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Vestibular dysfunction amongst adolescents: what do we know? A review

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Abstract

Background. Vestibular dysfunction in children is a debilitating condition that results in countless pernicious effects, such as motor development delay, poor academic performance and psychosocial impairment. Yet, research pertaining to vestibular and balance disorders amongst adolescents is still lacking and remains an enigma.

Methods. This paper outlines novel emerging aetiological factors contributing to vestibular dysfunction amongst adolescents by appraising published articles through a narrative review.

Results. Underlying aetiological factors of vestibular dysfunction can be identified among adolescents with thorough evaluation. Proper diagnostic evaluation of vestibular dysfunction is imperative in providing optimal care and guiding appropriate treatment strategies. The available literature demonstrated multifactorial aetiological factors that contribute to vestibular dysfunction in adolescents.

Conclusion. Outlining the underlying aetiological factors of vestibular dysfunction is vital to ensure that patients receive appropriate care and treatment.

Review Article

Dr J Saniasiaya takes responsibility for the integrity of the content of the paper

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Introduction

According to the World Health Organization (WHO), an adolescent is defined as a person aged 10–19 years. For decades, health issues concerning adolescents have been little understood and overlooked. Adolescence is regarded as a critical period of growth, reflecting a transition from childhood to adulthood. Vestibular dysfunction or impairment amongst adolescents has historically been assumed to be similar to the characteristics in younger children. What is unbeknown is that the relative neuroplasticity amongst children – which results in better tolerability to vertigo, ensuring the short-lived duration of symptoms and self-limiting nature – is not present in adolescents. Parallel to that, novel vestibular dysfunction related conditions are emerging, associated with rapidly evolving digital transformation and technology.

Nevertheless, medical practitioners – traditionally trained to use Occam's razor when making a diagnosis – may face a dilemma when dealing with an adolescent with vestibular dysfunction. This is because multifactorial characteristics associated with other vestibular disorders are demonstrated, which can occur before, alongside and/or following the current symptom.[1] Furthermore, deciphering triggers or symptoms amongst adolescents may be a conundrum because of poor understanding or awareness of vestibular dysfunction among the parents and the physician.

We reviewed the relevant literature in order to shed light on this important topic, and to understand the different factors contributing to vestibular and balance impairment amongst adolescents.

Materials and methods

A narrative review was conducted by searching for English-language articles in the electronic databases PubMed, Scopus (Elsevier, Amsterdam, the Netherlands) and Google Scholar, over a period of one month (March 2022). In addition, further relevant articles pertinent to this review were retrieved by inspecting the references of the articles that had been searched. The following key words were used either individually or in combination to aid in the retrieval of relevant articles: 'vestibular dysfunction', 'vestibular disorder', 'vestibular disease', 'vestibular deficiency', 'vestibular loss', 'vestibular impairment', 'vestibular paroxysmia', 'vertigo', 'dizziness', 'giddiness', 'light-headedness', 'imbalance', 'vertiginous migraine', 'vestibular migraine', 'migrainous vertigo', 'cybersickness', 'motion sickness', 'adolescent', 'teenager', 'juvenile', 'teen' and 'youth'. The exclusion criteria were non-English articles, and those focusing on children aged below 12 years or adults aged above 18 years.

The titles, abstracts and full text of all resulting papers, whenever available, were read and kept for reference, and the findings were critically summarised. A comprehensive narrative review regarding vestibular dysfunction among adolescents was conducted.

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Vertiginous migraine

Vertiginous migraine is also described using numerous other terms when there is a combination of migrainous and vestibular symptoms: migraine-associated dizziness, migraine-associated vertigo, migrainous vertigo, migraine-related vestibulopathy and benign paroxysmal vertigo.

