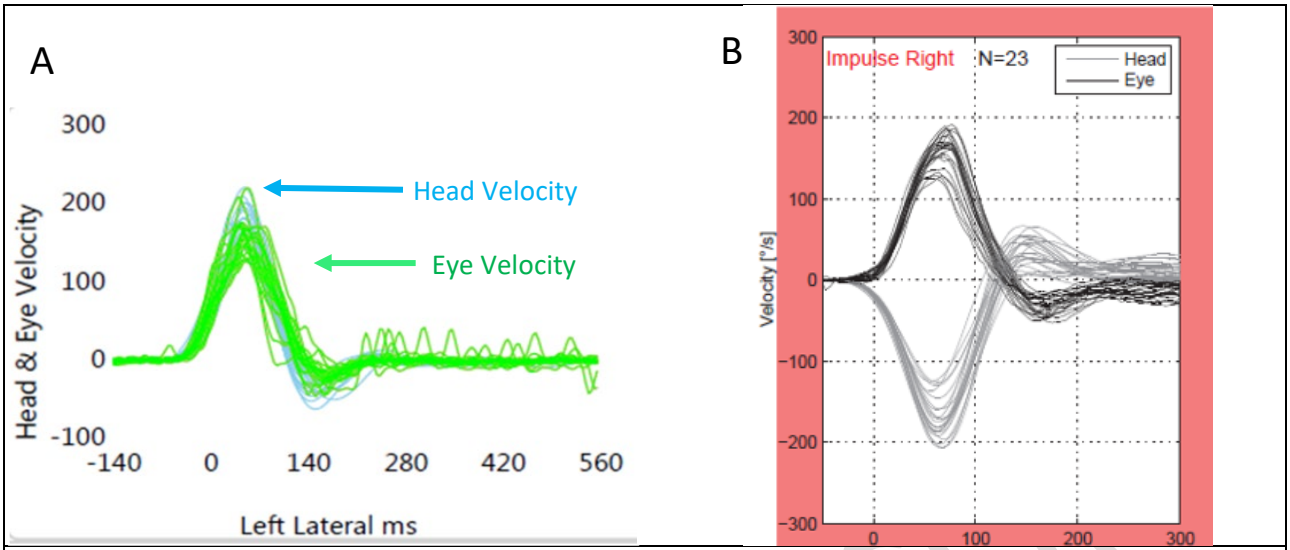

Figure 10. Normal vHIT recordings which displays **A**: eye velocity superimposed on head velocity and **B**: eye velocity opposite to, or out of phase with, head velocity.

b. **Abnormal Results:** In children with significant vestibular dysfunction, there is not enough vestibular input to drive the VOR when the head is turned toward the affected side. Thus, head impulses in the plane of the abnormal canal result in eyes that briefly move WITH the head, resulting in low gain values and requiring the patient to make a compensatory (catch-up) saccade back to the visual target. Catch-up saccades may be seen on the recording either during the head movement or following the head movement as a spike in the eye movement tracing.

   i. **Overt Saccades:** Overt saccades are corrective eye movements that occur at least 100 msec AFTER the head movement has ended (**Figure 11**).

   ii. **Covert Saccades:** Covert saccades are corrective eye movements that occur DURING the head movement. They may be seen beginning around 70 msec after the start of the head impulse and occur at any point in time while the head is in motion (**Figure 11**).

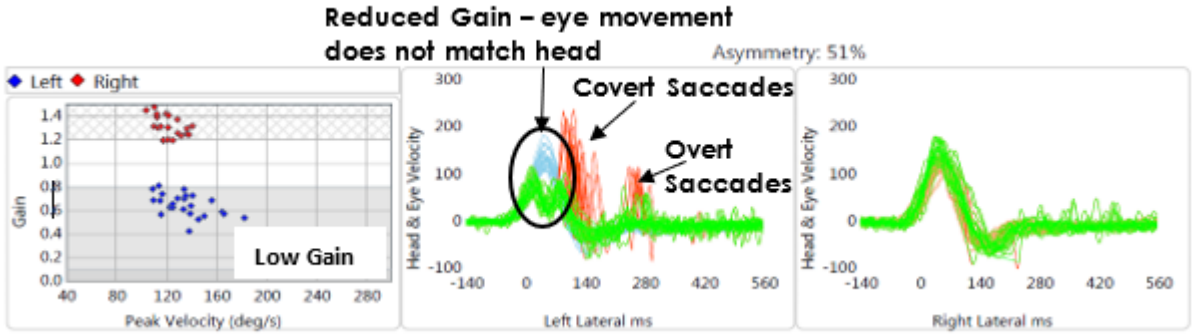

Figure 11. Example of an abnormal left lateral vHIT with normal right lateral vHIT. Note the reduced gain in blue (left ear, lateral canal) on the gain graph in the left panel of the figure, and the green tracing circled on the vHIT recording (center panel). Covert saccades are seen as red spikes DURING the head movement (light blue tracing) while overt saccades are seen as red spikes AFTER the head movement has ended.

For analysis purposes, determination of the presence of pathological catch-up saccades includes a consistent spike in the response tracing occurring on more than 50% of impulses and having a magnitude greater than half the size of the head movement.[127] Random or extraneous eye movements recorded on only a few tracings are not considered pathologic (**Figure 12**). Low gain and catch-up saccades are indicative of peripheral vestibular dysfunction in the SCC on the side and in the direction of head thrust. For example, if there is low gain and catch-up saccades observed with left horizontal head thrusts, this is indicative of left horizontal SCC dysfunction as seen in **Figure 11**.

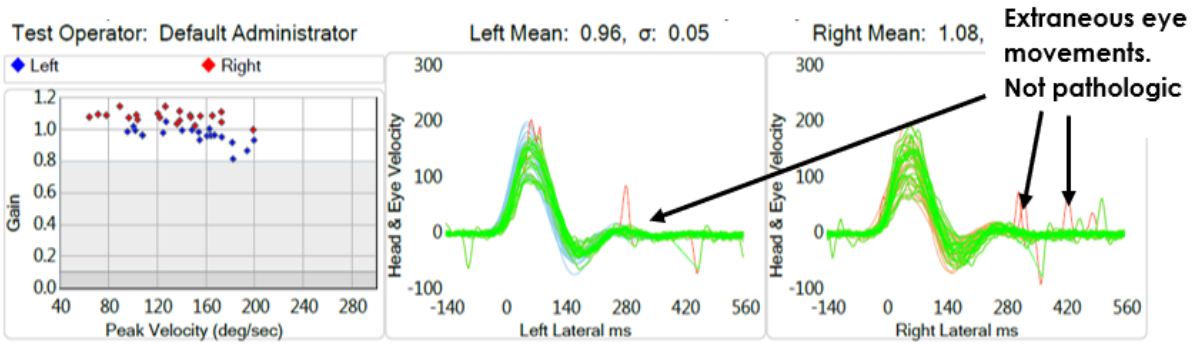

Figure 12. Example of normal vHIT tracings with some random or extraneous eye movements seen after the head movement (arrows). These eye movements are not consistent and are too small to be considered pathological catch-up saccades. See text for saccade definition.

5. Practice Guidance Method[128]:

a. The child should be seated in a chair 1 meter from a visual target (1" by 1" sticker or video on a cell phone – see tips to testing below) on the wall at eye level (**Figure 13**).
b. The vHIT goggles should be placed on the patient's face and firmly secured with the attached elastic band, provided by the manufacturer, around the back of the head to prevent goggle slippage and subsequent inaccurate gain data.
c. The goggle cord should be secured to the patient's clothing with a clip to limit cord movement that may cause movement of the goggles.
d. To obtain optimal pupil recordings, the loose skin above the eyelid of the recorded eye should be pulled up and secured with the goggles. Pulling down on the cheek below the recorded eye may also widen the eye by pulling the lower eyelid down.
e. Prior to the start of testing, calibration of the goggles should be performed according to manufacturer's instructions.
f. If calibration cannot be achieved by the patient, "default" calibration should be used.
g. After calibration is accepted by the system, calibration should be manually verified by slowly rotating the patient's head to the left and right while the patient maintains focus on the sticker or focal point, confirming that eye and head movement recordings are superimposed, or 180 deg out of phase, depending on the equipment used.
h. Following calibration, the patient should be instructed to maintain focus on the visual target, or sticker.

