CHAPTER

07 Paediatric Vestibular Assessment



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'Children's developing systems require not only smaller tools, but greater insight.'

~Piaget

Summary

This chapter explores the unique considerations for paediatric vestibular assessment, including developmental factors, test modifications, and interpretation of results. It highlights the importance of age-appropriate normative data and discusses practical strategies for optimising test outcomes in young or non-compliant children. By addressing the distinct challenges of assessing vestibular function in the paediatric population, this chapter aims to provide hearing healthcare professionals with the knowledge and tools needed to support early and accurate diagnosis and rehabilitation, ultimately improving outcomes for children with vestibular disorders.

Learning objectives

From this chapter, the reader will be able to:

1. Identify the common signs and symptoms of vestibular dysfunction in the paediatric population.
2. Recognise the unique challenges and considerations involved in assessing vestibular function in children.
3. Describe the key diagnostic tools and test protocols used in paediatric vestibular assessment, including their indications, procedures, and limitations.
4. Develop a comprehensive approach to diagnosing and managing vestibular disorders in the paediatric population.

Introduction

The vestibular system plays a critical role in maintaining balance, spatial orientation and gaze stability. In children, vestibular disorders can negatively affect both intellectual and physical development, with consequences for motor skills, learning and academic performance (Rogers 2010; Gioacchini et al. 2014). One key mechanism of the vestibular system is the vestibulo-ocular reflex (VOR), which stabilises vision during head movements. Impaired VOR function in children can make it difficult to keep text in focus during reading tasks, particularly in dynamic classroom environments that require frequent head movements, such as copying from the board or shifting attention between peers and materials. This visual instability may lead to impaired reading fluency, diminished comprehension and increased visual fatigue. Vestibular dysfunction can also disrupt spatial and non-spatial cognitive processes, delay gross and fine motor development and contribute to broader learning difficulties (De Kegel et al. 2012; Wiener-Vacher et al. 2013). Likewise, Franco and Panhoca (2008) found a statistically significant association between peripheral vestibular dysfunction and underperformance in school. A systematic review by Gioacchini et al. (2014) reported a prevalence of up to 15% for vestibular disorders in the paediatric population.

Vestibular-mediated reflexes are present at birth (for example, head righting response: an automatic body reaction that keeps the head straight, level, and upright relative to the ground) (Adamović et al. 2020). Children with impairments that alter the vestibular reflexes are slower than their normal counterparts in reaching motor key milestones (Inoue et al. 2013). In the paediatric population, disruptions in vestibular function can significantly impact motor development, coordination and overall quality of life. Despite its consequences, vestibular dysfunction in the paediatric population often goes underdiagnosed, partly due to the challenges of identifying and assessing vestibular impairments in this age group. Children might present with subtle or non-specific symptoms, such as delayed motor milestones, poor balance or frequent falls, which can easily be attributed to other causes.

Advances in diagnostic techniques have facilitated the evaluation of vestibular function in the paediatric population, enabling early detection and management of vestibular disorders. Paediatric vestibular assessments now encompass a range of assessment methods, including caloric testing, rotational chair testing, vestibular-evoked myogenic potentials (VEMPs) and video head impulse testing (vHIT). These tools, when combined with a thorough case history and clinical observation, provide a comprehensive approach to identifying vestibular dysfunction in children. However, the outcomes of these assessments are significantly influenced by the child's developmental stage, willingness to participate, capacity to co-operate and comprehension of the test instructions. As the vestibular test battery comprises multiple procedures, it is crucial to identify, prioritise and begin with the most suitable tests for each specific patient. This approach aims to maximise the diagnostic information obtained within a limited timeframe, acknowledging the potential for diminished concentration in younger patients. The overall aim of the assessment is to determine if the child presents with a possible peripheral or central vestibular disorder, guiding further intervention and referrals to other healthcare professionals.

Case History

The case history is essential in the paediatric vestibular assessment. It must be conducted at the outset as it provides critical context to guide test selection, interpretation, and clinical management. Children may not be able to describe their symptoms accurately, making a thorough history crucial for identifying potential vestibular dysfunction. Parents and caregivers

are essential sources of information when obtaining a comprehensive case history, particularly for non-verbal children. The hearing healthcare professional (HHP) relies on caregivers to report the child's developmental milestones, general behaviour and observations of balance and gait, as well as any avoidance behaviours, such as fear of heights or reluctance to walk in the dark or on uneven surfaces. To facilitate the case history, HHPs may provide a questionnaire, such as the Vanderbilt Paediatric Dizziness Handicap Inventory (VPDHI) (McCaslin et al., 2015) for caregivers to complete at home with the child or by observing the child before the day of testing. For verbal children, this questionnaire approach also allows the child to share details more comfortably and openly in a familiar environment. In addition, the caregiver can ask these questions in the child's first language. In this way, the HHP can clarify and confirm the information with the child on the day of the assessment. It is important to use age-appropriate language when communicating with the paediatric population and to avoid jargon (Chapter 15). Collecting detailed background information provides valuable context for interpreting vestibular assessment results and tailoring appropriate management strategies.

The case history should focus on family history, medical history, the impact of symptoms on the child's daily life, behavioural observations of the child, as well as the following aspects.

Prenatal and birth history

Understanding a child's prenatal and birth history is essential in identifying potential factors that may contribute to vestibular dysfunction. Maternal infections during pregnancy, such as cytomegalovirus (CMV) or rubella, can impact the developing auditory and vestibular system. Similarly, the use of certain medications during pregnancy may pose ototoxic or neurodevelopmental risks. Birth complications, including prematurity, hypoxia or low birth weight, can also affect the integrity of the inner ear and central nervous system (Chapters 2 and 3).