Vertiginous migraine is regarded as the second most common cause of recurrent vertigo in childhood and adolescence (17.6 per cent), following benign paroxysmal vertigo of childhood. Nine per cent of migraines in adolescence are reported to be secondary to vertiginous migraine. Vertiginous migraine has a higher female preponderance, with a male-to-female ratio of 1:1.5–5.[2]

Recently, the Committee for the Classification of Vestibular Disorders of the Bárány Society (International Classification of Vestibular Disorders) and the Migraine Classification Subgroup of the International Headache Society published a consensus document on vestibular migraine and recurrent vertigo in childhood.[3] Based on this consensus document, vertiginous migraine has been described in terms of a spectrum, with distinctions between vertiginous migraine of childhood, probable vertiginous migraine of childhood and recurrent vertigo of childhood, as summarised in Table 1. Of note, the Committee recommends thorough investigation of recurrent vertigo of childhood, to identify possible subtypes and links with migraine. A number of children may present with pure episodic vertigo on normal examination, as well as non-specific features like nausea and vomiting, which might reflect a migraine precursor.[3]

Table 1. Summary of vertiginous migraine spectrum[3]

Classification	Description
Vestibular migraine of childhood	A. ≥5 episodes with vestibular symptoms of moderate or severe intensity lasting 5 mins to 72 hrs
	B. Current or past history of migraine with or without aura
	C. At least half of episodes are associated with ≥1 of following 3 migraine features: – (1) headache with ≥2 of following 4 characteristics: (a) 1-sided location; (b) pulsating quality; (c) moderate or severe pain intensity; & (d) aggravation by routine physical activity – (2) photophobia & phonophobia – (3) visual aura
	D. Age <18 years
	E. Not better accounted for by another headache disorder, vestibular disorder or other condition
Probable vestibular migraine of childhood	A. ≥3 episodes with vestibular symptoms of moderate or severe intensity, lasting 5 mins to 72 hrs
	B. Only 1 of criteria B & C for vestibular migraine of childhood
	C. Age <18 years
	D. Not better accounted for by another headache disorder, vestibular disorder or other condition
Recurrent vertigo of childhood	A. ≥3 episodes with vestibular symptoms of moderate or severe intensity, lasting 1 min to 72 hrs
	B. None of criteria B & C for vestibular migraine of childhood
	C. Age <18 years
	D. Not better accounted for by another headache disorder, vestibular disorder or other condition

Min = minute; hr = hour

Vertiginous migraine is considered a continuation of benign paroxysmal vertigo of childhood. Benign paroxysmal vertigo of childhood, first described by Basser, is the most common cause of vertigo in children; it typically begins before the age of 4 years and resolves by 8–10 years of age.[4] The child presents with a history of recurrent spontaneous vertigo attacks associated with vomiting, pallor, fear, imbalance and discoordination in an otherwise healthy child, although all symptoms need not be present. Children with a history of benign paroxysmal vertigo of childhood tend to develop vertiginous migraine later in adolescence or during adulthood.

Parallel to that, the dysfunction of ocular vergence is also considered a possible subgroup of recurrent vertigo of childhood, albeit with limited data to date.

Vergence dysfunction

Ophthalmological impairment can result in vertigo or dizziness in adolescence. Ophthalmological impairment, notably vergence insufficiency, has traditionally been related to headaches, yet many may not be aware that dizziness and vertigo can be a sign of ophthalmological impairment. A growing number of adolescents who present to ENT clinics for vertigo demonstrate normal vestibular tests, but orthoptic tests reveal signs of vergence dysfunction.[5]

Convergence and divergence reflect changes between the visual axes of the two eyes that are collectively regarded as vergence eye movement, whereby an increase in angle is known as convergence and a decrease in angle is divergence.[6] Visual input has a major role in the maintenance of balance and posture. Akin to that, gaze stabilisation during head movement occurs following an oculomotor response triggered by vestibular input.

