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Effects of vestibular rehabilitation exercises on children with hearing loss, cerebral palsy, and attention deficit hyperactivity disorder: A systematic review.

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Abstract

Background: Children with hearing loss, Sensorineural Hearing Loss (SNHL), Cerebral Palsy (CP), and Attention Deficit Hyperactivity Disorder (ADHD) have vestibular hypo function that may co-exist, leading to postural instability and other impairments. However, there is a lack of evidence related to the effects of vestibular rehabilitation exercises on children with these conditions.

Purpose: A systematic review of randomized controlled trials was performed to investigate the effects of vestibular rehabilitation exercises on balance, motor skills, and cognitive function in children with hearing loss, SNHL, CP and ADHD.

Methods: PubMed, MEDLINE, king Abdulaziz university library, and Google Scholar were comprehensively searched. Inclusion criteria were: (1) Experimental studies, (2) Written in English, (3) Pediatric population (3–12 years) with either hearing loss, CP, or ADHD, (4) Exposure to vestibular rehabilitation exercises or balance training, and (5) Articles published in the last 10 years.

Results: Six experimental studies including 144 children met the inclusion criteria for this systematic review. Quality of assessment using the Physiotherapy Evidence Database (PEDro) scale revealed four high-quality studies: One quasi-experimental study (24 children), three randomized controlled trials (36 children), (16 children), (21 children). There were also two low to moderate quality studies: One randomized controlled trial study (33 children) and one longitudinal randomized controlled trial cross-over study (14 children). All studies showed that vestibular rehabilitation exercises had significant effects on children with hearing loss, CP and ADHD.

Conclusion: Limited evidence suggests that vestibular rehabilitation exercises improve balance, motor skills, cognitive function, and health-related quality of life in children with hearing loss, CP and ADHD. More high-quality randomized controlled trials with larger numbers of participants are needed to further establish and generalize the effects of vestibular rehabilitation exercises on children with hearing loss, CP and ADHD.

Keywords: Systematic review, Vestibular rehabilitation, Cerebral palsy, Attention deficit hyperactivity disorder, Children's disorders.

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Introduction

The vestibular system plays an essential role in gross motor development [1]. It is the first sensory system to develop in the uterus and works in combination with visual and somatosensory systems to control balance and coordinate movements [2]. The vestibular system has a significant impact on the motor system as well as a considerable effect on children's cognitive function [3]. This system helps children interpret things around them. However, impaired cognitive function resulting from vestibular disorders can interfere with this process, affecting the child's ability to distinguish their own movement from other movements in the surrounding environment as playing and exploration is a crucial function in children during their first year of life and is how they learn and gain different skills, demonstrating the need for coordinated and intact vestibular function integration with somatosensory and visual systems [4]. The vestibular system is responsible for postural control, gaze stabilization, and spatial orientation and is divided into two components: central (brainstem and cerebellum) and peripheral (inner ear and vestibular nerve) [5]. Each component manifests different symptoms following lesions or damage depending upon the condition, site of lesion, severity, and whether the damage is unilateral or bilateral [6].

Many pediatric disorders can lead to dizziness, which is "a sensation of lightheadedness or feeling faint" [7]. However, in approximately 50% of children reporting feeling faintness, it is due to vestibular hypo function [8]. Dizziness is likely under-reported due to the child's inability to express it. Moreover, dizziness causes unfavorable impacts, such as delaying postural control or lack of coordination [9]. It has been reported that vestibular function improvement contributes to dizziness improvement [10].

Given the negative effects dizziness has on quality of life, it is essential to conduct proper treatment for vestibular dysfunction [11]. Other common symptoms that contribute to vestibular dysfunction are imbalance, which increases the risk of falling; hearing loss, which contributes to gross motor function; poor spatial memory (short-term memory); motion sickness; developmental delays (inability to reach specific milestones at certain ages); and abnormal movement patterns resulting in gait abnormality, such as clumsy gait [12].

Previous studies reported the effect of vestibular dysfunction on children and how it might affect the equilibrium and protective reflexes, especially when it occurs in early childhood [13]. Furthermore, the overall reported prevalence of vestibular disorders in children is as high as 0.7%–15% [14]. Considering the difficulty of assessing and diagnosing children, this prevalence can be underestimated as there are many vestibular disorders in children left untreated; therefore, further research is needed regarding pediatric vestibular assessment and rehabilitation [15].

