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Video Head Impulse Test in Pediatric Age: Clinical Relevance and Practical Applications

PRODUCT INSIGHTS

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EPIDEMIOLOGY

Vestibular dysfunction is increasingly recognized in pediatric populations presenting with balance disorders. Epidemiological studies report a prevalence of up to 36.5%, a figure that rises significantly among children with sensorineural hearing loss (SNHL). In a cohort of 1,022 children not eligible for cochlear implantation (CI), vestibular abnormalities were detected in 54.5% of cases. Notably, mild vestibular deficits often remain undiagnosed due to effective compensation strategies and the absence of overt postural symptoms, thus eluding early neurotological evaluation.

THE VESTIBULAR SYSTEM: FROM BALANCE TO COGNITIVE SKILLS

The vestibular system is fundamental for postural control, spatial orientation, and the coordination of voluntary movements. Its integration with the central nervous system, in particular the cerebellum, and its interaction with auditory, visual, proprioceptive, and cognitive systems support both motor and higher-order functions. Through complex afferent and efferent pathways, the vestibular system ensures fine-tuned modulation between body position and the external environment.

Dysfunctions of the peripheral or central vestibular system will cause balance disorders. In adults, and in children between 7 and 12 years of age, a vestibular deficit affecting postural control can often be compensated by somatosensory and visual inputs. In contrast, during early development, the nervous system is not yet mature enough to compensate for vestibular deficits, due to the immaturity of both other sensory systems and the CNS itself. It is therefore evident that a child with a vestibular deficit, who walks cautiously and with great attention, may fail to adequately learn spatial relationships within the environment. This can hinder the development of internal spatial representations resulting in delayed achievement of motor milestones and impaired postural and motor skills. A theoretical framework on the emergence of cognitive representations in the brain suggests that sensorimotor circuit activity can be internally simulated and re-represented in the absence of direct sensory input or movement, facilitating anticipatory control and the emergence of cognitive representations. Evidence indicate that the vestibular system contributes to cognitive domains such as spatial navigation, body schema formation, numerical processing, and temporal cognition. Furthermore, vestibular afferents are involved in building a sense of agency (the sense of being the agent of actions), ownership of actions ("this action was mine") and a more global sense of belonging to one's body ("this body is mine"), major components of self-awareness. At the same time, putting yourself in someone else's shoes or third-person perspective taking is the visual-spatial ability through which you temporarily simulate the visual perspective of another individual, used, for example, to decide whether an object is to someone's left or right. In this sense, third-person perspective taking is rapid and involuntary, can be used to understand and predict other people's feelings and intentions and is the basis of empathy.

In light of these mechanisms, it is plausible that vestibular dysfunction may contribute to learning disorders, which are classified among neurodevelopmental disorders in the DSM-5. These include dyslexia, dysorthography, dysgraphia, and dyscalculia. They typically emerge during school age and interfere significantly with academic skills despite normal intelligence and motivation. Children with autism spectrum disorder (ASD), attention-deficit/hyperactivity disorder (ADHD), or other communication and intellectual disorders often show overlapping impairments in language, praxis, executive functions, and spatial reasoning. Moreover, increasing levels of childhood obesity and a sedentary lifestyle (smartphones and tablets) promote the reduction of muscle tissue and activity, with a reduction in the number of vestibular synapses. All these conditions can cause long-term personal discomfort and difficulties with social integration.

VESTIBULAR ASSESSMENT IN PAEDIATRIC AGE

All children with suspected balance or developmental disorders should undergo complete ENT and audiological evaluations. Vestibular assessment must be tailored to age and cooperation level, using tools validated for paediatric populations.

Thanks to the continuous evolution of the instrumentation, the advent of objective, non-invasive methods such as cervical Myogenic Vestibular Evoked Potentials, with air/bone stimulation (air/bone cVEMPS) and above all with remote camera Video Head Impulse Test (VHIT) allows accurate evaluation even in very young children.

In children under 1 year of age it is possible to detect the presence of VOR and Doll's eyes reflex and presence or absence of primitive reflexes.

In children aged 1 to 3 years it is necessary to observe posture, strength and coordination during spontaneous movements and playing, spontaneous walking, running, interaction with the environment and with the parents. Compatible with the little patient's ability to collaborate, at least the following tests must be performed: saccadic and smooth pursuit tests; frenzel glasses/Infrared Video-goggles search for spontaneous, positional and positioning nystagmus; Head Shaking Test (HST); VHIT; air/bone cVEMPs.