Figure 13. vHIT test set up for a pediatric patient. The child is seated in a chair 1 meter from a visual target (1"x 1" sticker) on the wall and a footstool is used to stabilize the feet.

i. **Horizontal/Lateral canal testing**: The patient's head should be rotated by the examiner using small (no larger than 15 deg), rapid (150– 300 deg/sec) head impulses to the left and right in the plane of the lateral SCCs.

j. **Left anterior and right posterior (LARP) canal testing**: The patient's head is initially rotated 35-45 degrees to the right with the examiner placing one hand under the patient's chin and one hand on top of the patient's head with the index finger pointing toward the visual target or sticker.

   The patient's head should be thrust forward for testing of the left anterior (LA) canal and backward for testing of the right posterior (RP) canal using rapid (100 deg/sec – 250 deg/sec) downward and upward head impulses.

k. **Right anterior and left posterior (RALP) canal testing**: The patient's head is initially rotated 35-45 degrees to the left with the examiner placing one hand under the patient's chin and one hand on top of the patient's head with the index finger pointing toward the visual target or sticker.

The patient's head should be thrust forward for testing of the right anterior canal and backward for testing of the left posterior canal using rapid (100 deg/sec – 250 deg/sec) downward and upward head impulses.

l. 20 acceptable impulses are recommended for each canal, if possible.

m. Results must be inspected for clean data prior to analysis. Messy tracings and poor-quality head impulses and eye recordings must be eliminated from the record before an accurate analysis of the data may be made. One of the most common artifacts seen during anterior canal testing in children is eyelid artifact.[129] An example of eyelid artifact is seen in **Figure 14**. A "V" shape in the response indicates that the top of the pupil was obscured by the eyelid. This is especially problematic in children because their pupil size is very large compared to an adult[130], [131]. As the crosshairs on the equipment are centered on the pupil, any change in pupil shape (caused by the eyelid covering the top portion of the pupil) will result in the crosshairs moving down on the pupil to find a new center. This is what causes the "V" in the eye response. To eliminate this, try pulling up on the eyelid or down on the cheek to create a wider recording area. Also, consider starting with the head tilted backwards slightly before thrusting anteriorly. In addition, it is important to perform vHIT in a well-lit room or area of the room, as the naturally larger pupil diameter in children makes pupil tracking difficult in a dimly lit environment. Use of a portable bright light, such as that from an otoscope, is helpful for constricting the pupil, allowing for easier pupil tracking and cleaner tracings.

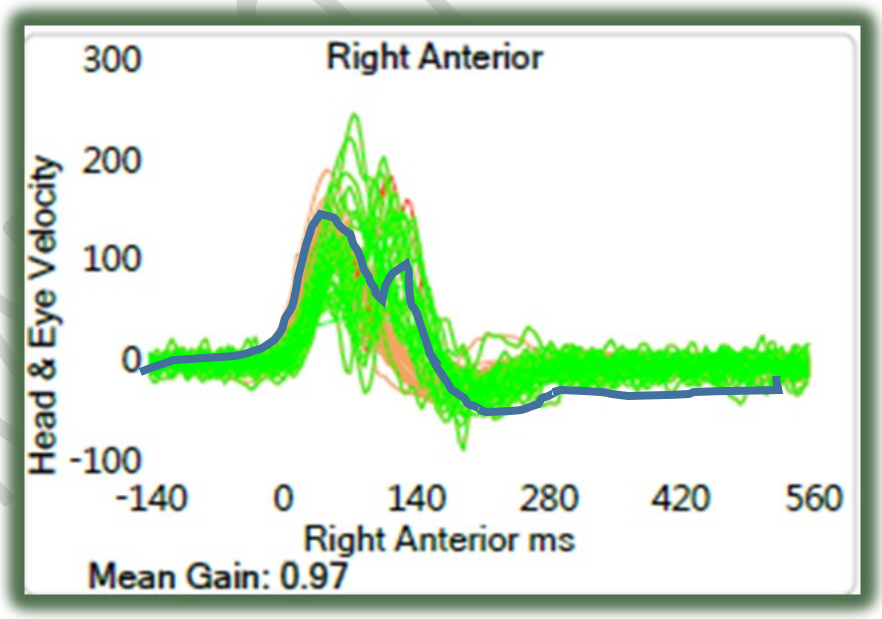

Figure 14. Example of recordings with eyelid artifact seen as the "V" in the tracings. See text for full explanation.

6. General rules for interpretation:

a. Results of each test should be evaluated for both average gain and the presence of consistent saccades occurring during the head movement (covert) or after the head movement (overt).
    i. It stands to reason that low gain will likely be accompanied by a catch-up saccade, as low gain is an indication that the eye has moved WITH the head to some degree and did not stay on target, requiring the eyes to make a saccade back to the target.
    ii. As described earlier in the text, determination of the presence of a saccade includes a consistent spike in the response tracing occurring on more than 50% of impulses and having a magnitude greater than half the size of the head movement.[127]

7. **Tips to Testing:** Pediatric modifications for vHIT testing are necessary to reduce goggle slippage and body movement, as well as to increase attention and focus on the target.
    a. Reducing body movement during head impulses
        i. The child may be seated with legs crossed on the chair
        ii. The child may be seated with feet placed on a step-stool
        iii. The child may be seated on the caregiver's lap

    b. Reducing goggle slippage on a child's fine, slippery hair
        i. A disposable bouffant cap (like that used for hair covering in food service) may be placed on the patient's head prior to placing the goggles on the patient. This is also helpful for infection control because the cloth strap cannot be adequately wiped down.
        ii. A piece of disposable foam or sponge (i.e., packing foam from a hearing aid box) may be placed inside the elastic headband on the back of the child's head. This adds bulk to the head to make the elastic band fit tighter and also serves to add friction so the elastic band cannot slip on the child's hair. The foam or sponge is disposed of following the test.
        iii. For children with long hair, putting the hair in a low ponytail on the head is effective for preventing the elastic band from slipping down the child's head. Just make sure the ponytail sits below the elastic strap of the goggles.

    c. Increasing attention and focus on the focal point
        i. Ages 4-10
            1. A cell phone with the child's favorite video or show playing on it may be used as a focal point.
            2. Colorful stickers may be used as the focal point.
            3. To ensure the child is looking at the visual target during head impulses, questions about the video or sticker should be asked to the child (i.e., how many sprinkles are on the cupcake? How many tires on the fire truck? What colors are on that flag?). When using a sticker as the focal point, the sticker should be replaced with a new sticker if the child is losing interest.
        ii. Ages 11 – 21

1. A colorful sticker, or the sticker provided by the manufacturer may be used.

   **NOTE: It is not recommended to use a cell phone with a video due to unpublished data which showed that older children do not focus as well with a video as the focal point, perhaps due to an increased level of relaxation and overall reduced alertness watching a show.

IV. Videonystagmography

1. **Test Name**: Videonystagmography (VNG) refers to video recording of eye movements. VNG is broken down into multiple subtests including High Frequency Head Shake, Positional Testing, Dix-Hallpike, Skull Vibration Induced Nystagmus Test, Ocular Motor Testing and Caloric testing. While VNG is the most readily available assessment in vestibular testing centers, it is often not used in children less than 5 – 7 years due to limitations discussed below (i.e., goggle fit, invasive nature of the test, length of the test, etc).