Various pediatric disorders can negatively impact the vestibular system's functions, such as hearing loss, Cerebral Palsy (CP), and Attention Deficit Hyperactivity Disorder (ADHD). Vestibular end-organ dysfunction shows a high prevalence in children with Sensor Neural Hearing Loss (SNHL) [16]. Compared to children with normal hearing, children with SNHL can experience weak dynamic and static balance, gait changes, postural instability, and slow gait speed [17]. A systematic review suggests the effectiveness of vestibular rehabilitation in improving physical function in children with SNHL [18]. Sensory impairment is one of the CP abnormalities that can affect the vestibular system. Furthermore, the decreased activity of children with CP affects the use of vestibular end-organs [19]. As the vestibular function decreases, it can lead to delays in motor skills. Activation of the vestibular system helps to normalize muscle tone as well as gross motor function. Numerous studies have reported the effect of vestibular dysfunction on cognitive function in adults and have proposed that it may affect children's cognitive function to the same extent [20]. Considering that cognitive function relies on adequate sensory systems input, which the vestibular system is one component, the effects of vestibular hypo function found in adults can be applied to children [21].

Vestibular rehabilitation exercises can be explained as movement-based and training-based approaches taking many forms, including adaptation, substitution, and habituation [22]. These exercises are composed of two major elements: (1) Gaze stability exercises to promote vestibulo-ocular reflex function adaptation and (2) Balance exercises (e.g., substitution and habituation exercises) to restore the vestibulo-spinal reflex function [23]. As well as the vestibulo-ocular reflex the vestibulo-colic reflex can be used for stimulation of the vestibular system either actively or passively. The vestibulo-ocular reflex maintains gaze stability during movement of the body or head, which is essential for hand–eye coordination [24]. The vestibulo-spinal reflex is responsible for neck muscle contraction to maintain head stability; which is essential for stabilizing the body and posture during head movement. Given the importance of these reflexes for controlling the coordination of the head, vision, and posture during a child's movement, vestibular rehabilitation exercises can improve reflex function by stimulating the vestibular system [25].

Vestibular dysfunction that develops early in childhood can negatively affect childhood development and lead to complications that could last into adulthood [26]. Therefore, raising awareness of the prevalence of vestibular dysfunction in children is necessary for improving the likelihood of them being assessed and treated [27]. Cronin et al. reported that children have a faster response to vestibular rehabilitation than adults, owing to their ability to compensate and adapt faster to vestibular impairment, which is known as plasticity. An Additional trait in children is that as long as there is fun and motivation in physical therapy we can expect a higher level of cooperation. Moreover, the importance of proper assessment of children with vestibular dysfunction is that it eliminates other serious disorders (e.g., brain tumors) to guide the choice of the most applicable rehabilitation [28].

Timely intervention in early childhood can prevent serious impairments that can occur later in life [29]. Vestibular rehabilitation exercises have been shown to significantly improve balance and gait for children with vestibular disorders. However, no previous systematic reviews have evaluated the importance and effectiveness of vestibular rehabilitation exercises for pediatric disorders (ADHD, CP, and SNHL). The objective of this systematic review was to investigate the evidence of effects vestibular rehabilitation exercises have on children with hearing loss, CP, and ADHD.

Methods

A systematic review was conducted according to internationally Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines.

Searching strategy

To inform the systematic review, the literature search was performed in the following electronic databases: PubMed, MEDLINE, king Abdulaziz university library, and Google Scholar. The following keywords were used: Vestibular rehabilitation, pediatric vestibular disorder, vestibular stimulation, balance training, cerebral palsy children, children with attention deficit hyperactivity disorder, and children with hearing impairment.

Participants, interventions, comparisons, outcomes, and study designs were used to define the search strategy and eligibility criteria. Articles were included in the systematic review according to the following inclusion criteria: (1) Experimental studies (quasi-experimental studies, randomized controlled trial studies), (2) Written in English, (3) Pediatric population (3–12 years) with either CP, ADHD, SNHL, or hearing deficits, (4) Exposure to vestibular rehabilitation exercises or balance training, and (5) Articles published in the last 10 years.