Vergence dysfunction results in postural instability in adolescence by affecting the efferent and afferent proprioceptive signals.[7] Additionally, in children, the postural impairment is demonstrated to be a result of poor vergence inputs along with poorly developed compensatory mechanisms that control postural stability.[8] Parallel to that, any impairment of the oculomotor response can lead to blurring of vision, diplopia, oscillopsia, vertigo and dizziness. It is axiomatic that these symptoms become exaggerated when accompanied by any situation that requires concentration and convergence, such as reading and playing video games, and with prolonged screentime.[9] Oculomotor impairment has contributed to nearly 15 per cent of the total dizziness cases amongst children and adolescents, and is attributed to the increased usage of gadgets and increased screen time.

Persistent postural-perceptual dizziness

Persistent postural-perceptual dizziness is a relatively newly described entity, defined as a form of chronic functional neurological disorder resulting from sensory misperception or mismatch.[10] Persistent postural-perceptual dizziness was included in the Bárány Society's classification of vestibular disorders in 2017, although many of the clinical features have been diagnosed with varying terms, including space and

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motion discomfort, agoraphobia, psychogenic dizziness, phobic postural vertigo, visual vertigo, and chronic subjective dizziness.[11] In 2015, the diagnosis of persistent postural-perceptual dizziness entered the 11th edition of the WHO International Classification of Diseases (beta draft, 2022).[12] Persistent postural-perceptual dizziness is diagnosed based on the presence, for more than three months, of one or more symptoms of non-spinning vertigo, dizziness or unsteadiness, which can be exacerbated by movement, position, exposure to moving or complex visual stimuli.[12] Importantly, persistent postural-perceptual dizziness is typically triggered by an additional vestibular dysfunction, medical illness or psychological disturbance, which results in tremendous distress to the patient.

Although the diagnostic criteria remain a conundrum, the International Classification of Diseases, 11th (beta) edition, describes persistent postural-perceptual dizziness as follows:

> 'Persistent non-vertiginous dizziness, unsteadiness, or both lasting three months or more. Symptoms are present most days, often increasing throughout the day, but may wax and wane. Momentary flares may occur spontaneously or with sudden movement. Affected individuals feel worst upright, exposed to moving or complex visual stimuli, and during active or passive head motion. These situations may not be equally provocative. Typically, the disorder follows occurrences of acute or episodic or balance-related problems but may follow non-vestibular insults as well. Symptoms may begin intermittently and then consolidate. Gradual onset is uncommon'.[12]

Despite the increase in research and publications involving adult patients with persistent postural-perceptual dizziness,[10,13] data on children are still scarce.

Children and adolescents with persistent postural-perceptual dizziness experience constant low-level dizziness on a daily basis with frequent episodic flares.[1] Large, open spaces, bright lights, and complex arrangements such as those in a shopping centre are amongst the triggering factors. Being in constant trepidation and fear of when and what will trigger the next episode puts every child and adolescent in a gruelling situation, as carrying out normal everyday activities seems taxing. In a recent study by Wang *et al*., 7.3 per cent of children and adolescents who visited the paediatric vestibular programme had persistent postural-perceptual dizziness; most of the patients had significantly impaired quality of life, as approximately half of all the children and adolescents were partly or completely out of school or work because of persistent postural-perceptual dizziness.[1]

Children and adolescents with persistent postural-perceptual dizziness typically have a co-existing disorder such as vertiginous migraine, benign positional paroxysmal vertigo (BPPV) or concussion.[14] In addition, in the study by Wang *et al*., abnormal static subjective visual vertical test results were demonstrated, especially amongst children with co-existing BPPV.[1] This may be the result of utricular involvement following divergent weighting of the displaced otolith particle into the semicircular canal,[15] or a skewed perception of verticality associated with persistent postural-perceptual dizziness.

Cybersickness

Cybersickness is defined as a condition that results in dizziness, nausea, fatigue and headache triggered by moving objects in immersive technology such as augmented reality and virtual reality,[16] with a prevalence of 50–80 per cent in users. Cybersickness has been related to the usage of immersive technology, whereby severe nausea, discomfort and vertigo can set in after only 15 minutes of usage.[17] Virtual reality and augmented reality have been demonstrated to stimulate real-world stimuli, as they provides sensory input.