2. **Purposes**: VNG is helpful for differentiating central versus peripheral vestibular system involvement and side of lesion.

3. **Populations Intended**: While children as young as 6 months can complete some subtests and most manufacturers claim their goggles fit children ages 3 and above, VNG is typically not used in the pediatric population until 5 – 7 years (Figure 15).

4. **Expected Outcome and Methods**: Like adults, children are asked to refrain from using any vestibular suppressant medications (i.e., Dramamine, meclizine, etc) prior to testing. There are several subsets of the VNG test battery. Each subtest is designed to target either the central and/or peripheral vestibular system physiologically. Outcomes vary based on each subtest, which are described below.

1. **Test Component:** High Frequency Head Shake[132]
    - **a. Purpose:** Used to assess asymmetrical vestibular system function.
    - **b. Population:** Children over 10 months
    - **c. Expected Outcome:** In normal subjects no nystagmus should be observed in response to horizontal head shake. If there is asymmetric vestibular function an initial burst of nystagmus (typically horizontal and beating towards intact ear) which decays over approximately 30 seconds will be recorded. For central involvement, nystagmus can occur with a latent onset and/or may be persistent (beyond 30 seconds). In addition, cross-coupling, or vertical nystagmus seen after horizontal head shake, can also suggest central pathology.
    - **d. Method:** The patient is seated with vision denied and head tilted 20 deg downward. The tester moves the patient's head horizontally at about 2 Hz with displacement of approximately 30 deg horizontally. The head shaking continues for 15-20 seconds. Once the head shaking is stopped, the eyes are observed for nystagmus for up to 60 seconds.
    - **e. Normative Data**
        - **i.** None specific to children. Most labs consider 3 consecutive beats of nystagmus pathologic.
    - **f. Considerations:**
        - **i.** Patients with complete bilateral vestibular loss will not have nystagmus post headshaking; however, post head shake nystagmus can occur in cases of asymmetric bilateral loss.

ii. Post-head shake testing can also be completed while recording in rotary chair or with electrodes.
iii. Telling the child "Let's be silly and shake our head and say 'no! no! no!' 10 times!"

2. **Test component:** Positional Testing
   a. **Purpose:** To determine if certain positions elicit nystagmus, thus indicating abnormal or asymmetrical firing in the vestibular system
   b. **Population:** 4 years of age and older. This test is easily tolerated by children, though is often not localizing on its own.
   c. **Expected Outcome:** Nystagmus may be observed in one or several positions. To classify positional nystagmus as clinically significant, nystagmus should be present in at least half of the positions or be greater than 6 degrees/s in any one position.
   d. **Method:** The patient is placed with vision denied in a combination of the following positions: sitting neutral, supine head center, supine head right, supine head left, side lying right, side lying left, head hanging, and a pre-caloric position (inclined 30 degrees). Eyes are observed for nystagmus for approximately 30 seconds. If nystagmus is present, a fixation light is turned on to determine if central suppression is present.
   e. **Normative Data:** [133] [134]
      i. 15%-22% of healthy children have positional nystagmus.
      ii. Most clinics use persistent nystagmus greater than 4-6 degrees/sec that appears in greater than 50% of the tested positions to be clinically significant; however, other adult studies suggest that observing 3 or more beats of nystagmus in a 10 second window to be clinically significant.[135] Of note, these guidelines were based on adult data. Different cut-off criteria could exist for children; however, have not been studied or established.
   f. **Considerations**
      i. May not be beneficial when bilateral vestibular loss is identified and/or there is no complaint of positional dizziness.
      ii. For children, consider tasking appropriately with songs, games, colors, etc
      iii. In these authors' collective experience, nystagmus without fixation is a non-localizing finding when all other peripheral tests yield normal results. This finding has been documented in peripheral, as well as, central etiologies (i.e. migraine). [136]

3. **Test Component:** Dix Hallpike Test/Roll Test [137]
   a. **Purpose:** To assess for Benign Paroxysmal Positional Vertigo (BPPV)
   b. **Population:** For patients complaining of positional vertigo. BPPV is not a common entity in pediatrics.[138]
   c. **Expected outcome:** In patients without BPPV, no nystagmus will be observed in each position. If nystagmus is observed, it should present with an initial burst that gradually fatigues and reverses upon sitting. The direction/type of nystagmus should be noted to determine which semicircular canal is affected. (For a practical

guideline for diagnosis and treatment, see reference [139]) If nystagmus is noted the Dix Hallpike should be repeated. Nystagmus should fatigue quicker on repeat. The roll maneuver can also be performed if horizontal canal BPPV is suspected. The roll test will be positive when horizontal nystagmus is observed in each head position. Geotropic nystagmus is horizontal nystagmus beating towards the earth (i.e., right beating with head right and left beating with head left) and is consistent with canalithiasis. The side with more intense nystagmus is the affected side. Ageotropic nystagmus is consistent with cupulolithiasis. The side with less intense nystagmus is the affected side.

d. **Method:**

Dix Hallpike: The patient starts in a seated position with their head turned 45 degrees towards the test ear. The patient is then placed in a supine position with their head extended about 20 degrees below the horizontal plane. The eyes are observed for 30 seconds. The patient is then brought back to the sitting position with the head remaining turned and the eyes are again observed for nystagmus for 30 seconds.

Roll Test: The patient will lie supine on the bed and the head will be supported into 30 degrees of flexion to align the lateral semicircular canal in the horizontal plane. Then, the head is quickly rotated 90 degrees to one side. The eyes are observed for nystagmus for 60 seconds. The head is then returned to the straight face-up supine position. After any nystagmus subsides, the same is repeated to the other side. In a positive test, the patient will experience vertigo during this test. In the case of horizontal semicircular canal BPPV the nystagmus will be predominantly horizontal.

e. **Considerations:** Testing should be avoided and/or extreme care taken with patients who have cervical or vascular issues such as vertebrobasilar insufficiency or craniovertebral junction abnormalities (Ex: Patients with Down Syndrome). Asses the patient's ability to rotate their head safely prior to performing the maneuver.

4. **Test Component:** Skull Vibration Induced Nystagmus Test (SVINT)
   - **a. Purpose:** To assess asymmetrical firing in the peripheral vestibular system.
   - **b. Population:** All children
   - **c. Expected Outcome:** Skull vibration induced nystagmus starts and stops immediately with stimulation, is continuous, reproducible, and beats in the same direction irrespective of which mastoid process is stimulated. A positive test is most widely seen in patients with asymmetric vestibular function.[140] The nystagmus typically beats towards the healthy ear. Positive cases have also been noted in those with 3rd window lesions. In the literature, 3rd window pathologies may show nystagmus beating towards the affected side[141].
   - **d. Method:** Patient is seated upright with fixation removed. Apply 10 seconds of low frequency vibration at 100 Hz to the mastoid process on each side. Eye movements are recorded before, during, and after vibration application.
   - **e. Normative Data:**[141–143]

i. The first effects of vibration (motion and reflexes) were described by Von Bekesy (1935) and the vibratory-induced nystagmus test was first introduced in 1973 by Lücke[144]. The primary response expected is nystagmus in the direction of the healthy end organ during 100 Hz skull vibration. As noted above, nystagmus can beat towards the affected ear in cases of 3rd window pathologies. The primary method of stimulation is vibration between 60-100 Hz. The most recent study[142] that assessed children ages 5-17, applied 100 Hz stimulation to each mastoid and the vertex. Nystagmus was considered pathologic when horizontal/rotary nystagmus was observed (> 10 beats and SPV > 2°/s) beating toward the same direction and reproducible in at least 2 locations. If there was pre-existing nystagmus, the nystagmus had to enhance by 50%. Most protocols call for recording without stimulation for 5 seconds, then applying vibration for 10 seconds. This study recorded for 20 seconds because of the high number of blinks in children.