Study selection

Studies that met the inclusion criteria were selected in this systematic review through the PRISMA flowchart. Studies were excluded based on scanning of the article's title and abstract. All research team members conducted a full-text reading and screening of the selected studies; disagreements regarding whether to include articles were resolved by the examiner (Table 1).

Author	**Country**	**Disorders**	**Design**	**Characteristics of volunteers**	**N**	**Characteristics of interventions**		
					CG	**IG**	**CG**	**45-minute sessions 2**
(Ebrahimi et al., 2017)	Tehran, Iran	Sensory hearing loss with bilateral vestibular impairment	Quasi-experimental study	Children aged 7–12 diagnosed with profound sensorineural hearing loss(*PTA>90 dB)	12	12	Intervention after the study	Times/week for 12 ; 45-minute sessions 2 weeks of vestibular. Rehabilitation exercises. The sessions included balance, gait, postural stability, and eye movement exercises
(Hedayatjoo et al., 2020)	Tehran, Iran	Hearing deficit	Randomized controlled trial	Children aged 7–12 diagnosed with hearing deficit	18	18	Educational program	45-minute sessions 3 times / week for 6 weeks in a vestibular-specific neuromuscular training program.
(Hosseini et al., 2015)	Tehran, Iran	Cerebral palsy	Randomized controlled trial	Children aged 3–10 diagnosed with cerebral palsy	8	8	Current stander occupational therapy for 45 minutes 2 times / week	20-minute sessions 2 times / week for 6 weeks in a vestibular stimulation 10 session of exercise in addition to 25 minutes of current stander occupational therapy.10 sessions of training; each child received 20 minutes of neurodevelopment treatment and 30 minutes of vestibular training over a 5-week period.
(Lotfi et al., 2017)	Iran	ADHD* and concurrent vestibular impairment	Randomized controlled trial	Children aged 7–12 diagnosed with chronic ADHD combined with vestibular impairment based on DSM IV* criteria	17	16	No intervention, intervention after the study	
(Rajendran et al., 2013)	India	Hearing impairment	Randomized controlled trail	Children aged 7.5–8.1 with hearing impairment	10	11	45-minute sessions 3 times / week for 6 weeks in a vestibular-	

							specific neuromuscular training program	
(Tramontano et al., 2017)	Italy	Cerebral palsy	Longitudinal, randomized controlled, cross-over study	Children aged 3–7.5 diagnosed with cerebral palsy (mono spastic hemiparesis, bilateral spastic hemiparesis, ataxia)	7	7	Neurodevelopment treatment group; each child received 10 50-minute sessions over a 5-week period	

Table 1. Summary of trials included in the review.

Data extraction

Data were collected with the acceptance of all authors, with the exception for the last author. From each article, these data were collected: Characteristics of the study (author, publication year, country, article design), characteristics of the participants (number, age, disorder), characteristics of the intervention (control group, experimental group), assessment tools, and main findings (Table 2).

Author	Country	Disorders	Assessment	Main finding
(Ebrahimi et al., 2017)	Tehran, Iran	Sensory hearing loss with bilateral vestibular impairment	Bruininks–Oseretsky test of motor proficiency and posturography sensory organization testing	Vestibular rehabilitation exercises focused on adaptation and substitution can improve postural control ability and vestibular function for children with sensorineural hearing loss and vestibular impairment.
(Hedayatjoo et al., 2020)	Tehran, Iran	Hearing deficit	Bruininks–Oseretsky test of motor proficiency and continuous performance test	Balance exercises, including vestibular sensory and motor exercise programs, can improve balance performance, motor coordination, and attention in children with hearing deficits.
(Hosseini et al., 2015)	Tehran, Iran	Cerebral palsy	Force plate	Vestibular stimulation exercises could be effective for balance performance; children can also change and control center of pressure displacement faster.
(Lotfi et al., 2017)	Iran	ADHD and concurrent vestibular impairment	Vestibular test, choice reaction time test, balance test, spatial working memory test	Vestibular rehabilitation exercises can improve cognition performance as well as balance function for children with ADHD and concurrent vestibular impairment.
(Rajendran et al., 2013)	India	Hearing impairment	Test of gross motor development-2, pediatric reach test, one leg standing balance test and postural sway meter, PedsQL generic core scale	Vestibular-specific neuromuscular training programs may improve postural control and motor skills, which would enhance the health-related quality of life in hearing-impaired children.
(Tramontano et al., 2017)	Italy	Cerebral palsy	Goal attainment scale, root mean square of head accelerations, gross motor function measurement-88 scale	Vestibular rehabilitation exercises combined with neurodevelopmental training could be effective for facilitating neuromotor development in both static and dynamic tasks, such as motor control in children with cerebral palsy.