Developmental milestones

A child's developmental milestones provide insight into their vestibular function and overall motor development. The timing of major milestones, such as sitting, crawling, standing and walking, can indicate whether vestibular or motor delays are present. Delays in achieving

these milestones may suggest vestibular hypofunction or other underlying issues affecting balance. Additionally, difficulties with gross motor skills, such as frequent falls or an inability to navigate age-appropriate physical tasks, can further highlight potential vestibular dysfunction. It has been reported that gross motor milestones predict vestibular loss in children with hearing loss (HL) (Janky and Shepard 2019).

Hearing and vision history

A history of HL, tinnitus or recurrent ear infections can signal potential inner ear dysfunction, which may impact both auditory and vestibular pathways. Similarly, pathologies of the visual system, such as strabismus (misalignment of the eyes) or difficulty focusing, can exacerbate balance problems or contribute to sensory integration challenges.

Symptom inquiry



Treasures of Wisdom

Case History

- Encourage parents/caregivers to complete a case history questionnaire with their child before the assessment.
- Use age-appropriate language to communicate with the child and give the child an opportunity to explain their symptoms.
- Use open-ended questions that encourage the child to describe their symptoms.

A structured approach, such as the **SOSTONED** acronym—**S**ymptoms, **O**nset, **S**ituation, **T**riggers, **O**thers affected, **N**eurological symptoms, **E**volution and **D**uration—can ensure that a thorough and systematic history is obtained. The HHP should elicit a detailed description of the child's symptoms in their own words, including:

- Type of sensation: for example, room spinning, feelings of falling, nausea, vomiting or imbalance in specific situations.
- Onset and evolution: sudden or gradual onset, changes over time, duration and frequency of symptoms.
- Situational context and triggers: for example, during movement, positional changes, exposure to loud sounds, or visual stimuli.
- Environmental factors: whether others in the environment experienced similar

symptoms (to rule out environmental causes).

- Neurological symptoms: for example, blurred or double vision, numbness or photophobia.

Table 7.1 outlines the symptoms that can be expected with a peripheral vestibular pathology versus central pathology.

Table 7.1: Symptoms of a peripheral vestibular pathology versus central pathology

Peripheral Vestibular Pathology	Central Pathology
Sudden onset of symptoms	Gradual onset of symptoms
Intermittent attacks with severe symptoms	Symptoms are constant but mild.
Symptoms are worsened by changes in head position and movement.	Symptoms are unaffected by head position and movement.
Nausea and vomiting are severe and frequent.	Nausea and vomiting are infrequent and mild.
Motor function, gait and coordination are typically intact.	Motor function, gait instability and loss of coordination are more likely to occur.

Vestibular Test Battery

Once a comprehensive case history has been conducted, the HHP should determine which test procedures to prioritise. The vestibular test battery comprises a series of diagnostic tools designed to evaluate the functional integrity of the peripheral vestibular system, as no single test can evaluate all aspects of vestibular function. Each test targets specific components, including the semicircular canals, otolith organs and their associated neural pathways. In the paediatric population, selecting appropriate tests requires careful consideration of developmental stages, co operation levels and the presenting symptoms. By combining physiological and behavioural measures, HHPs can obtain a detailed understanding of the child's vestibular function.

Behavioural test battery

Behavioural vestibular assessments play a critical role in evaluating balance and spatial orientation in paediatric populations, especially when physiologic testing may not be feasible, readily available or tolerated. These tests rely on observing the patient's responses to structured tasks that challenge the vestibular system in age-appropriate and developmentally appropriate ways. The behavioural test battery offers valuable insights into vestibular function by assessing postural control, gaze stability and compensatory strategies through non-invasive and often play-based methods. In children, especially those under the age of five years or with neurodevelopmental differences, behavioural assessments serve as a practical and informative alternative or complement to physiologic vestibular tests. Table 7.2 outlines the components, administration and interpretation of the behavioural vestibular test battery, emphasising its clinical relevance and adaptability across the paediatric age range.

These behavioural vestibular assessments provide a crucial and adaptable approach to evaluating vestibular function in children, particularly when traditional physiologic tests are not practical or tolerated. By using these observation-based, developmentally appropriate methods, HHPs can gather meaningful information about a child's balance, gaze stability and spatial orientation. These assessments are especially valuable in younger children (under three years) and those with neurodevelopmental differences, offering a flexible, non-invasive means of identifying vestibular impairments. When integrated with caregiver input and physiologic clinical findings, behavioural vestibular assessments enhance diagnostic accuracy and support early intervention planning, reinforcing their indispensable role in paediatric vestibular evaluation.

Table 7.2: The components, description and interpretation of the behavioural vestibular test battery

Test	Age Range	Test Description	Instructions (Age-Appropriate Language)	Interpretation
Romberg Test	3+ years	Assesses postural stability with eyes open and closed to identify proprioceptive or vestibular deficits.	"Stand like a statue with your feet together. First keep your eyes open, then close them and stay very still."	Normal: Stable with minor sway. Abnormal: Excessive sway or falling with the eyes closed may indicate vestibular or proprioceptive dysfunction.
Modified Clinical Test of Sensory Interaction on Balance (mCTSIB)	4+ years	Evaluates balance under different sensory conditions, including firm and foam surfaces with the eyes open and closed.	"Let's play a balance game! You'll stand still on different surfaces with your eyes open and closed."	Poor performance on foam with the eyes closed may indicate vestibular dysfunction.