The study also looked at 120 healthy controls compared to 60 children with hearing loss with bilateral and unilateral vestibular loss (with hearing aids and cochlear implants). 104 SVINT was clinically significant in the controls only 2.5 % of the time. SVINT showed a sensitivity of 86% and specificity of 96%. The positive predictive value is 75% and negative predictive value is 98%. It also statistically correlated well with patients with a caloric weakness. The SVINT was not useful in bilateral weaknesses. Thus, it is a useful and non-invasive tool when evaluating for vestibular asymmetry.

f. Considerations:

i. Observe pre-existing nystagmus prior to the application of vibration

ii. Show the children the vibrator and let them touch it. "This is going to tickle our ears and we are going to sing Happy Birthday. When we are done, we are going to tickle the other ear and sing!"

5. **Test Component:** Ocular Motor Test
   a. **Purpose:** To assess the Central Vestibular Ocular Motor system
   b. **Population:** minimum age of 4 years, though best completed on ages 9 and up.
   c. **Expected Outcome:** A series of Ocular Motor tests are completed to assess central vestibulo-ocular pathway function. An abnormality in one of the tests may indicate central vestibulo-ocular abnormalities or other ophthalmologic issues.
   d. **Method:**
      i. **Smooth Pursuit Test.** Patients are instructed to watch a visual target that moves smoothly side to side. Gain (Eye velocity divided by target velocity) and symmetry (a comparison of right versus left gain) are recorded.
      ii. **Optokinetic Test.** For optimal results, this test should be completed in the full field condition. Often, this test can be completed in the rotary chair while the head is immobile. Patients are instructed to gaze at a moving

visual target (similar to watching a train move across their visual field) and a reflexive eye movement (similar to nystagmus) is generated. The slow component eye movement is generated in the direction of the moving target and the fast phase is generated in the opposite direction. Gain and symmetry are calculated.

iii. **Random Saccade Test.** The central nervous system can generate a fast conjugate eye movement that orients both eyes in the same direction and brings the foveae onto the target. This helps to see the environment when targets are moving quickly in the visual field. Patients are instructed to watch a visual target randomly appear. Latency (the time from target onset to the initiation of eye movement), velocity (speed of eye movement) and Accuracy are calculated.

iv. **Gaze Test.** Patients are instructed to watch a visual target that is oriented in center, right, left, up, and down gaze. Testing is then repeated with fixation removed. In all conditions the eyes are observed for nystagmus and other abnormal eye movements in each eye position.

e. **Normative Data**: While the data remain sparse, the following normative data have been reported. These data show differences in pediatrics compared with adults as children continue to develop their brainstem, cerebellum, and parietal, temporal, and frontal cortices. Children also showed an increased amount of artifact in their responses, especially under the age of 7. This is thought to be related to reduced attention.[145] [146] [147] The pursuit system enables one to generate a conjugate eye movement that can hold the foveae on a slow moving target. Testing is often completed at different frequencies.

i. **Smooth Pursuit Testing:** Children have lower gains and more varied asymmetry at all test frequencies[146] . In fact, there appears to be an age trend with the youngest participants (age 4) demonstrating the lowest gains**.**

ii. **Optokinetic Test:** This test looks at a reflexive fast tracking eye movement and is considered central if dysfunctional. Often, OPK nystagmus must be at least 80% of the target velocity (i.e., nystagmus must be at least 16 deg/sec using a 20 deg/sec target and 32 deg/sec when using a 40 deg/sec target). Asymmetry is also assessed. In pediatrics, it has been reported[146] that the average asymmetry is 14% at 20 deg/sec and 19% at 40 deg/sec.

iii. **Random Saccade Test:** Longer saccadic latencies have been reported in children[147]: up to 309 msecs (48 msec SD) for children under 8 years and up to 276 msec (22 msec SD) for children 9-10 years.

f. **Considerations:**

i. Infants and toddlers: Not needed to record formally due to time, goggle fit, and attention limitations.

1. General observational assessment of each test can be produced with visual targets at the bedside (puppet, stickers, finger, light wand,

etc). For example, children can watch a cell phone and tester moves it to see if there is gaze evoked nystagmus or presence of smooth pursuit. Place the child on their parent's lap facing out. Have the child's parents hold their head forward so that only the eyes are following the target and not the head.

2. Questions to be answered: Does the child have smooth eye movements? Is the child able to move their eyes quickly and accurately for saccade testing? Is nystagmus present when gazing right, left, up, down? Do the eyes work together?

ii. Age 4-8 years: Consider skipping if time and attention are limited, assessment can take place using pediatric goggles.

1. **Modifications:**
    a. Use a cartoon character as the visual target (software dependent).
    b. Shorten the recording time.
    c. Hold the child's head for stability.
    d. Consider using default calibration, although if the child has difficulty calibrating, then they may have increased difficulty completing recorded ocular motor assessments.
    e. Complete in rotary chair so the child can have full field vision with limited distraction.
    f. Artifact is common in young children[146]

iii. Ages 9-Teenage

1. Assessment can take place using appropriately fitting goggles. Calibration can be completed for those that are typically developing. Different normative data used. Children greater than 9 years can usually complete the entire ocular motor battery.

g. **MODIFICATIONS:** Often, calibration may not be completed and default may have to be used. Keep in mind, this may affect test results. Consider shortening the testing once repeatable data is collected. Consider altering instructions (i.e., Games, win prizes for focus and attention). Consider changing the target for continued interest, some systems offer different cartoon targets.

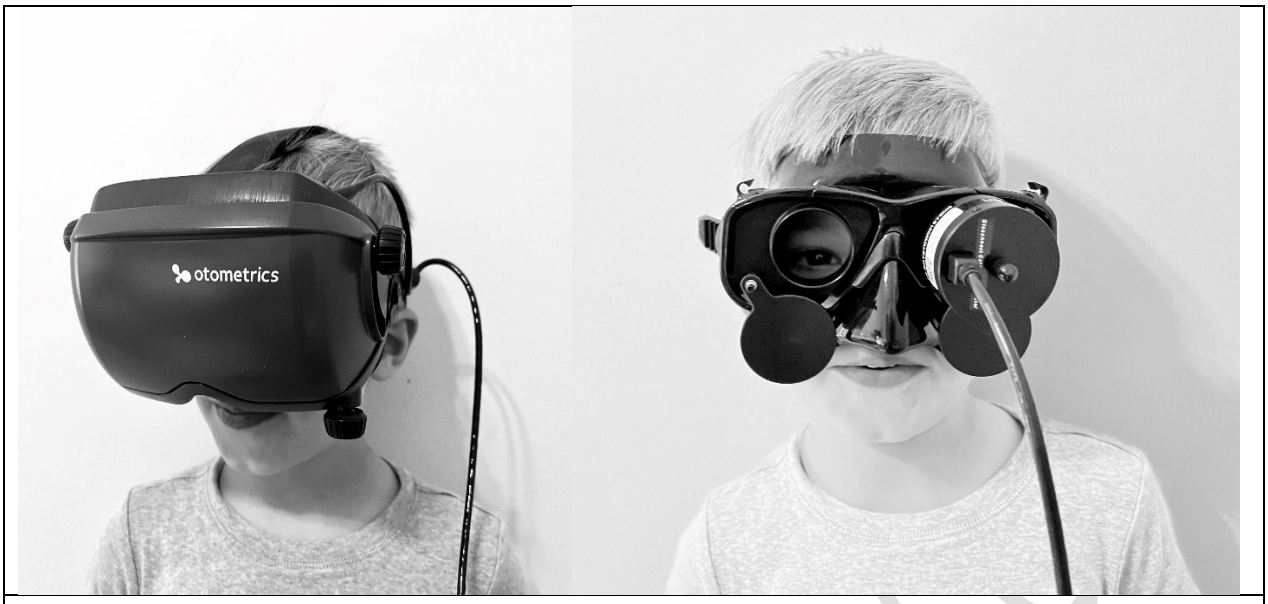

Figure 15: Options for VNG goggles on a 4-year-old's face.

