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Incorporating a Graded Vestibular Spinning Program into the Plan of Care of a 17-Month Old with Gross Motor Delay: A Case Report

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Abstract

Background: Delays in gross motor skills can occur in patients with diagnosed damage to the vestibular system or vestibulocochlear nerve. However, without a diagnosed impairment, dysfunction in the vestibular system may go unnoticed and still be contributing to developmental delay. **Case Description:** The patient in this case study was a 17-month old male with gross motor delays who continued to demonstrate aversion to standing and walking and presented with delayed balance abilities. **Purpose:** The purpose of this case study is to describe a vestibular assessment and associated treatment to include in the plan of care of a 17-month old male with gross motor delay. **Intervention:** Tolerance to 10 spins in the clockwise and counterclockwise directions in sitting and prone with associated nystagmus was assessed. This patient demonstrated decreased tolerance to spinning in both the sitting and prone positions and showed no nystagmus in prone. As a result of this assessment, graded spinning program in both the sitting and prone positions was added to the plan of care to be performed once daily and assessed at weekly therapy appointments for five weeks. **Outcome Measures:** Tolerance and nystagmus following clockwise and counterclockwise spinning in each position were assessed at each weekly appointment. Standing tolerance, gait ability and degree of toe walking were objectively assessed at each appointment. **Discussion:** Improvements were seen in toe walking, standing tolerance and gait distance after five weeks of this treatment. These results indicate graded spins in sitting and prone may benefit the progression of gross motor skills in pediatric patients with delays in gross motor skills.

Background

Gross motor delay is a very common diagnosis seen in the pediatric setting of physical therapy. The cause for this delay could come from a wide number of diagnoses with the prognosis varying depending on the systems involved. Treatment is often driven by developmental milestones, with emphasis placed on learning skills that should be mastered at their given age. Many systems within the body are growing and developing at exceptional rates throughout the first years of life, with their development spurred on by increased movement and mobility[4]. An important system to consider throughout this development is the vestibular system, as it has the crucial role of informing the brain where the body is in space. Increased body awareness can encourage increased movement as the child grows more confident in his/her mobility[4] and this increased exploration of the environment is crucial for cognitive development[6]. When the vestibular system is not functioning correctly it has detrimental effects on posture and body awareness, which is well documented in adults[16,17]. Symptoms of vestibular dysfunction include dizziness, nausea, vomiting and nystagmus. These symptoms often result in decreased activity, as the common reaction is to avoid the movements that cause the symptoms. However, it is important to consider how this system is developing in children and understand that dysfunctions within the vestibular system can often go undiagnosed with young children who are unable to express and vocalize feelings of dizziness or nausea.

The nerve associated with the vestibular system is the vestibulocochlear nerve which synapses on multiple nuclei on the brainstem; these include the superior, inferior, medial and lateral vestibular nuclei. From there, signals are sent to the cerebellum, thalamus, extraocular motor nuclei, and motor neurons in the neck, trunk, and limbs. With communication between these peripheral and central structures, it allows for central processing of the input and associated motor output including eye and positional movements. A primitive role between these structures is to protect the head through reflexes in the neck and limbs[12]. This demonstrates the ability of these systems to understand and interpret where the body is in space and form the appropriate response from the given input.

Literature supports that there is increased occurrance of vestibular hypofunction in children with sensorineural hearing loss[1]. The extremely close proximity of the hearing and vestibular systems, along with their shared vestibulocochlear nerve, helps explain how dysfunction in one system can lead to dysfunction in the other. With diagnosed hearing loss, children more often demonstrate dysfunction in balance as well as delays in head control, sitting, and walking[1]. Similarly, with dysfunction in the otolith children are delayed in learning to walk and fall more frequently[4]. Research supports that the critical period for postural control is between 4-6 years of age[2], and to prevent further delay, motor deficits should be addressed before this age, as these delays can impact the child's quality of life and hinder the level of involvement in activities normal for their age. Therefore, it is important to consider this system when looking at the development of a child, especially when gross motor delays are noted. The ability to assess vestibular function and treat if deficits are noted are tools pediatric physical therapists should have.

While it is difficult to determine a specific time in development when the vestibular system is developing most rapidly, what is often called a critical period, literature supports that by the age of two navigation skills and hippocampal development should be well engrained[4]. Vestibular function would precede these skills, therefore implying the importance of addressing dysfunction of the vestibular system earlier than two to prevent the sequelae of associated dysfunctions. A recent study on rats demonstrated through providing spins and assessing vestibular maturation that the rats showed a faster maturation of the peripheral structures compared to rats that did not experience spinning[14]. Through the specific input to the vestibular system through graded rotations, a similar increase in maturation of the vestibular system may occur to progress standing and balance related gross motor skills in children.