Test	Age Range	Test Description	Instructions (Age-Appropriate Language)	Interpretation
Head Impulse Test (Bedside vHIT)	5+ years	Assesses semicircular canal function through high-acceleration head impulses while monitoring eye movement.	"Keep your eyes on my nose. I'm going to give your head a quick turn!"	Normal: Eyes remain on the target. Abnormal: Eyes move off the target with a catch-up saccade, indicating peripheral vestibular loss.
Head Shake Test	5+ years	The head is shaken from side to side. The presence of nystagmus after movement may indicate unilateral dysfunction.	"I'm going to gently shake your head from side to side. Just relax and keep looking straight ahead."	Post-head-shake nystagmus suggests unilateral vestibular hypofunction.

Test	Age Range	Test Description	Instructions (Age-Appropriate Language)	Interpretation
Dynamic Visual Acuity (DVA)	6+ years	Compares visual acuity during head movement with static visual acuity to assess vestibulo-ocular reflex (VOR) function.	"Tell me what letters you see on the wall in front of you. Now I'll gently move your head while you keep reading."	A drop of more than three lines in visual acuity during head movement may suggest bilateral vestibular loss.
Oculocephalic Reflex (Doll's Eye Reflex)	0–2 years	Assesses brainstem function by observing compensatory eye movement during passive head turning.	Gently rotate the infant's head from side to side while observing the eyes. No instruction is needed.	Normal: Eyes move in the direction opposite to the head. Absent response: Possible brainstem dysfunction or vestibular loss.

Test	Age Range	Test Description	Instructions (Age-Appropriate Language)	Interpretation
Vestibular-Triggered Postural Reactions	0–2 years	Observes vestibular responses, such as head righting, during changes in position.	Observe spontaneously or during postural transitions. No instruction is needed.	Delayed or absent head righting may suggest vestibular impairment in infants.
Gait Observation and Tandem Walking	4+ years	Assesses balance and coordination by observing the walking pattern along a straight line.	"Can you walk to me on this line like you're on a tightrope?"	Normal: Smooth, stable gait. Abnormal: Ataxia, veering or a wide-based gait may indicate vestibular or cerebellar pathology.

Test	Age Range	Test Description	Instructions (Age-Appropriate Language)	Interpretation
Spontaneous and Gaze-Evoked Nystagmus (can also be performed using VNG goggles)	All ages with co-operation	Examines involuntary eye movements that may indicate vestibular or central dysfunction.	Ask the child to look straight ahead and then to the left and right. “Watch this toy or finger move.”	Present at rest: Possible acute vestibular neuritis or central pathology. Direction-changing nystagmus may indicate a central lesion.
Dix-Hallpike Test (can also be performed using VNG goggles)	5+ years	A positional test used to diagnose posterior canal benign paroxysmal positional vertigo (BPPV) by observing nystagmus and vertigo in a head-hanging position.	“I’m going to help you lie back quickly with your head turned to the side. Try to stay still and tell me how you feel.”	Torsional, upbeating nystagmus indicates posterior canal BPPV on the side of the downward ear.

Test	Age Range	Test Description	Instructions (Age-Appropriate Language)	Interpretation
General Positional Tests, for example the Supine Roll Test (can also be performed using VNG goggles)	5+ years	Assesses horizontal canal BPPV and other forms of positional vertigo by moving the child's head into various supine positions.	"We'll play a game where I move your head while you're lying down. Just relax and look at me."	Horizontal nystagmus suggests horizontal canal BPPV. Its direction and duration help differentiate geotropic and apogeotropic variants.

Physiological test battery

The physiologic vestibular test battery encompasses a range of assessments designed to objectively evaluate the functional integrity of the vestibular system. In paediatric populations, physiologic vestibular testing presents unique challenges due to developmental, cognitive and behavioural factors. However, advancements in technology and age-appropriate protocols have improved test feasibility and reliability across a wide age range. Understanding the indications, proceduresand interpretation of the available physiologic tests is essential for accurate diagnosis and effective management of vestibular disorders in the paediatric population.

a) Vestibular evoked myogenic potential (VEMP) testing

The vestibular evoked myogenic potential (VEMP) is a clinical test for assessing vestibular pathologies by evaluating otolith function (Özgür et al. 2015; Walther and Cebulla 2016). It measures an electromyographic (EMG) response elicited by sound, vibration or electrical stimulation (Murofushi 2016). Colebatch and Halmagyi (1994) first described the cervical VEMP (cVEMP) as a short-latency response from the sternocleidomastoid muscle (SCMm), mediated by the saccular macula, inferior vestibular nerve and vestibulospinal pathways. Later, Rosengren et al. (2019) and Todd, Rosengren and Colebatch (2007) identified ocular VEMPs (oVEMPs), recorded from extraocular muscles and reflecting utricular function (Rosengren et al. 2010).

The clinical application of VEMPs in the paediatric population has been proven by the test's ability to aid in the diagnosis of vestibular neuritis, congenital vestibular hypofunction, ototoxicity, vestibular migraine and superior semicircular canal dehiscence syndrome (SCDS) (Cal and Bahmad 2009). Children with syndromes associated with HL, for example, Usher syndrome and Waardenburg syndrome, often exhibit vestibular dysfunction that can be detected using VEMPs.