6. **Test Component:** Bithermal Alternating Caloric Irrigation
    a. **Purpose:** To assess function of each vestibular end organ independently of each other. Most commonly used test to identify presence of vestibular weakness and side involved. Warm and cool air or water irrigations are performed on each ear.
    b. **Population:** Most widely tolerated on cooperative children developmentally 5 years of age and older with normal middle ear status.
    c. **Expected Outcome**: Nystagmus should be elicited from each ear with the peak slow phase velocity > 5 deg/sec and total velocity of all 4 irrigations > 20 deg/sec. Monthermal caloric irritations are also acceptable assuming all other tests suggest a normal exam. The cut off for a normal monthermal irrigation test is considerably more stringent and has been reported as 10-15% asymmetry[148] [149]with each irrigation requiring a magnitude of 8-15 deg/sec.
    d. **Normative Data**:
        i. It is important for each Center to establish their own norms. Studies have shown that caloric responses in the pediatric population tend to be more robust.[150]
        ii. In general, most labs continue to use a cut off of 20-30% for asymmetry and directional preponderance. In addition, the magnitude of caloric response decreases with age[151].
    e. Method
        i. Position: Patient's head is positioned at a 30-degree angle.
        ii. Temp: Warm and cool water or air irrigations should be performed for each ear. (Air caloric temperatures: warm 48 degrees Celsius and cool 24 degrees Celsius; water caloric: warm 44 degrees Celsius and cool 30 degrees Celsius).

Younger children may tolerate less for warm air/water. Keep consistent between ears.

iii. **Caloric calculation:** To calculate the asymmetry, the peak slow phase velocity is used (degrees/second). The peak response for right warm (RW)irrigation, right cool (RC)irrigation, left warm (LW) irrigation, and left cool (LC) irrigation are used to calculate unilateral weakness (UW) and directional preponderance (DP). While UW represents the asymmetry between the ears responses, the directional preponderance represents the stronger beating nystagmus in one direction compared to the other direction.

100 x (RW+RC)-(LW+LC)/ (RW+RC+LW+LC) = % UW
100 x (RW+LC)-(LW+RC)/ (RW+LC+LW+RC) = % DP

*If horizontal spontaneous nystagmus is observed in the pre-caloric position, it should be added into the calculation to adjust for this.

iv. **Acronym:** COWS (Cold Opposite Warm Same) is used to remember the expected response. For example, left cold irrigations will yield right beating nystagmus, whereas left warm irrigation will yield left beating nystagmus

v. **Irrigation recording time:** 60 seconds for air/40 sec for water; consider reducing this time for younger children

vi. **Flow Rate:** Water: 250 ml/min

vii. **Time in between:** 5-minute interval between each irrigation is necessary to ensure complete decay of nystagmus response from previous irrigation

viii. **Tasking:** Mental tasking is performed to avoid suppression of nystagmus. Consider the use of age-appropriate tasking (i.e., nursery rhymes, songs, easy trivia questions, colors, ice cream flavors, pizza toppings, cartoons, etc.).

ix. **Suppression Fixation:** A fixation index of at least 50% should be obtained to determine central mechanisms are intact

x. **Hyperactive responses:** Some children may show robust responses. Based on Cincinnati Children's Hospital Medical Center unpublished normative data an SPV greater than 50 deg/sec with air stimulation is considered a central vestibular finding. In the literature responses have been established to be hyperactive when greater than 40 to 80 deg/sec [152]or if the total of all 4 caloric irrigation is greater than 140 deg/sec. The right ear and/or left ear can be considered hyperactive if the total for that ear is greater than 110.[153]

xi. **PE tubes/TM perforation:** When using warm caloric irrigations on patients with tympanic membrane perforations or PE tubes you may get a paradoxical response. The warm air actually produces a cooling effect on the wet middle ear mucosa, thus the nystagmus will be in the opposite direction than expected. A hyperactive response may be observed with this

population and based on the comfort level of the patient the irrigation time may need to be shortened.

f. Considerations and Modifications

i. Though children should have a recordable caloric response by 10 months of age, calorics are not tolerated by young children. Factors influencing this include loudness of stimulation, sensitivity to temperature, being tested in the dark, and the sensation of dizziness. Consider lowering the warm temperature, performing monothermal irrigations[154], or shortening the test time to improve compliance[150].

ii. Only air caloric irrigations should be used on patent tympanic membranes (ex: perforation or PE tube).

iii. May not perform if other vestibular tests confirm bilateral hypofunction, or consider using ice water caloric(not always available)

iv. Monothermal screening may be applied if meets the following criteria:[149]

1. Warm monothermal caloric asymmetry (MCA) < 15 %
2. Responses from each ear are > 8 degrees per second
3. Any spontaneous nystagmus present is <4 degrees per second

v. *Downfall of Caloric Irrigations: The variability in the strength of the caloric response from individual to individual can be due to external ear canal size and efficiency of thermal energy transfer across the middle ear*

vi. Be aware that certain medications may interfere with the VNG test battery causing both inhibitory and excitatory responses

V. Pediatric Rotational Chair

1. **Test Name**: Rotational Chair. There are three rotational chair tests used clinically with pediatric patients: sinusoidal harmonic acceleration (SHA), step velocity, vestibulo-ocular reflex (VOR) suppression.

2. **Purposes**: The purpose of rotational chair testing is to assess peripheral and central VOR function as well as the central vestibular system's ability to suppress the VOR.

3. **Populations Intended**: Children 10 months through adulthood can complete SHA and Step Velocity. Children 7 years through adulthood can complete VOR suppression.

4. **Expected Outcomes:**
    a. Gain: Ratio of slow-phase eye velocity to chair/head velocity
    b. Phase: Timing relationship between chair/head velocity and eye movement
    c. Gain Symmetry: Ratio of the rightward and leftward slow-phase eye velocities
    d. Time Constant: Time, in seconds, for the VOR response to decay to 37% of the peak value
    e. VOR Suppression Percentage: Percentage of VOR gain reduction with fixation

5. **Normative Data:** Equipment software has normative data for patients 5 years old through adulthood available as the basis for analyses. It is recommended that each testing center collect and establish normative data with their equipment and patient population.[155–161] The lack of normative data in young children provides future multi-center research opportunities.

6. **Practice Guidance:**

    a. **Test Component:** Sinusoidal Harmonic Acceleration (SHA)
        i. **Purpose:** Assess the vestibulo-ocular reflex (VOR) by rotating the child in a pendular (back-and-forth) pattern at various frequencies while their vision is denied
        ii. **Populations Intended:** 10 months through Adulthood
            1. VOR responses are present across all frequencies by 10 months of age. While infants younger than 10 months of age can be tested, any abnormalities found should be confirmed after 10 months of age to rule out maturational factors before a definitive statement regarding VOR function can be made.[156,160–164]
        iii. **Expected Outcome:** gain, phase, and gain symmetry
        iv. **Normative Data:** Several studies have attempted to establish pediatric normative data for SHA testing. While these studies have yielded conflicting results in relation to patient age and gain, one consistent finding is higher gain in children compared to adults. Therefore, high gain should not be considered an abnormal finding when assessing children.[155,157–159,162,164–166]
        v. **Method:** Due to nonlinearities of the vestibular system, assessment at a minimum of three frequencies is recommended. These frequencies should

include a high, a mid, and a low frequency (i.e., 0.01, 0.04, and 0.16 Hz).[156,157,159,161–163,165,167,168] If SHA results at these frequencies are normal, testing can be stopped. If SHA results at any of these frequencies are abnormal, testing should be repeated to ensure consistency before completing additional testing at adjacent frequencies. In addition, tympanometry should be performed prior to testing as middle ear dysfunction can impact results.