In children over 3 years of age it is possible to use almost any diagnostic test used in adulthood.

HOW PERFORM VHIT IN CHILDREN

The test is performed similarly to the adult protocol, with adaptations for age and compliance:

- it is necessary to gain the trust of the patient by welcoming him into a room with toys, dolls, etc.
- when the baby is comfortable, he will be made to sit in the caregiver's arms, facing the remote camera
- the target consists of colored concentric circles or of eye-catching object that gradually reduce in size
- head impulses are administered when the child focuses on a target approximately 2 cm in diameter. In case of limited cooperation, testing may proceed with larger targets.

At least 10 valid impulses per side are required. Trials may need repetition due to blinking, inattention, or spontaneous movements. Lateral and vertical canal hypofunction were defined as a gain value lower than 0.8 and 0.7, respectively.

CASE REPORTS

Case 1 : Figure 1 shows normal video-HIT results in RB, a 12-month years old female, affected by severe bilateral and symmetrical sensorineural hearing loss. Excellent compliance allowed full evaluation of all semicircular canals.

Case 2: Figure 2 shows video-HIT results in AG, a partially compliant 11-month years old male, affected by moderate bilateral and asymmetrical sensorineural hearing loss. Only horizontal canal responses were reliably obtained, showing normal gains bilaterally.

Case 3: Figure 3 shows video-HIT results in ER, a partially compliant 14-month years old male, affected by severe bilateral and symmetrical sensorineural hearing loss, who underwent cochlear implant on right ear at 11 months. The child showed clumsiness and uncertainty in walking, characterized by numerous falls, especially in dim lighting. VHIT showed left lateral canal hypofunction, while right canal (CI side) was normal.

DISCUSSION AND CONCLUSION

Early identification and management of vestibular dysfunction in children is essential for optimizing motor and cognitive development. This requires a multidisciplinary approach involving clinicians, families, and educators, and should include public awareness initiatives. VHIT is a valuable, feasible, and reproducible tool for assessing semicircular canal function in children with SNHL, balance disorders, or even without apparent symptoms. Universal vestibular screening, extending beyond high-risk or symptomatic populations, should be considered to prevent diagnostic delays.

Timely vestibular rehabilitation is crucial in cases of confirmed deficit.

However, vestibular-based interventions may also benefit children with learning difficulties despite normal vestibular function. Vestibular re-education through playful activities e.g., swinging, rolling, somersaults, trampoline, cycling, may enhance neurodevelopmental trajectories by stimulating the sensorimotor system.

Promoting knowledge exchange and developing age-appropriate, evidence-based vestibular training programs are fundamental to support academic performance and psychosocial integration.