VEMPs are widely considered as a safe, non-invasive tool that is useful to supplement caloric, video head impulse and rotational chair testing, all of which are limited to the evaluation of the horizontal semicircular canal function and superior vestibular nerve integrity. VEMP testing is generally feasible in children aged three and older. At this age, many children are able to engage in brief periods of co-operation and, in the case of cVEMPs, can generate sufficient tonic activation of the sternocleidomastoid muscle (SCMm) through head-lift or resistance tasks. However, test success improves with age and development. For oVEMPs, children must remain still and fixate their gaze upward, which may be challenging for those under

five years. Modifications, such as using play-based approaches or shortened protocols, may enhance test feasibility in younger children. Table 7. 3 depicts the test set-up for cVEMP and oVEMP.

The test procedures for VEMPs are as follows:

- It is essential to conduct otoscopy and tympanometry (Chapter 5) before commencing with cVEMP and oVEMP testing to exclude an outer or middle ear pathology, as this would most likely result in absent responses. In cases of abnormal outer- or middle-ear functioning, bone-conduction VEMP testing can be done.
- The child can be seated independently or placed on the caregiver's lap.
- The skin should be cleaned with nu-prep to reduce impedance and surface electrodes should be placed according to the test type. The electrode impedance should not exceed 5kΩ.

Table 7.3: cVEMP and oVEMP test procedure and interpretation

Aspect	cVEMP	oVEMP
Electrode placement	Electrodes are placed on the belly of the sternocleidomastoid muscle (SCM), with a reference electrode on the sternum and a ground electrode on the forehead.	Electrodes are placed below the eyes over the inferior oblique muscle, with a reference electrode on the chin and a ground electrode on the forehead (Figure 7.1).
Test position	The patient sits upright or lies supine with the head turned away from the stimulated ear to activate the SCM. Encourage consistent muscle contraction through verbal prompts or engaging activities, such as holding a toy.	The patient sits upright and gazes at a point on the ceiling, or lies supine and gazes upward at a fixed point or toy placed at a 30–40° angle to engage the extraocular muscles.

Aspect	cVEMP	oVEMP
Test interpretation	A positive peak, referred to as P1, is recorded at approximately 13.00 ms, and a negative peak, referred to as N1, is recorded at approximately 23.00 ms, as depicted in Figure 7.2A (Chihara et al. 2007; Todd, Rosengren and Colebatch 2007; Welgampola et al. 2009). Larger amplitudes can be expected in children.	A negative peak, referred to as N1, is recorded at approximately 10.00 ms, and a positive peak, referred to as P1, is recorded at approximately 15.00 ms, as depicted in Figure 7.2B (Chihara et al. 2007; Todd, Rosengren and Colebatch 2007; Welgampola et al. 2009). Larger amplitudes can be expected in children.



Figure 7.1: oVEMP patient set-up

Figure 7.2: (a) cVEMP and oVEMP, (b) results for the right and left ear

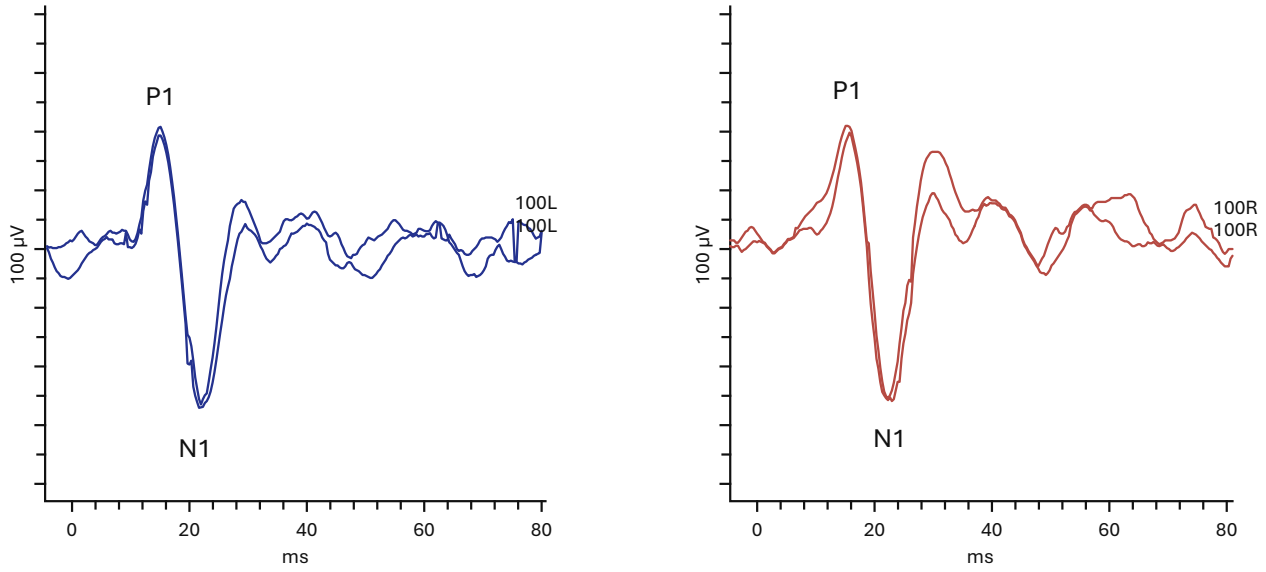


Figure 7.2: (a)