vi. **Considerations:** The order of testing frequencies can be varied for patient comfort and to increase compliance for completion of testing battery. Starting with a higher testing frequency (e.g., 0.16 Hz) should be considered over a low testing frequency (e.g., 0.01 Hz) as lower frequencies are more likely to provoke symptoms of motion sickness.[155,158,168] Particular consideration should be made for patients with known motion intolerance, generalized anxiety disorders (GAD), or nervousness in testing environment.

vii. **Interpretation and Reporting:**[155,156,167,168]

1. Gain:
    a. High gain: Not considered an abnormal finding for children
    b. Low gain: Peripheral vestibular pathology (unilateral or bilateral)
    c. Factors that affect gain: Fatigue, stress/anxiety, level of alertness, difficulty mental tasking[155,156,158,160,162,165,167,168]
2. Phase:
    a. Phase lead: Peripheral vestibular pathology (unilateral or bilateral)
    b. Phase lag: Central vestibular disorders.
    c. Factors that affect phase: Head movement/slippage during testing
3. Gain Symmetry:
    a. Asymmetry: Indicates a bias in the vestibular system and can be present in unilateral and/or asymmetrical bilateral peripheral vestibular pathology particularly if the pathology is in an uncompensated state.
    b. Studies have documented greater variability for gain symmetry in children compared to adults. However, it is still considered a reliable measurement.

b. **Test Component:** Step Velocity

i. **Purpose:** Evaluate the peripheral vestibular system (cupulae mechanical response) and central vestibular system (velocity storage and adaptation)

ii. **Populations Intended:** 10 months through Adulthood

1. VOR responses are present across all frequencies by 10 months of age. While infants younger than 10 months of age can be tested, any abnormalities found should be confirmed after 10 months of age to rule out maturational factors before a definitive statement regarding VOR function can be made.[156,160–164]

iii. **Expected Outcome:** gain, time constant, and time constant symmetry
iv. **Normative Data:** Current research suggests that step velocity testing results in children should fall within established adult normative data.[169]
v. **Method:** Assessment at one rotational velocity is recommended. Equipment software may default to 100 deg/s, which is a suitable velocity for the pediatric population. The rotational chair accelerates to the set velocity, maintains the velocity for 30-45 seconds, and decelerates to a stop. Acceleration and deceleration phases are completed in the clockwise and counterclockwise directions. Any abnormalities found should be repeated to ensure consistency. As with SHA testing, tympanometry should be performed prior to testing as middle ear dysfunction can impact results.
vi. **Interpretation and Reporting:**
    1. Gain:
        a. High gain: Like SHA testing, high gain is not considered an abnormal finding in children[155–158,162,164,166]
        b. Low gain: Peripheral vestibular pathology (unilateral or bilateral) or central vestibular pathology
    2. Time Constant:[156,164,168]
        a. Reduced time constants (<10 seconds): Peripheral vestibular pathology (unilateral or bilateral) or central vestibular pathology. Correlate with phase lead in SHA testing
        b. Long time constants (>26 seconds): Central vestibular pathology, migraine, or motion intolerance
    3. Time Constant Symmetry:[156,164,168]
        a. Asymmetry of time constant (>30%) is consistent with unilateral peripheral pathology

c. **Test Component:** Vestibulo-ocular (VOR) Suppression
i. **Purpose:** Assess the central vestibular pathway's ability to suppress the VOR
ii. **Populations Intended:** 7 years old through Adulthood[155,164]
    1. Testing can be performed with children who demonstrate an understanding of the test instructions and ability to maintain visual focus on the target
iii. **Expected Outcome:** Percentage of VOR gain reduction with fixation
iv. **Normative Data:** Expected VOR suppression in adults is greater than 70% across frequencies.[167] Like SHA testing, there is a lack of established pediatric normative data. Greater variations in VOR gain reduction are possible given the well documented high VOR gains in the pediatric population.
v. **Method:** Assessment at two frequencies, a high and a low frequency (i.e., 0.16 Hz and 0.04 Hz) is recommended.[155,167,168] Select frequencies previously completed with SHA testing, however frequencies below 0.04 Hz should not be assessed.[164] Any abnormalities found should be repeated to ensure consistency.
vi. **Interpretation and Reporting:**
    1. VOR Gain Suppression Percentage:

a. Low suppression: Indicative of central vestibular pathology[155,161,164,168]
    i. Cross-check for other abnormal central vestibular test findings

7. Pediatric Considerations and Modifications:

a. **Calibration:** Standard calibration should be completed if the patient is at an age/developmental level to participate in the task. Default calibration is often used with infants and young children when standard calibration cannot be adequately performed.

b. **Seating and Head Position:**
    i. Children should be in a seated position, properly buckled in the rotational chair. Infants and young children under 40 pounds can utilize a car seat designed for use with the rotational chair. Children who do not tolerate sitting in the car seat can sit in the lap of a caregiver. Children over 40 pounds can be seated on booster seat or standard seat of the rotary chair depending on their height.
    ii. The child's head should be positioned to ensure the horizontal canal is in the lateral plane and secured in a way to avoid excessive movement during testing.[155,159,162,168] This can be achieved by holding the child's head throughout testing when seated on a caregiver's lap or using Velcro straps that are similarly used in testing adult patients when seated in the rotational chair, car seat, or booster seat.
    iii. Young children can hold a toy for comfort during testing; however, light up toys are prohibited. Additionally, shoes that light up should be removed prior to testing and caregivers with watches that light up should remove their watch if riding with their child.

c. **Recording Method**: Various recording methods are available for rotational chair testing. The recording method used will be dependent on child's age, size, developmental level, and overall compliance.[155,162,164]
    i. Currently there are no commercially available binocular goggles sized for infants and young children to allow for video data collection and the pediatric-sized goggles available are designed to fit school-aged children.
    ii. Testing with electronystagmography (ENG) electrodes and/or infrared camera is recommended for infants and young toddlers until goggle options are an appropriate physical fit on the head/face. The downside of using an infrared camera is that is only allows subjective observation of the VOR response. Given the lack of gain, phase, and symmetry data, only the presence/absence of a VOR response can be reported. The infrared camera cannot be used for VOR suppression testing.
    iii. Monocular goggles fit children around 2 years of age. If children are sitting with a caregiver, consider instructing the caregiver to assist with goggle retention during testing. When children are resistant to goggle placement, goggles may

be held to the patient's face to allow for video data collection, however this may not be feasible for step velocity testing given the speed of rotation.

iv. Adult binocular goggles can be used if a binocular recording is preferred and both eyes can be centered between the goggles and software; however, there is the potential for gapping between the child's face and goggles. Other modifications to the testing environment may be needed to ensure a vision denied state if testing is not conducted in an enclosed rotational chair

d. Tasking:

i. Tasking should focus on keeping the child mentally distracted, aware, alert, and motivated to keep their eyes open, while minimizing excessive eye blinking/shifting, fear, and crying throughout testing. Include a caregiver as a familiar voice for the child's comfort and compliance for testing. The child's language and developmental level should be taken into consideration when determining appropriate tasking speed and difficulty. If suppression of the VOR is suspected, increasing the difficulty of tasking is recommended.[155,156,158,160,162,165,167,168]

ii. Examples of tasking by age include:

1. Infants: Singing favorite songs/nursery rhymes, reciting stories, and other age-appropriate acoustic rituals
2. Preschool: Asking simple questions about their daily routine, family/friends, and favorite activities can be incorporated once child has the speech and language skills to answer "wh" questions.
3. 5 - 9 years old: Asking questions about their home/school routine, family/friends/pets, and favorite activities (i.e., sports, movies/tv/video games, books).
4. 10 years and older: Asking questions about their family/friends/pets, and favorite activities (i.e., sports/dance/martial arts), reciting plots of movies/books, steps in recipes, listing school schedule, and/or describing their room/house.

e. **Testing Environment:** To fully deny vision, a rotational chair with light free enclosure is recommended. To minimize patient fear/anxiety in the testing environment, visual access can be allowed as needed between cycles throughout testing.