Cybersickness is a part of a visual-vestibular conflict resulting from a mismatch of information between visual and vestibular and somatosensory information, when the visual illusion of self-movement does not correspond to the vestibular and somatosensory systems, which results in sensory conflict. The symptoms, which set in gradually, seem to worsen over time.[18] The main symptoms of cybersickness include nausea, vomiting and dizziness. This can be accompanied by oculomotor signs, fatigue, eye strain and disorientation.[19] Drowsiness and postural instability have been reported following training using virtual reality, which occurs either instantaneously or after a few hours.[20]

Cybersickness is a distinct shortcoming of virtual reality that results in excessive vigilance, notably affecting the adoption of virtual reality in teaching and learning amongst children and adolescents. Exposure to excessive screen time has recently been regarded as a culprit of cybersickness, especially amongst adolescents and young adults. The vast expansion in screen-based electronic devices, such as smartphones, tablets, laptops and portable game devices, which are light, portable and multipurpose, led to the progressive rise in users. In addition, the recent pandemic has doubled the number of users as well as the duration of usage.

The effects of electronic screen-based activity on the general wellbeing of children and adolescents remains a conundrum to date. Roberts and Foehr reported that the total daily screen time amongst adolescents in the USA is 6 hours.[21] Interestingly, these groups of children were also exposed to long hours of watching television.[21] Frequent regular usage of various electronic screen-based devices or immersive technology can result in dizziness or a spinning sensation, along with nausea and vomiting, which in the long-term affect the quality of life and wellbeing of the child.

Conclusion

Vertigo following concussion in adolescents has been widely reported and is attributed to the rapid rotational acceleration resulting from the impact. Adolescents who actively engage in high-impact sports activities such as American football, rugby and boxing are prone to post-concussion vestibular dysfunction. Parallel to that, there has been a rising number of cases of concussion amongst adolescent athletes in the outpatient and emergency departments.

The 2017 Concussion in Sport Group defined concussion as a direct blow to the head, face or neck, or a strong force transmitted to the head, which is typically short-lived and resolves spontaneously.[22] Nevertheless, some clinical manifestations such as vertigo or imbalance may persist. Post-concussion vestibular dysfunction has been demonstrated to turn into a chronic condition in one out of five patients, with some having to endure symptoms for more than five years.[23] The exact pathophysiological mechanism of vestibular dysfunction post-concussion remains unclear; however, several postulations include post-traumatic BPPV, labyrinthine concussion, delayed endolymphatic hydrops, brainstem concussion or VIIIth cranial nerve injury, and cervical vertigo.

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A number of triggers have been identified as potential causes of post-concussion vestibular dysfunction amongst adolescents, notably computer screen time and watching television.[24,25] Pavlou *et al.* reported that post-concussion adolescents are more susceptible to visually induced dizziness.[26] It is imperative that these adolescents seek early treatment, as persistent vestibular dysfunction has been shown to result in psychological distress and work-related disability,[27] which may significantly impair overall quality of life.

Somatoform vertigo

Vertigo and dizziness are extremely distressing conditions in both children and adults. Adolescents typically develop somatic symptoms upon encountering a distressing situation.[28] Reported somatic symptoms amongst adolescents include aches, pains, tiredness and dizziness; these are more prevalent amongst girls (11 per cent) than boys (4 per cent).[29]

Of note, somatic symptoms can be an expression of an underlying psychological impairment such as depression and anxiety. Somatisation becomes more exaggerated in adolescence owing to psychological and biological development. The everyday challenges faced by adolescents, notably difficulties arising from relationships with family members, peers and society, have been reported to lead to somatisation in adolescence.[30] Parallel to that, the adolescent's everyday environment plays a great role; psychological stress associated with broken homes, abusive parental behaviour, or substance abuse by a parent or caretaker, contributes to somatisation amongst adolescents.