Table 2. Summary of trials included in the review.

Risk of bias evaluation

All authors, except for the last author, shared in evaluating the risk of bias in each study independently using the Physiotherapy Evidence Database (PEDro) scale. The scale consists of 11 items with a maximum score of 10 excluding the first item (eligibility criteria). The following reference was used: High quality when the score was 6 or more, moderate quality when the score was 4–5 and low quality when the score was less than 4 (Table 3) [30].

Item	**(Lotfi et al., 2017)**	**(Ebrahimi et al., 2017)**	**(Tramontano et al., 2017)**	**(Hedayatjoo et al., 2020)**	**(Hosseini et al., 2015)**	**(Rajendran et al., 2013)**
Eligibility criteria specified	Y	Y	Y	Y	Y	Y
Random subject allocation	Y	Y	Y	Y	Y	Y
Allocation was concealed	N	N	N	Y	Y	Y
Groups were similar at baseline	N	Y	N	Y	Y	Y
Blinding of all subjects	N	N	N	N	Y	N
Blinding of therapists administering therapy	N	N	N	N	N	N
Blinding of assessors	N	N	Y	Y	N	N
Measures obtained from more than 85% of initial subjects	N	Y	Y	N	Y	Y
All subjects received treatment or controlled intervention; if not, data analyzed by 'intention to treat'	N	Y	N	Y	N	N
Results of between-group comparisons reported for at least one key outcome	Y	Y	Y	Y	Y	Y
Provides both point measures and measures of variability for one key outcome	Y	Y	Y	Y	Y	Y
Total score	03-Oct	06-Oct	05-Oct	07-Oct	07-Oct	06-Oct

Table 3. Quality of included studies (PEDro). PEDro: Physiotherapy Evidence Database; Y: Yes; N: No.

Results

Study selection and characteristics

The total number of articles found within the three different databases was 32,443. After the removal of duplicates, 9,523 articles were considered.

Out of these, 700 articles were screened by reading article titles and abstracts. Seventeen of the screened articles were selected after full-text analysis. Six of the articles met the eligibility criteria after analysis, as shown in Figure 1.

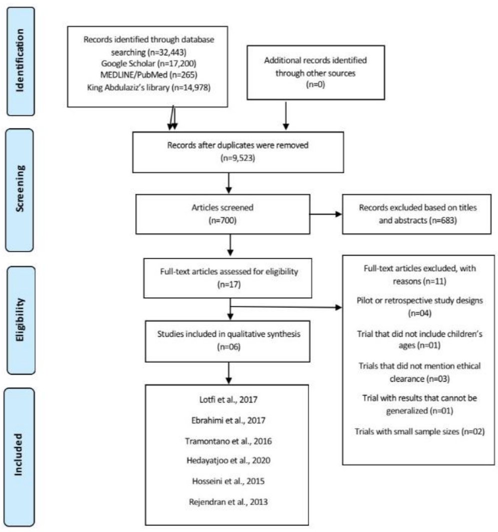

Figure 1. Flow chart of studies in the review, according to Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA).

All included articles were experimental studies. Participants were 144 children with ages ranging from three to twelve. Study designs, populations, outcome measures, and intervention characteristics and descriptions are shown in Table 1: Ebrahimi et al. (quasi-experimental study, n=24), Hedayatjoo et al. (randomized controlled trial, n=36), Hosseini et al. (randomized controlled trial, n=16), Rajendran et al. (randomized controlled trial, n=21), Lotfi et al. (randomized controlled trial, n=33), and Tramontano et al. (longitudinal randomized controlled trial cross-over study, n=14). All studies compared vestibular rehabilitation exercises with occupational therapy, Neuro Developmental Training (NDT), an education program, or no intervention.