1. Examples: Opening pediatric monocular goggle cover, opening rotational chair enclosure door, using light emitting toys

8. **Supplies:** Standard goggles, pediatric goggles, infrared camera, ENG electrodes/leads, car seat, booster seat, intercom, wireless video camera, illuminated toys for mid-line focus, quiet toys for patient distraction/comfort

9. **Infection Control Procedures:** All testing procedures must follow universal precautions (e.g., prevention of bodily injury and transmission of infectious disease). Decontamination, cleaning, disinfection, and sterilization of multiple-use equipment (e.g., goggles, electrode leads,

seating) must be carried out at the completion of testing according to facility-specific infection control policies and procedures and according to manufacturer's instructions

10. **Reporting:** Written interpretation of results, recommendations and additional referrals should use language appropriate for caregivers, healthcare providers, educators, and other intervention providers.

VI. Pediatric Vestibular Questionnaires

1. **Test Name**: Questionnaires available for the pediatric population differ from their adult counterparts because in some instances the data is collected by a caregiver or tester. While there are a variety of questionnaires that can be used with children, four interview-style questionnaires will be detailed below including the Vanderbilt Pediatric Dizziness Handicap Inventory for Patient Caregivers (DHI-PC)[170], the Ages and Stages Questionnaire (ASQ)[171], the Pediatric Vestibular Symptom Questionnaire (PVSQ)[172], and the Pediatric Visually Induced Dizziness Questionnaire (PVID)[173]. Additional questionnaires such as the Fear of Falling Avoidance Behavior Questionnaire are also available. It should also be noted that some scales can be useful when obtaining the case history. For example, children can be asked to rank the degree of their dizziness (0 – 10; 0 = no dizziness while 10 = unable to move because of dizziness). The FACES pain scale or FLACC (Face, Legs, Activity, Cry) scales can be used for younger children to gauge the degree of their dizziness.

2. **Purpose**: To gain a better understanding of any symptoms the child is experiencing and determine if the child needs a diagnostic vestibular evaluation. In addition, questionnaires can help the clinician better understand the impact of vestibular impairment/symptoms on the child and help guide treatment/management. Questionnaires may also be used to track progress towards therapy goals using the pre-/post-test paradigm. No specialized equipment is needed, and the questionnaire can be completed prior to the test visit or at a separate appointment.

3. **Expected Outcome and Methods**: See below for each questionnaire:

1. **Test component**: **Ages and Stages Questionnaire – Gross Motor Section Only**[171]
    a. **Purpose:** To evaluate age-appropriate gross motor milestones.
    b. **Population:** Birth to 60 months of age.
    c. **Expected Outcome:** The score for each milestone associated with the child's age is added and used to determine if the child is above, close to, or below the cut off score. The recommendation is to seek services if below target and monitor closely if close to the cutoff.
    d. **Method:** The caregiver answers 6 questions about the child's progress toward an age-appropriate gross motor milestone, indicating "Yes" (10 points), "Sometimes" (5 points), or "Not Yet" (0 points). The points are totaled for the gross motor section and a cut off score is given based on the child's age.
    e. **Normative Data:** Once the questionnaire is completed, the score is plotted on the score sheet. If the score falls in the darkest shaded section, this suggests the child is below the cutoff score and is not yet meeting age-appropriate gross motor targets; therefore, the child should be referred for services (ex: Physical Therapy). If the score falls in the light shaded section, this suggests the child is close to the cut off score and should be monitored. If the score falls in the white section, this suggests the child is above the cut off and no intervention is needed.
    f. **Considerations:** This is a helpful screener that can be quickly given at a hearing aid check or other audiological appointment. The test seems most sensitive for

vestibular losses that are bilateral or uncompensated. This test can be given more than once as a child grows and has different motor expectations.

2. **Test Component: Vanderbilt Pediatric Dizziness Handicap Inventory- Patient Caregiver (DHI-PC)**[170]
    a. **Purpose:** This is a validated dizziness disability/handicap outcome measure for use with the pediatric population. This questionnaire gives information on the functional impact of the child's dizziness on their life and quantifies the psychosocial impact.
    b. **Population:** Children ages 5-12 years of age
    c. **Expected Outcome:** Children who are affected the most by dizziness will have a higher score.
    d. **Method:** The caregiver will answer "yes" (4 points), "sometimes" (2 points), or "no" (0 points) to 21 questions about their child's dizziness. The total score is out of 84.
    e. **Normative Data:** A DHI-PC total score of 0–16 indicates no participation and activity limitation; A score of 16–26 indicates mild participation and activity limitation; A score of 26–43 indicates moderate participation and activity limitation; A score >43 points indicates severe participation and activity limitation.
    f. **Considerations:** Can be used as a pre-/post-test treatment measure. Proxy bias should be considered when evaluating the scoring.
3. **Test Component: The Pediatric Vestibular Symptom Questionnaire (PVSQ)**[172]
    a. **Purpose:** To screen children for vestibular symptoms
    b. **Population:** Children ages 6 – 17 years
    c. **Expected Outcome:** Children with higher scores have greater symptom severity. **Method:** Children answer 10 questions about how often they feel dizziness or unsteadiness. They rate the severity of their vestibular symptoms in the past month using a Likert scale: 0 (never), 1 (Almost never), 2 (Sometimes), and 3 (most of the time). Of note, this scale is not reflected in the published questionnaire; however, the 0 – 3 scale should be used when scoring. Children are asked to respond with the help of a parent or caregiver as needed.
    d. **Normative Data:** Scores $\geq$ 0.68 out of 3 can differentiate a child with a vestibular disorder or concussion from a healthy child (95% sensitivity and 85% specificity) and indicate the need for a diagnostic vestibular evaluation.
    e. **Considerations:** The PVSQ is valuable in differentiating healthy children from children with vestibular symptoms; however, does not differentiate children with vestibular dysfunction from children with concussion.
4. **Test Component: Pediatric Visually Induced Dizziness Questionnaire (PVID)**[173]
    a. **Purpose:** To quantify the presence and severity of visually induced dizziness.
    b. **Population:** Children ages 6 – 17 years
    c. **Expected outcome:** Children with higher scores have greater symptom severity.
    d. **Method:** Children answer 11 questions about how often they feel dizziness or unsteadiness in different places and situations. They rate the severity of their vestibular symptoms in the past month using a Likert scale: 0 (never), 1 (Almost

never), 2 (Sometimes), and 3 (most of the time). Children are asked to respond with the help of a parent or caregiver as needed.

e. **Normative Data:** Scores ≥ 0.45 out of 3 can differentiate a child with visually induced dizziness from a healthy child (83% sensitivity and 75% specificity) which may be helpful for guiding treatment. The patient group consisted of children with migraine, concussion, and vestibular dysfunction. Although not statistically significant, children with vestibular dysfunction had the highest scores, followed by concussion and migraine.

f. **Considerations:** The PVID is valuable in differentiating healthy children from children with visually induced symptoms; however, does not differentiate children with migraine, concussion, and vestibular dysfunction from one another.

Appendix: Questionnaires

Pediatric Vestibular Symptom Index

Table I. The PVSQ

The following questions ask about how often you feel dizziness and unsteadiness. Please circle the best answer for you.
How often in the past month have you felt the following?