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Figure 1

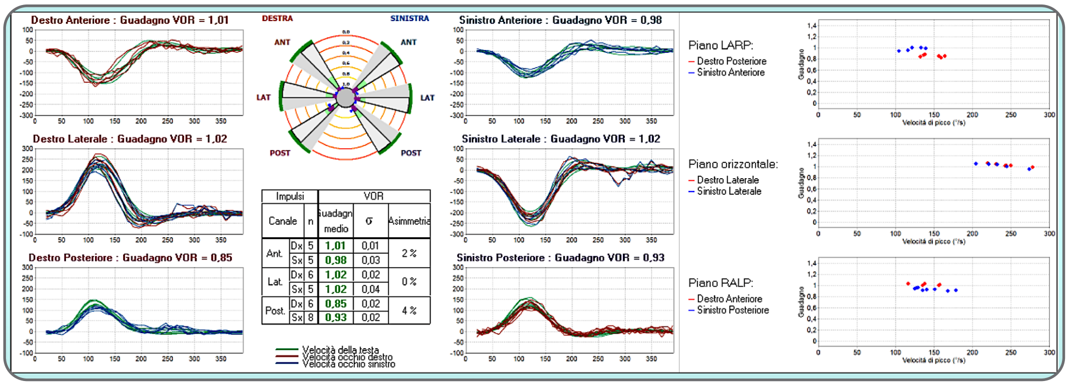


Figure 2

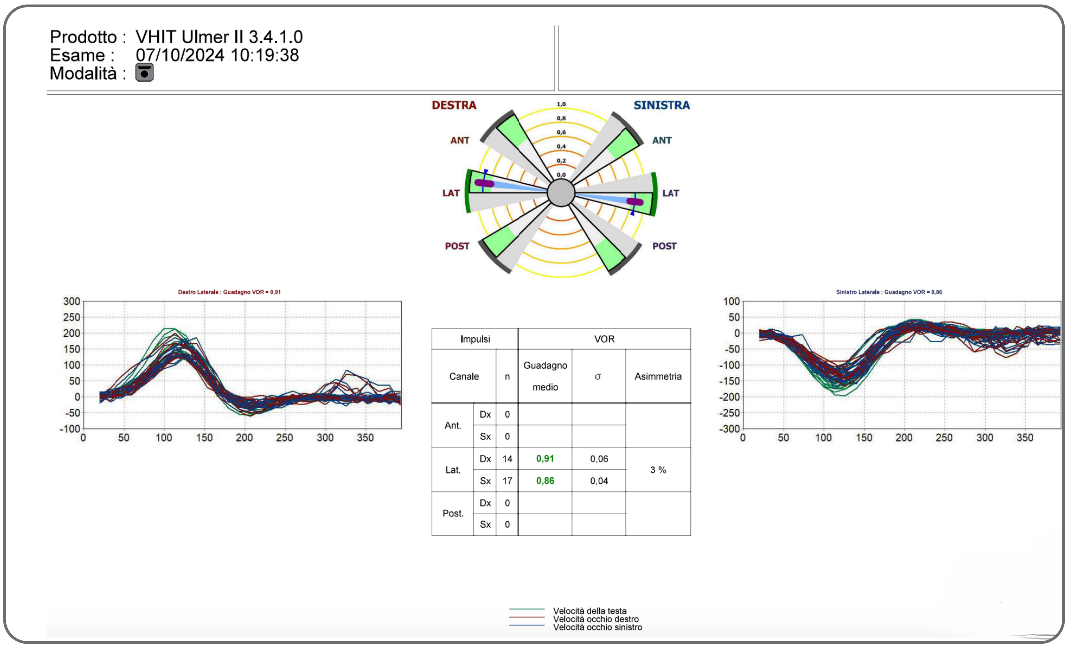
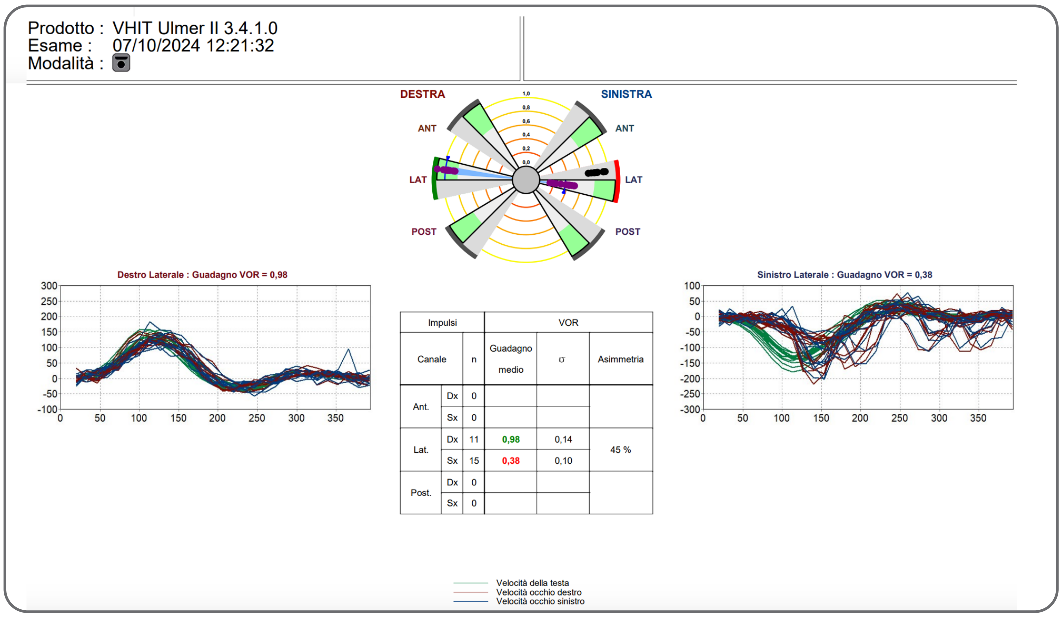


Figure 3



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