Risk of bias assessment

PEDro scale results revealed four articles with high scores: Ebrahimi et al. and Rajendran et al. with scores of 6/10 and Hedayatjoo et al. and Hosseini et al. with scores of 7/10, which indicates good quality and evaluation. Two articles showed low to moderate quality: Lotfi et al. and Tramontano et al. with scores of 3/10 and 5/10, respectively (major allocation concealment and blinding limitation) (Table 3).

Outcome measures

As shown in Tables 1 and 2, the assessment tools used for each study were described as follows. Two assessment tools were used for the evaluation of attention performance: The continuous performance test and the choice reaction time test. The spatial working memory test was used to assess the ability to retain spatial information and manipulate items remembered in the working memory. Balance and postural stability in the included studies were assessed using the root mean square of head acceleration, the Bruininks–Oseretsky Test of Motor Proficiency (BOTMP), the balance test, the pediatric reach test, the one-leg standing balance test, and the postural sway meter.

Head and trunk stabilization in standing and sitting positions were assessed using the goal attainment scale. The Sensory Organization Test (SOT) was used to evaluate the coordination and interaction of visual, somatosensory, and vestibular systems during postural responses. The force plate was used to assess the Center of Pressure (COP) displacement parameters as well as velocity, area, and displacement along the X and Y axes. The gross motor function measurement-88 scale was used to evaluate changes that occurred over time in the gross motor function of children with CP. Motor skills were evaluated using the gross motor development scale. Health-related quality of life was evaluated using the PedsQL generic core scale.

Discussion

The objective of this systematic review was to investigate the evidence for vestibular rehabilitation exercises having effects on children with ADHD, CP, and hearing loss. All studies affirmed that vestibular rehabilitation exercises have a positive effect on children with hearing loss, CP, and ADHD, and that they can improve balance performance, motor skills, and cognitive function as well as control hearing loss.

Hearing loss

Hearing impairment usually occurs in childhood, resulting in communication difficulties [31]. Motor and balance deficits are most likely to occur in children with hearing impairment [32]. Integration of the vestibular, somatosensory, and visual systems is important for a child to be able to control their postural stability [33]. It has been reported that 1-6 out of each 1000 children are suffering from moderate to severe hearing deficits (conductive and SNHL) [34]. Conductive hearing damage leads to an inability to conduct sound waves through the outer and middle ears, whereas SNHL is caused by damage to the inner ear, auditory nerve, and/or auditory cortex. Mixed hearing loss is referred to as a sensor neural and conductive hearing loss combination [35]. A prevalence of 20%–70% of children with SNHL has vestibular dysfunction. According to the anatomical location of the vestibular system and inner ear, lesions or damage to the auditory system may extend into the vestibular system, contributing to coordination, balance, and postural stability issues.

The results of the Hedayatjoo et al. study indicated significant improvement in all three measured variables of balance, motor coordination, and attention. Balance depends on the integration of proprioceptive, vestibular, and visual sensory systems. The exercises that focus on these systems, especially the vestibular system, facilitate improvements in static and dynamic balance, as reported by Hedayatjoo et al. Many studies reported the negative effects of balance disorders on motor coordination. Conversely, Hedayatjoo et al. suggested that a positive impact may be found on motor coordination with improvemed balance function. In this study, three items of motor coordination were tested: Upper limb coordination, bilateral coordination, and visual-motor control.

Greater improvement in the upper limb coordination was observed. Following exercises that help in maintaining the visual field limited to a specific point led to an improvement in attention in this study. These exercises prevent spreading visual attention over a broad visual field with a lack of concentration, which is an issue for deaf children. However, Hedayatjoo et al. did not collect detailed information about the amount of sway in static balance in comparison with other studies that investigated the effects of different exercises on static balance using a force platform.

In Rajendran et al. the aim was to determine the effects of vestibular-specific neuromuscular training on motor performance, balance, and health-related quality of life for children with hearing impairment. Visual and vestibular-specific exercises were prescribed for the intervention group to enhance substitution by improving somatosensory and visual systems and neuromuscular control. Unlike in Effgen's et al. findings, there was no improvement in static balance, as they used conventional exercise programs only for ten days to facilitate balance performance.