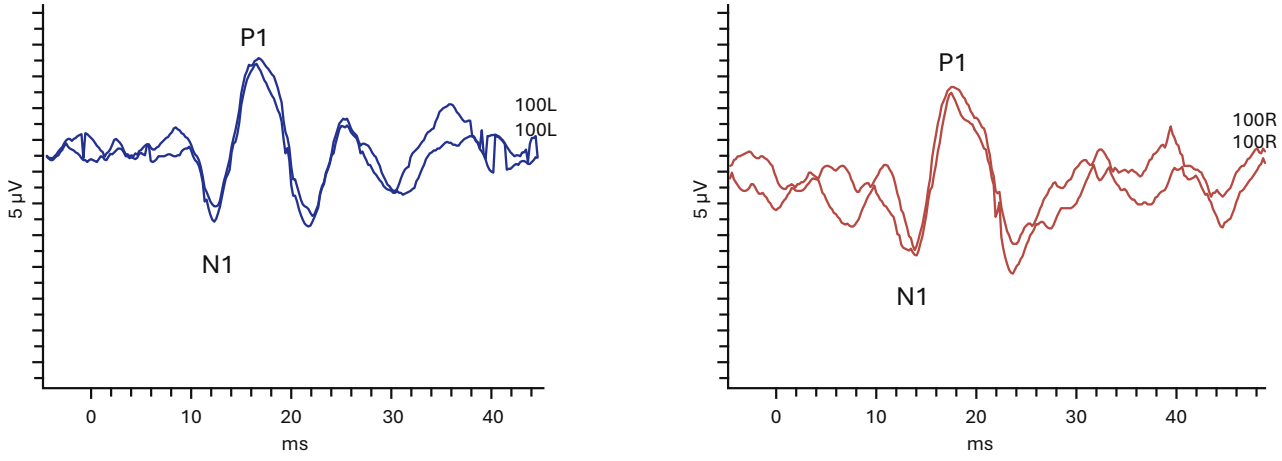


Figure 7.2: (b)

Video head impulse test (vHIT)

The video head impulse test (vHIT) provides an assessment of the function of the vestibular ocular reflex (VOR), which is one of the primary vestibular reflexes. When a child with a normal vestibular system moves their head, the eyes reflexively deviate in the opposite direction so that the image is stabilised on the retina without blurring. This reflexive eye movement is called the VOR and may also be referred to as the angular vestibulo-ocular reflex (aVOR). In recent years, the vHIT has become a valuable tool in assessing all six semi-circular canals individually at higher frequencies (Ross and Helminski 2016). This test is well tolerated by children and can also be done using a remote camera system instead of goggles (Wiener-Vacher and Wiener 2017).

When specifically looking at the paediatric population, Ross and Helminski (2016) observed challenges in the vHIT system. Due to children's smaller physical features, such as smaller head sizes and smaller eyelid openings, measurement errors seem to occur more easily than in adults. These measurement errors are caused by goggle slippage, excessive blinking, etc., which can result in artifacts and inaccurate aVOR gain recordings (Mantokoudis et al. 2014). Another consideration is that the results are dependent on the experience and skills of the examiner to elicit correct and precise impulses. Additionally, a lack of inherent stiffness of the cervical spine is observed in the paediatric population, resulting in difficulty eliciting a head impulse greater than 100°/sec2. Despite these limitations, the vHIT has proven to be a sensitive and efficient vestibular test for the paediatric population and is well tolerated by children aged three to sixteen (Hulse et al. 2015). Success depends on the patient's ability to



Treasures of Wisdom

VEMPs

- Young children may struggle to maintain the required muscle activation (for example, SCM contraction for cVEMPs or remaining still during testing. Visual aids, toys and interactive instructions can improve co-operation. For cVEMP, ask the child to look at the external EMG monitor and play a game to see how long they can hold the muscle contraction in place.
- For oVEMP place stickers on the ceiling for the child to focus on during testing.
- Modified testing techniques, such as using lower intensities, are often necessary for younger or more sensitive children.
- Interpretation requires age-specific normative data due to developmental changes in VEMP parameters and each clinic should develop its own normative data for reference.

maintain steady visual fixation and tolerate rapid, passive head movements without excessive blinking or head resistance.

a) Patient and caregiver preparation

Use a child-sized chair or allow the patient to sit on a caregiver's lap if necessary for comfort and compliance. Visual aids, toys or demonstrations may be used to reduce anxiety and gain co operation. Provide the following test instructions:

- To the caregiver: 'We're going to do a simple test to check how your child's balance system is working. It involves wearing lightweight goggles, like a pair of special glasses, which will help us see how their eyes move when we gently turn their head. The test is quick, doesn't hurt, and will only take a few minutes. You can stay right here to keep them comfortable, and I'll explain everything as we go along.'
- To the patient (for a younger child < six years): 'We're going to play a fun game! You'll wear some cool goggles, like superhero glasses, and all you have to do is keep looking at the dot on the wall (or a fun cartoon). I'm going to gently turn your head—kind of like a little dance move—but don't worry, it won't hurt at all. Just keep your eyes on the dot, and we'll finish super quickly!'
- To an older child (> six years): 'These special goggles help us see how your eyes and balance system work together. All you need to do is sit still, keep looking at the target on the wall, and I'll gently move your head back and forth a little. It won't hurt, and you'll be done before you know it!'

b) Positioning and Testing

- Seat the patient upright in a stable position.
- Align the patient's head in the horizontal plane for testing the horizontal semicircular canals or in the appropriate orientation for vertical canal testing.
- Instruct the patient to fixate on a target (for example, a dot or toy) placed at eye level about one meter away.
- Perform small, quick, unpredictable head movements (10–20 degrees amplitude) in the plane of the semicircular canal being tested, ensuring the movements are

within physiological range and not abrupt or excessive.