1. A feeling that things are spinning or moving around

3	2	3	4	?
Most of the time	Sometimes	Almost never	Never	Don't know

2. Unsteadiness so bad that you actually fall

3	2	3	4	?
Most of the time	Sometimes	Almost never	Never	Don't know

3. Feeling sick

3	2	3	4	?
Most of the time	Sometimes	Almost never	Never	Don't know

4. A light-headed or swimmy feeling in the head

3	2	3	4	?
Most of the time	Sometimes	Almost never	Never	Don't know

5. Feeling of pressure in the ear(s)

3	2	3	4	?
Most of the time	Sometimes	Almost never	Never	Don't know

6. Blurry vision, difficulty seeing things clearly, and/or spots before the eyes

3	2	3	4	?
Most of the time	Sometimes	Almost never	Never	Don't know

7. Headache or feeling of pressure in the head

3	2	3	4	?
Most of the time	Sometimes	Almost never	Never	Don't know

8. Unable to stand or walk without holding on to something or someone

3	2	3	4	?
Most of the time	Sometimes	Almost never	Never	Don't know

9. Feeling unsteady, about to lose balance

3	2	3	4	?
Most of the time	Sometimes	Almost never	Never	Don't know

10. A fuzzy or cotton wool feeling in the head

3	2	3	4	?
Most of the time	Sometimes	Almost never	Never	Don't know

11. Do any of these symptoms stop you doing what you want to do?
If yes, which ones? .....

Questionnaire copy not to scale.

1340 **Vanderbilt Pediatric Dizziness Handicap Index Patient Caregiver**

NAME: DATE:

VANDERBILT PEDIATRIC DIZZINESS HANDICAP INVENTORY (DHI) (Age 5-12)

Instructions: The purpose of this questionnaire is to identify difficulties that your child may be experiencing because of his or her dizziness or unsteadiness. Please answer "yes", "no", or "sometimes" to each question. **Answer each question as it pertains to your child's dizziness problem only.**

	Yes (4)	Sometimes (2)	No (0)
1. Does your child's problem make him/her feel tired?			
2. Is your child's life ruled by his/her problem?			
3. Does your child's problem make it difficult for him/her to play?			
4. Because of his/her problem, does your child feel frustrated?			
5. Because of his/her problem, has your child been embarrassed in front of others?			
6. Because of his/her problem, is it difficult for your child to concentrate?			
7. Because of his/her problem, is your child tense?			
8. Do other people seem irritated with your child's problem?			
9. Because of his/her problem, does your child worry?			
10. Because of his/her problem, does your child feel angry?			
11. Because of his/her problem, does your child feel "down"?			
12. Because of his/her problem, does your child feel unhappy?			
13. Because of his/her problem, does your child feel different from other children?			
14. Does your child's problem significantly restrict his/her participation in social or educational activities, such as going to dinner, meeting with friends, field trips, or to parties?			
15. Because of your child's problem, is it difficult for him/her to walk around the house in the dark?			
16. Because of his/her problem, does your child have difficulty walking up stairs?			
17. Because of his/her problem, does your child have difficulty walking one or two blocks?			
18. Because of his/her problem, does your child have difficulty riding a bike or scooter?			
19. Because of his/her problem, does your child have difficulty reading or doing schoolwork?			
20. Does your child's problem make it difficult to successfully do activities that others his/her age can do?			
21. Because of his/her problem, does your child have trouble concentrating at school?			
		TOTAL SCORE	

McCaslin DL, Jacobson GP, Lambert W, English LN, Kemph AJ (2015). "The development of the vanderbilt pediatric dizziness handicap inventory for patient caregivers (DHI-PC)." *Int J Pediatr Otorhinolaryngol.* 79 (10): p1662-1666. doi: 10.1016/j.ijporl.2015.07.017

Significant change: >18 points; 0-16 no activity limitation; 16-26 mild activity limitation; 26-43 moderate activity limitation; >43 severe limitation

1341
1342

Ages and Stages Questionnaire Example (Gross Motor Questions only), excerpt

ASQ-3 — 36 Month ASQ-3 Information Summary

34 months 16 days through 38 months 30 days

Child's name: _____ Date ASQ completed: _____

Child's ID #: _____ Date of birth: _____

Administering program/provider: _____

1. **SCORE AND TRANSFER TOTALS TO CHART BELOW:** See *ASQ-3 User's Guide* for details, including how to adjust scores if item responses are missing. Score each item (YES = 10, SOMETIMES = 5, NOT YET = 0). Add item scores, and record each area total. In the chart below, transfer the total scores, and fill in the circles corresponding with the total scores.

Area	Cutoff	Total Score	0	5	10	15	20	25	30	35	40	45	50	55	60
Communication	30.99		●	●	●	●	●	●	●	○	○	○	○	○	○
Gross Motor	36.99		●	●	●	●	●	●	●	●	○	○	○	○	○
Fine Motor	18.07		●	●	●	●	○	○	○	○	○	○	○	○	○
Problem Solving	30.29		●	●	●	●	●	●	●	○	○	○	○	○	○
Personal-Social	35.33		●	●	●	●	●	●	●	●	○	○	○	○	○

2. **TRANSFER OVERALL RESPONSES:** Bolded uppercase responses require follow-up. See *ASQ-3 User's Guide*, Chapter 6.

1. Hears well? Yes **NO** — Comments:
2. Talks like other children his age? Yes **NO** — Comments:
3. Understand most of what your child says? Yes **NO** — Comments:
4. Others understand most of what your child says? Yes **NO** — Comments:
5. Walks, runs, and climbs like other children? Yes **NO** — Comments:
6. Family history of hearing impairment? **YES** No — Comments:
7. Concerns about vision? **YES** No — Comments:
8. Any medical problems? **YES** No — Comments:
9. Concerns about behavior? **YES** No — Comments:
10. Other concerns? **YES** No — Comments:

3. **ASQ SCORE INTERPRETATION AND RECOMMENDATION FOR FOLLOW-UP:** You must consider total area scores, overall responses, and other considerations, such as opportunities to practice skills, to determine appropriate follow-up.

If the child's total score is in the ▭ area, it is above the cutoff, and the child's development appears to be on schedule.
If the child's total score is in the ▭ area, it is close to the cutoff. Provide learning activities and monitor.
If the child's total score is in the ■ area, it is below the cutoff. Further assessment with a professional may be needed.

4. **FOLLOW-UP ACTION TAKEN:** Check all that apply.

_____ Provide activities and rescreen in _____ months.
_____ Share results with primary health care provider.
_____ Refer for (circle all that apply) hearing, vision, and/or behavioral screening.
_____ Refer to primary health care provider or other community agency (specify reason): _____.
_____ Refer to early intervention/early childhood special education.
_____ No further action taken at this time
_____ Other (specify): _____

5. **OPTIONAL:** Transfer item responses (Y = YES, S = SOMETIMES, N = NOT YET, X = response missing).

	1	2	3	4	5	6
Communication						
Gross Motor						
Fine Motor						
Problem Solving						
Personal-Social						

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Conclusion:

Vestibular function testing is recommended in children with complaints of dizziness and in children with imbalance or delays in gross motor milestones. This document was meant to serve as a guide for choosing the appropriate vestibular function tests when working with young children. **Table 1** provides a brief overview of the vestibular function tests available by age of the child. Whether or not vestibular function tests yield positive findings, children may need additional evaluation by other practitioners. Physical therapists and occupational therapists are the most common complement to the diagnostic assessment; however, children may also need assessment by psychology for underlying psychological comorbidities (i.e., anxiety), developmental optometry, cardiology, or neurology. While finding individuals in each of these disciplines can be challenging, they all provide a unique contribution to the assessment and rehabilitation of children with dizziness. Thus, having knowledge of these disciplines is necessary when working with pediatric vestibular patients. Children have activities of daily living that are different than adults, so the overall goal of assessment and intervention should be to arrive at the best recommendations to help the child return to their lives without hinderance to educational, social, and developmental outcomes.

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