However, the exercise group showed an improvement in health-related quality of life compared to the control group through focusing on motor and balance exercises. Furthermore, Rajendran et al. suggested that social activities that aim to increase social interaction during the program can have a beneficial effect on the psychosocial aspect of health-related quality of life. The study reported that the exercise protocol used in this study which is visual and vestibular-specific exercise training is appropriate for children with hearing impairment. This study was limited due to the absence of blinding, small and restricted sample size, and it lacked follow-up. Studies with wider sample sizes and follow-ups are required to confirm the positive impact of vestibular-specific neuromuscular training programs.

Ebrahimi et al. aimed to determine the effect of vestibular rehabilitation on the bilateral vestibular disorder. The authors reported that any damage or disorder influencing the three-sensory input systems would appear in children's abilities, functions, and social interactions. It was suggested that for children having experienced bilateral vestibular dysfunction since birth or in early childhood, visual and somatosensory systems can be affected, leading to poor postural control compared to their peers of the same age, secondary to a vestibular disorder.

The intervention in the Ebrahimi et al. study was designed to improve the abilities of visual-motor and somatosensory systems that tend to enhance postural control *via* the sensory organization which included both adaptation and substitution exercises for gaze stability and balance training by using the BOTMP, audiogram and SOT assessment tools. The BOTMP was used to assess balance performance, whereas the audiogram was used to assess hearing loss, and the SOT was used to assess postural control. The main finding of this study was a significant improvement in postural control and vestibular function for children with SNHL.

Cerebral palsy

Cerebral palsy is a condition that starts in infancy and continues, requiring management, into adulthood. It can have a detrimental impact on a child's development because it interferes with their ability to explore, learn, communicate, and become self-sufficient. It can be defined as a non-progressive injury to the developing brain that causes multiple disorders that lead to movement, balance, and postural problems. It may manifest as hemiplegia, diplegia, or quadriplegia.

Cerebral palsy is the most common cause of disability in children, which occurs in 2–2.5 per 1,000 live births. There are four major types of CP: spasticity, dyskinesia, ataxia, and mixed. Spasticity is the most common type in children, accounting for 80% of the cases. Factors that contribute to the impairment of posture and balance in CP are poor selective control of muscle activity, poor management of muscle activity in anticipation of postural changes and body movements, and a reduced capacity to learn unique movements. Different studies reported that the vestibular system could be affected in children with a brain injury that occurs during birth, which leads to postural imbalance and poor equilibrium. Regulated vestibular stimulation and multi-sensory stimulations have been shown to enhance motor development in several studies Kanagasabai et al.

Sensory input integration is important in maintaining balance and COP. Any reduction in these inputs will directly affect balance and increase the displacement of the COP. Hosseini et al. aimed to investigate the effects of vestibular stimulation on COP parameters in children with CP. The study reported no significant difference between the control and the intervention group except for the velocity parameter, which increased in the intervention group. This change means that the children could control their COP displacement faster, and thus this helped to maintain their stability, which allowed them to move around and explore. Another study by Hosseini et al. supported the finding of this study and suggested that a combination of two treatments has significant effects on multiple aspects in children with CP (e.g., postural control and balance).

The method of intervention used in this study matches the one Hosseini et al. used in his other study, which reinforces the findings of this study. Contradictory results were found between four different studies about the effect of vestibular stimulation on motor development. Sellick et al. results were negative in contrast with the others, including Chee et al. This contradiction was a consequence of the limited sample of children with CP, the presence of various deficit characteristics, and the difference in objective assessment tools used for motor performance. Further studies should be done to confirm the effectiveness of vestibular stimulation on motor function and with consideration for vestibular performance, age, classification, and therapy history. Hosseini et al. suggested the need for more studies to determine the most efficient intervention in terms of protocol, the patient's position, and the time and duration of the intervention. The small sample size was one of the study limitations. This was due to the specific inclusion criterion that children were required to be able to stand independently on the force plate, but most of the children with CP were not able to stand independently.