Multiple tests exist to assess vestibular function, but these tests can be expensive and require equipment not readily available in most physical therapy clinics or general hospital settings. These tests include vestibular evoked myogeneic potentials (VEMPs) and caloric or rotational testing with the

Damped Rotation. A recent study demonstrated that through the use of these, there was a significant correlation between children that showed abnormal responses on the vestibular tests and were also delayed in developing independent head control and walking[1].These results demonstrate the potential relationship between an impaired vestibular system and delays in gross motor milestones. Where it becomes particularly important to consider this correlation is in children that have not been diagnosed with hearing loss or vestibular dysfunction but are still demonstrating general delays in developmental milestones with the cause not yet identified. In these cases, a simpler and affordable form of vestibular assessment is available that can readily be applied and incorporated into the plan of care as an additional treatment.

A protocol titled “Astronaut Training: A Sound Activated Vestibular-Visual Protocol,” utilizes a platform swing, which is found in most all pediatric clinics, or spinning board to assess the function of the patient’s semicircular canals. This is completed by the child maintaining the sitting and prone positions with spins applied at one full rotation per second up to 10 times. Tolerance to this activity as well as the number of beats due to nystagmus are noted to assess whether the vestibular system response is greater or less than the norm. The treatment program states that beating nystagmus should roughly correlate to the number of spins, with 10 beats considered normal for 10 spins. Disparity between number of spins and beats of nystagmus or intolerance to the rotations would indicate possible dysfunction of the vestibular system. The purpose of this case report is to describe the protocol and demonstrate the use of a graded spinning program to provide input to the semicircular canals with the goal of progressing developmental milestones in a 17-month old male with gross motor delay.

Patient History and Systems Review

The patient involved in this case study was referred to physical therapy from his Family Practitioner at 12 months old with the diagnosis of gross motor delay and lack of coordination. He was born at 39 weeks with no complications during the pregnancy or during birth. Prior to his physical therapy evaluation, he had been treated with anti-biotics for a double ear infection but had no other medical concerns. His mom reported that he was progressing in height and weight within age-appropriate norms. Upon his evaluation, he presented with increased tightness in bilateral hip flexors, hamstrings, hip internal and external rotators. He demonstrated a slouched sitting posture with increased posterior pelvic tilt that required max tactile cues to correct with poor to fair balance in sitting. In standing he demonstrated a forward flexed trunk and required bilateral upper extremity and chest support to maintain balance. In both sitting and standing he demonstrated little to no ability to rotate at the trunk to reach for objects. He did not ambulate and refused to bear weight through his lower extremities even with assistance, which his mother reported was typical behavior. He demonstrated poor control of his scapula as well as poor core control. Righting and protective reactions indicate the body’s ability to self-correct its position to remain upright and protect itself from harm and both of these were absent in the forward, lateral and posterior directions. He required assistance to transition between all positions and maintain static posture. This evaluation demonstrated delays in sitting balance, reaching, righting and protective reactions, transitional abilities in prone, quadruped, sitting, and standing, crawling and ambulating. His parents hoped for him to progress in his motor abilities to be age appropriate. They were educated on a stretching program to address muscle length as well as core strengthening through sitting on a wedge with bilateral trunk rotation, shoulder strengthening with overhead reaching and maintaining wheel barrow position and the transitional progression of side-sit to quadruped to tall kneel to half kneel at support surface to standing. He was scheduled for 45 minute sessions once a week.

He made remarkable progress initially by addressing muscle length and incorporating transitional movements along with static and dynamic developmental positions to meet the gross motor skills of independent sitting with upright posture, transitioning independently to sitting or hands and knees and crawling. However, after three months of therapy where he demonstrated consistent, linear

improvement in gross motor skills, the patient continued to demonstrate little progression with bipedal gross motor skills including static stance, side stepping along a support surface and walking. In standing, the patient typically stood on his toes instead of with feet flat and walked with this same stance, a behavior termed toe-walking, between 75-90% of the time in standing. With pressure applied to bilateral lower extremities through the hips, he could maintain feet flat but often came up onto his toes shortly after. The patient displayed little interest in standing activities and would often pick his feet up off the floor when placed in standing, a behavior termed abasia that is not normal for this age. When placed behind a push toy or supported in standing with a target to go to, the patient could walk between 3-20 feet before going to hands and knees to crawl, which continued to be his preferred form of mobility. His gait appeared ataxic with uneven step length and width, with most steps demonstrating toe-walking.

Clinical Impression #1

After 5 months of therapy at 17 months old, the lack of standing and decreased interest in walking which appeared ataxic when performed indicates continued delay in typical age-appropriate skills. This implied that further evaluation should be done to assess the function of the vestibular system to determine if the delay could in part be explained by impaired function of the balance organs. Given that these delays persisted through six months of weekly skilled therapy implies his current plan of care should be re-evaluated to assess if additional treatments or referrals are necessary. His current plan of care involved neuromuscular re-education and therapeutic activities that centered around maintaining and transitioning between positions in the skills he was deficient in. The lack of interest in standing and abasia behavior he demonstrated could indicate hypersensitivity in the hip, knee and ankle joints with the increased pressure placed on them through standing so joint compression through bilateral hips when standing was incorporated into his HEP to familiarize this sensation. A brushing program consisting of different textures being brushed on his feet was also incorporated in his HEP to address any potential hypersensitivity to the entire foot being in contact with the ground. If these behaviors are due to the increased sensory input involved with these positions which is misinterpreted as unpleasant to the patient, this could explain why he is avoiding these positions[2,11]. This avoidance due to the perceived discomfort then limits the progression of standing motors skills.