- Test each ear separately by rotating the head to the left and right for horizontal canals or tilting for vertical canals.

c) Test interpretation and normative values

Normative data for paediatric populations is age-dependent and varies slightly between studies (Table 7.4). Figure 7.3 depicts normal vHIT results and VOR function of the right and left lateral canals, and Figure 7.4 demonstrates abnormal VOR function of the right lateral canal, with reduced gain and covert saccades observed at approximately 100 ms and covert saccades observed at approximately 200 ms.

Table 7.4: Age-based normative vHIT data for paediatric patients

vHIT Parameters	Typical Range/Interpretation
VOR Gain – Horizontal Canals (Infants & Toddlers, up to three years)	Approximately 0.60–0.75
VOR Gain – Horizontal Canals (Preschool-aged, 4–6 years)	Approximately 0.75–0.90
VOR Gain – Horizontal Canals (older children and adolescents, 7+ years)	Approximately 0.90–1.00
VOR Gain – Vertical Canals	Typically lower than horizontal canals; ~0.60–0.85 depending on age and canal
Asymmetry (Inter-ear Gain Difference)	< 7% is considered normal
Latency of Corrective Saccades	Presence of covert or overt saccades suggests semicircular canal dysfunction

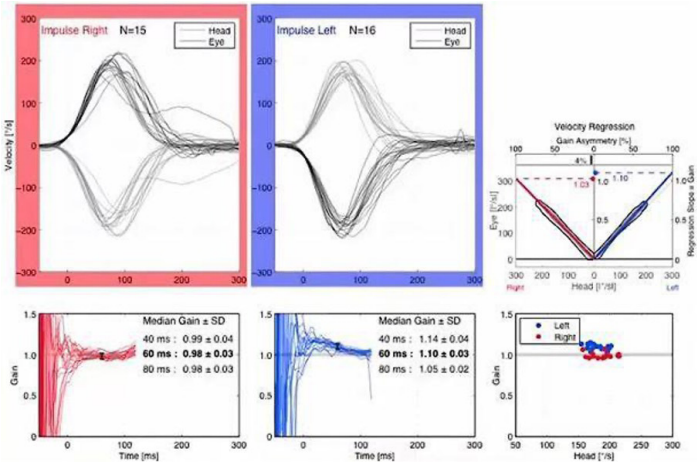


Figure 7.3: vHIT results depicting normal VOR function of the right and left lateral canals (Interacoustics A/S, 2023)

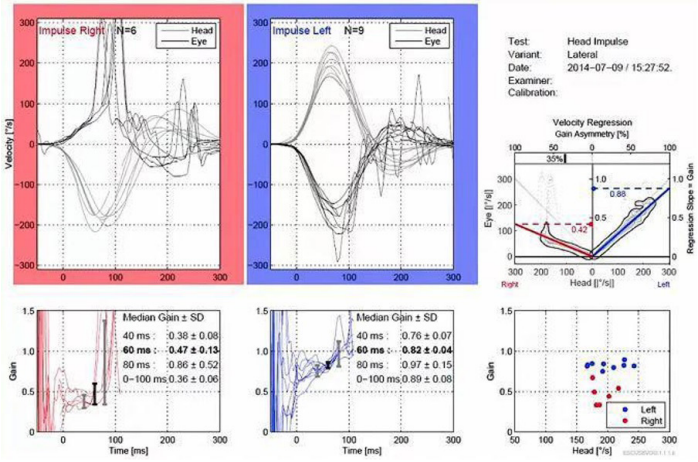


Figure 7.4: vHIT results depicting abnormal VOR function of the right lateral canal (Interacoustics A/S, 2023).

Treasures of Wisdom

vHIT

- Age-appropriate normative values should always be used to avoid overinterpreting subtle variations.
- Use gentle movements to avoid startling the child.
- If the child is reluctant or unable to comply, allow them to watch a favourite video or engage in a game to sustain focus on the target.
- Fatigue, inattention, or poor compliance can impact results; repeat testing may be necessary in these cases.

Caloric testing

The caloric test assesses the low-frequency function of the horizontal semicircular canal and the superior vestibular nerve and offers valuable diagnostic information when appropriately tailored to the paediatric population. The caloric test is useful in identifying unilateral or bilateral vestibular hypofunction which may manifest as delayed motor milestones, imbalance or dizziness in children. The test is recorded using Videonystagmography and is conducted by introducing air or water at a specific temperature into the external auditory canal. This process induces endolymphatic flow within the vestibular system, creating a non-physiological stimulus. The resulting temperature gradient across the canal alters the density of the endolymph, leading to measurable vestibular responses. A normal caloric response is characterised by a clear, sustained horizontal nystagmus with an appropriate directional component based on the temperature used, whereas reduced or absent responses may indicate peripheral vestibular hypofunction. Figure 6.5 depicts a right unilateral peripheral vestibular weakness. The procedure and its underlying mechanisms were first described by Robert Bárány in 1907. Bárány proposed that the test be conducted with the patient in a supine position, with the head elevated at a 30-degree angle from the horizontal plane to align the horizontal semicircular canal optimally. As the head is positioned at an angle of 30 degrees with the body in the supine position, the horizontal semicircular canal develops the largest temperature gradient due to its proximity to the stimulus (Baloh and Kerber 2011). A warm stimulus causes the endolymph to become lighter and move upwards, resulting in an ampullopetal (towards the ampulla) flow. This induces horizontal nystagmus beating toward the stimulated ear. Conversely, a cool stimulus causes the endolymph to become heavier and move downwards, resulting in an ampullofugal (away from the ampulla) flow and horizontal nystagmus away from the stimulated ear (Baloh and Kerber 2011; Barin 2008). This is known as the 'COWS' rule, that is: cool opposite, warm same.