Additionally, somatisation has been demonstrated to be closely associated with personality disorders in adulthood.

Orthostatic dizziness

Orthostatic dizziness is attributed to brief light-headedness, dizziness, blackout, or a faint-like sensation upon sudden arising from sitting or the supine position following hours of recumbency.[31,32] Orthostatic dizziness commonly occurs among adolescents aged around 12–14 years, which corresponds to the middle of the growth spurt. Traditionally, transient pallor, blurred vision or blackout, whiteout, and spots, as well as occasionally loss of consciousness, prevail during the episode.[33]

Orthostatic hypotension occurs with a decrease of at least 20 mmHg systolic blood pressure or 10 mmHg or higher of diastolic blood pressure within a period of 3 minutes of standing or during 60-degree tilt table testing.[34] In adults, upright posture shifts approximately 300–800 ml of blood to the heart, increases interstitial volume and reduces venous return to the heart, resulting in decreased cardiac output. However, the volume shift in children and adolescents is still unknown. Risk factors for orthostatic dizziness include female gender, dehydration, deconditioning, warm temperature and prolonged recumbency.

Benign paroxysmal positional vertigo

Benign paroxysmal positional vertigo is a peripheral vestibular disorder characterised by the presence of intermittent episodes of a spinning sensation or vertigo, typically occurring with changes in head position.[35] Whilst BPPV is the most common cause of peripheral vestibular disorder in adults, it remains elusive amongst adolescents. Nonetheless, data show that BPPV amongst adolescents is on the rise. The incidence of BPPV increases with age, hence adolescents are more predisposed compared to children, and the condition is more common in female adolescents.[36] However, the higher female prevalence is demonstrated after puberty (15 years or older), supporting the hypothesis of hormonal effects on the pathophysiology of BPPV.[37]

Benign paroxysmal positional vertigo has historically been attributed to the detachment of otoconia from the utricular membrane, which subsequently dislodge into the semicircular canal. Otoconia dislodge into the posterior semicircular canal because of its gravity-dependent nature, followed by the lateral and anterior canals.[38] Interestingly, a higher preponderance of lateral, anterior and multiple canal involvement has been reported amongst children and adolescents compared to adults, and is attributed to multiple high-functioning physical activities such as gymnastics, swimming, diving and dancing, resulting in the displacement of otoconia into non-gravity-dependant canals such as the lateral and anterior canals.[36] These findings were echoed by another study whereby lateral canal involvement was approximately 45 per cent,[37] and was related to the dynamic physical activity of the adolescent. The disability associated with lateral canal involvement is more severe and debilitating than that associated with other canal involvement, which could enable earlier detection of the disease. However, it should be considered that faster spontaneous resolution has been associated with lateral semicircular canal BPPV, which warrants earlier clinic appointments for those children and adolescents affected.[39]

Whilst BPPV in adults is typically linked to idiopathic causes, most cases of BPPV amongst children and adolescents are secondary to a triggering event such as concussion or traumatic brain injury, surgery, vestibular neuritis, or migraine.[36] Choi *et al.* reported that 45 per cent of children and adolescents in their study had associated co-morbidities, notably sudden sensorineural hearing loss followed by head trauma.[37]

What do we know?

Vestibular dysfunction amongst adolescents may be related to either a single factor or be multifactorial. Adolescents, who are in the midst of processing the rampant physical, emotional and psychosocial changes experienced during puberty, may have difficulty understanding and describing their symptoms. At the same time, behavioural and cultural resilience, as well as repressiveness from certain societies, adds strain to the adolescent, causing them to suffer in silence. The appalling long-term ramifications of vestibular dysfunction include anxiety, depersonalisation, depression, overall poor quality of life and, in extreme cases, suicidal ideation. Hence, it is imperative that long-term studies are carried out across various centres, both nationwide and globally, to better understand the characteristics of vestibular dysfunction amongst adolescents, in order to address this entity, and to develop a clear diagnostic protocol and algorithm in the near future.

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