The Tramontano et al. study aimed to assess the improvement of motor function in children with CP using vestibular rehabilitation training. The tools that were used to assess the motor function were the goal attainment scale, the root mean square of head accelerations, and the gross motor function measurement-88 scale. The intervention group received neurodevelopmental training depending upon Bobath techniques to reach their goals of enhancing postural alignment and functional handling abilities. Besides the neurodevelopmental training, the control group received three vestibular rehabilitation exercise s according to the child's ability: gaze stability training, balance and gait training, and somatosensory integration training. The results reported by Tramontano et al. showed a positive effect for both static and dynamic balance, but the effect during static balance was greater than that of dynamic balance. Measures of stability also showed greater improvement after neurodevelopmental training and vestibular rehabilitation exercises. The main limitations of this study were the small number of participants, heterogeneity, that the study may be considered a pilot study, and that the presentation of the study was difficult to understand.

Attention deficit hyperactivity disorder

Attention deficit hyperactivity disorder is one of the most common neurodevelopmental disorders. It is also described as a neuropsychiatric disorder. It affects 3%–7% of school-age children in the United States starting at seven years old. The incidence is more frequent in boys than girls. Children with ADHD are characterized by paying less attention, hyperactivity, somatosensory insufficiency with impulsivity, distractibility and risk of fall due to balance instability. Attention deficit hyperactivity disorder is classified into three types: Inattentive ADHD, experiencing difficulties with paying attention to details or finishing tasks; hyperactive ADHD, which leads to impulsive and impatient behavior; and combined ADHD, the most common type, which refers to a combination of inattentive and hyperactive ADHD.

According to the symptoms and signs, physicians can diagnose and differentiate between these types as studies have reported that all these features could affect the child's behavior as well as developmental and functional abilities. Chang et al. stated that children with ADHD showed cognitive function improvement following acute aerobic exercise intervention as a result of influencing the dorsolateral prefrontal cortex and the release of dopamine. Pontifex et al. both reported that attention had been improved in children with ADHD after a specific intervention program.

Lotfi et al. hypothesized about whether improving balance can positively affect the cognitive function of children with combined ADHD and concurrent vestibular disorder. Participants were randomly assigned to the control and intervention groups. The vestibular rehabilitation exercises program consisted of balance, gait stability, and eye movement exercises for the intervention group and no intervention for the control group. The findings suggest that vestibular rehabilitation exercise s can be useful for children with ADHD since they had a favorable impact on balance, choice reaction time, vestibulo-ocular reflex gain as well as smooth pursuit gain, and saccadic accuracy.

However, no improvement was reported for spatial memory, taking into consideration the combination between vestibular rehabilitation exercises and cognitive therapy programs for a prolonged period to improve memory function. Overall improvements in attention tasks and cognition function were found following vestibular rehabilitation exercises for children with combined ADHD and concurrent vestibular impairment. According to these findings, impulsive and attentive behavior will decrease in response to an increase in reaction time in children with combined ADHD following vestibular rehabilitation exercises. Further investigations are required to confirm the efficacy of vestibular rehabilitation exercises for cognitive performance of children with combined ADHD. One major limitation of this study was the short period of intervention to assess the cognitive function improvement in all domains. In addition, limited analysis for a specific group (children with accompanying vestibular disorders) and the absence of assessor blinding are other weaknesses.

Conclusion

The present systematic review suggests that vestibular rehabilitation exercises for children with hearing loss; CP and combined ADHD are effective. Improvement of balance, motor skills, cognitive function, and health-related quality of life were the main findings of our review. The combination of vestibular rehabilitation exercises with either neurodevelopment or occupational therapy protocols may have a stronger effect on the development of children with CP than neurodevelopment or occupational therapy alone. The review faced some limitations. First, only 6 articles have met these systematic review inclusion criteria, further research is needed to build a stronger case. Secondly, most of the studies found originated from Iran, the results of which cannot be generalized to other countries.

Recommendations

Future studies should consider further research is needed regarding pediatric vestibular assessment and rehabilitation. Also, more high-quality randomized controlled trials with larger sample sizes. Furthermore, future trials should control the blinding of the subjects, therapists, and assessors. Different countries should consider more randomized controlled trials that study the efficacy of vestibular rehabilitation exercises on children with hearing loss, CP, and ADHD to minimize the effect of vestibular dysfunction on these children and to improve their balance, motor skills, and cognitive function.

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