Caloric testing in children presents unique challenges due to developmental, behavioural and anatomical aspects that should be considered when interpreting results. The caloric test may not produce reliable results in very young children (for example, under two years of age) due to underdeveloped vestibular responses or lack of co-operation. Children may have limited understanding or ability to comply with the test instructions. Anxiety and fear of unfamiliar procedures can hinder co-operation. Strategies like explaining the procedure in simple terms or using distraction techniques (for example, toys, videos) can help for older children. However, testing younger children or those with special needs may require mild sedation or alternative vestibular assessments. Therefore, caloric testing is typically reserved

for children aged five to six years and older. Water irrigation is often preferred over air in paediatric patients due to its greater reliability and ease of inducing a response. However, the temperature and volume must be carefully adjusted for smaller ear canals. Particularly in the paediatric population, further contra-indications to caloric testing include a significant degree of space-occupying cerumen, otitis externa, middle ear effusion or the presence of a hypermobile tympanic membrane (British Society of Audiology 2010).

a) Patient and caregiver preparation

- It is essential to conduct otoscopy and tympanometry prior to commencing with caloric testing to exclude an outer or middle ear pathology.
- Explain the procedure in simple, child-friendly language.
- Reassure the child and involve the parent or caregiver to reduce anxiety.
- Use toys or videos to explain the process where appropriate.
- The environment may need to be modified (for example, allowing the caregiver to hold the child or shortening the test duration) while focusing on obtaining critical data.

b) Positioning and testing

- When using videonystagmography (VNG), the lights in the room should be dimmed to prevent light from entering the goggles, a common issue caused by the smaller head size of children, which can affect the fit of the goggles.
- The child should be placed in a supine position on an examination bed.
- The head should be elevated by approximately 30 degrees from the horizontal plane to align the horizontal semicircular canal with gravity for optimal stimulation.
- Warm and cool water or air should be used, depending on equipment availability and patient tolerance. For water irrigation, insert water at 30 degrees Celsius (cool) and 44 degrees Celsius (warm) for 30–40 seconds. If water is contraindicated or not well tolerated, use air irrigation by inserting air at similar temperatures for 60 seconds. Proper positioning of the probe is crucial during air irrigation to ensure that the air is directed toward the tympanic membrane. Incorrect positioning, where air is delivered into the ear canal instead, may cause irritation or damage to the skin within the canal.
- Each ear should be stimulated sequentially, alternating between warm and cool stimuli with five-to-seven-minute rest periods between irrigations.

c) Monitoring and observation

- Watch for signs of discomfort, fear or distress.
- Pause or stop the procedure if the child becomes excessively agitated.
- Observe and record nystagmus direction, duration and velocity during and after each irrigation. If testing is incomplete and needs to be stopped due to the child's inability to tolerate the procedure, visually observe the strength and direction of the nystagmus, even if accurate readings cannot be obtained from the equipment. This observation may still provide valuable information on whether vestibular function is present in both systems.

d) Interpretation

- Age-appropriate normative data should be used for interpretation as depicted in Table 7.5.
- Total Response: The total caloric response is calculated based on the sum of the peak slow phase velocity (SPV) of all four irrigations; left warm (LW), left cold (LC), right warm (RW) and right cold (RC). It is widely accepted that a bilateral weakness is present if the total caloric response is less than 25 degrees per second, or if the total left or right ear response is less than 12 degrees per second.
- Directional Preponderance (DP): DP is a calculated value that compares the nystagmus strengths in the right beating direction with the nystagmus strengths in the left beating direction. The DP is given as a percentage. A value of 30 % or greater is generally used to suggest the presence of a DP.
- Unilateral Weakness (UW): Unilateral Weakness is a calculated value that compares the nystagmus strength induced by irrigation of the left ear with that of the right ear (Figure 7.5). The UW is given in percentage. A difference greater than or equal to 25 % is indicative of a clinically significant UW in the ear producing the lesser responses.
- Fixation Index (FI): This is a measure of the change in nystagmus intensity when comparing the nystagmus observed during fixation to the intensity of nystagmus immediately prior to fixation. The FI is measured in both directions as suppression of nystagmus may occur in one direction and not the other

Table 7.5: Age-appropriate normative data for caloric testing in paediatric populations

Parameter	Age Group	Typical Value/ Range	Interpretation/ Notes
Response Magnitude (SPV)	< 3 years	Variable/Often low	Immature responses; difficult to interpret
Response Magnitude (SPV)	3–6 years	≥ 10°/sec	May be lower than adults; variable
Response Magnitude (SPV)	7+ years	20–30°/sec	Approaches adult norms
Unilateral Weakness (UW)	All ages (if tolerable)	< 25%	Suggests unilateral hypofunction if >25%
Directional Preponderance (DP)	All ages (if tolerable)	< 30%	Increased DP may reflect central asymmetry
Test Tolerance	< 6 years	Often limited	Incomplete testing common; consider using air calorics
Test Tolerance	7+ years	Improved	More complete, reliable data possible

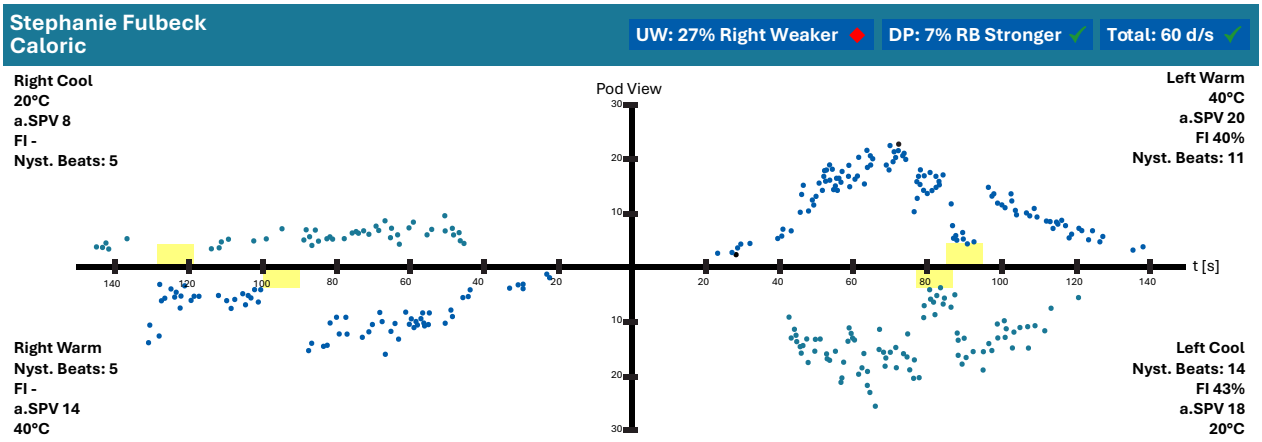


Figure 7.5: Caloric test results depicting a right unilateral peripheral vestibular weakness

Treasures of Wisdom

Calorics

- In children, caloric testing is often reserved for cases where peripheral vestibular dysfunction is strongly suspected and other non-invasive tests, such as VEMPs or vHIT, have been inconclusive.
- A less invasive alternative test is the Sinusoidal Harmonic Acceleration (SHA) test as part of the rotary chair test battery. This test also provides information on low-frequency function of the horizontal semicircular canal and will more likely be tolerated by children.

Intervention and rehabilitation

Intervention in paediatric vestibular disorders requires a multidisciplinary and individualised approach. Once vestibular dysfunction is identified, timely referral is critical to minimise the impact on a child's motor development, balance, spatial orientation and academic performance. Children exhibiting significant delays in gross motor milestones, persistent imbalance or vertigo should be referred to a paediatric neurologist or Ear, Nose and Throat Specialist for further diagnostic workup and medical management where necessary. In parallel, referral to a paediatric physiotherapist or vestibular rehabilitation therapist is essential for developing an age-appropriate vestibular rehabilitation programme, which may include balance training, gaze stabilization exercises and motor coordination activities. While most evidence-based protocols are derived from adult populations, paediatric vestibular rehabilitation therapy (VRT) is adapted to the developmental level, attention span and motor abilities of each patient. Coordination with occupational therapists, speech-language pathologists or audiologists may also be warranted for patients with coexisting sensory or developmental challenges. The patient's teachers and caregivers should be included in the vestibular rehabilitation plan to ensure that appropriate environmental and educational accommodations are made to support the child in activities of daily living.

Management strategies should be guided by whether the vestibular dysfunction is of peripheral or central origin. In peripheral vestibular disorders, such as vestibular neuritis, bilateral vestibular hypofunction or congenital malformations, intervention typically focuses on promoting compensation through VRT. Activities might include gaze stabilisation exercises (for example, VOR x1 viewing), dynamic balance activities using uneven surfaces or balance boards, and age-appropriate locomotor tasks to improve postural control. In contrast, central vestibular disorders, often associated with conditions such as cerebellar ataxia, traumatic brain injury or multiple sclerosis might require a broader neurorehabilitative approach. This could involve coordination and proprioceptive training, visual motion sensitivity exercises and cognitive-motor integration tasks, often in collaboration with neurology and neuropsychology services. Medication management may be indicated in central pathologies to address symptoms such as migraines or seizures. In both cases, consistent monitoring and re-evaluation are crucial to tailor intervention goals as the child develops and their needs evolve.

Conclusion

The assessment of vestibular function in children is a complex yet essential aspect of paediatric care. Early identification of vestibular disorders through age-appropriate testing, combined with careful interpretation and multidisciplinary collaboration, can significantly improve outcomes in balance, motor development and quality of life. Incorporating both behavioural observations and physiologic tests that are tailored to the child's developmental age ensures a more accurate diagnosis. Equally important is timely intervention, including vestibular rehabilitation, referrals to specialists and supportive educational strategies. As awareness of paediatric vestibular dysfunction grows, HHPs are better equipped to provide comprehensive, family-centred care that supports each patient's full potential.

Test your knowledge:

Based on the content covered answer the following questions:

1. What are the key challenges in conducting vestibular assessments in paediatric populations?
2. Why is age-appropriate normative data important for interpretation of tests like vHIT and VEMPs?
3. List at least three vestibular assessment methods commonly used in children and describe the specific aspect of vestibular function each test evaluates.

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