Given the importance of the visual system in maintaining balance, it is also possible that this patient had a vision problem which would affect how comfortable he felt in standing and with dynamic activities like walking which require greater balance ability compared to the more stable sitting or quadruped positions. His parents did not report any concerns in regard to vision and the patient had passed his previous infant vision assessment. If the patient's visual ability had changed since it had been tested, corrective glasses could be trialed to assess changes in standing and gait, but this specific clinic did not have these on site and would have to wait two or more weeks for them to arrive. Given how the spinning protocol can readily be applied with the necessary equipment already available, this avenue was pursued first.

It is also possible that the delays could be due to unknown damage to the motor cortex or cerebellum. The lack of progression of motor skills after continued therapy could indicate that the cerebral areas involved in motor planning or motor coordination, namely the thalamus or cerebellum, are impaired and unable to complete the feedforward and feedback mechanisms required for coordinated movement[11]. Damage can occur from the child suffering a pre-natal stroke or from injury acquired during the delivery[6]. The child was referred to receive a MRI which showed no such damage. The patient was also awaiting an appointment with a pediatric neurologist at the time this study was completed.

Examination

To assess the patient's vestibular processing through the Astronaut Training protocol, the patient undergoes spins in the clockwise and counterclockwise direction in sitting and in prone with the head slightly rotated to the side. The sitting position isolates the horizontal canal, which ideally should include 20 degrees of neck flexion to fully isolate, but this specific position is difficult to attain with young children so the test was completed with the neck in neutral. The Astronaut Training protocol utilizes the prone position with the head rotated to the side to assess both the anterior-posterior and superior-inferior canals. The spinning can take place on a platform swing or spinning board (Figure 1.) that allows the patient to safely sit and lie prone. This patient was unable to remain still in the prone position on the spinning board or platform swing and was held in the therapist's arms in the prone position. The protocol states that 10 spins in each direction should be tolerable and followed with 10 beats of nystagmus in the same direction of the spin, which would indicate a normal response. The patient tolerated seven vertical spins in both directions in the sitting position, which assesses the horizontal canal, and demonstrated six beats of nystagmus to clockwise and seven beats of nystagmus to counterclockwise. The patient demonstrated a normal reaction after this spinning and did not demonstrate any behavior to imply an increased amount of discomfort, which could suggest that activation of the horizontal canal does not cause a heightened reaction. In the prone with head tilted position, the patient tolerated five horizontal spins before growing visibly uncomfortable and upset with no beats of nystagmus to either direction, indicating vestibular hypofunction of the superior-inferior and/or anterior-posterior semicircular canal(s).

Figure 1. The child is positioned on a spinning board demonstrating the position to isolate the horizontal semicircular canal with 20 degrees neck flexion.

Clinical Impression #2

From the examination, it was apparent that with activation of the anterior-posterior as well as superior-inferior canals through horizontal spinning the patient had a heightened perception to the stimulus as compared to vertical spinning. Because of this, the patient may be avoiding movements or positions that activate these canals due to the uncomfortable sensation. The ramifications from this compensation can be widespread given his young age and could potentially impact the rest of his life. Given the adverse reaction to the horizontal spinning, this indicates that the patient would benefit from graded horizontal spins in the clockwise and counterclockwise directions to improve the sensory perception and integration from the superior-inferior and anterior-posterior canals. A hypothesized outcome from this intervention was improved tolerance to weight bearing on lower extremities and a decrease in toe-walking to less than 25% of the time spent in standing. For the intervention to be seen as successful, the patient would make further progression in his gross motor skills overall, including cruising, transitioning from floor to stand independently, standing independently, and walking with assistance. These improvements would indicate improved balance ability from increased communication between the vestibular system to the associated cerebral structures.

Intervention

The intervention is a graded form of the examination procedure which takes into account the number of spins that were possible by the patient before they became uncomfortable and tailors it to a range that the patient demonstrates tolerance to. For this patient it was determined from his maximum of seven horizontal spins both clockwise and counterclockwise that four spins in each direction would be manageable, with the goal of increasing this number as the patient tolerated. The patient's mother was instructed on how to hold her son in prone and demonstrated the ability to perform the protocol safely. The family was instructed to perform this activity once daily every day of the week and, given the skill and understanding required to assess nystagmus, the family was not asked to monitor this throughout the week. At each of his weekly PT appointments, the therapist attempted up to 10 spins in both sitting and prone, assessing the patient's tolerance as well as nystagmus after each direction.

Outcome

Specific outcome measures are not commonly used in this specific clinic; rather, outcomes were functionally based on subjective impression and objective measures of standing, gait and toe walking. The subjective impression involved general aversion to standing and willingness to attempt walking compared to crawling. Specific objective measures included time spent in standing, gait distance and percent of gait with toe walking. It was observed after one week of the daily spinning regimen at home that the patient demonstrated increased willingness to bear weight on bilateral lower extremities when initially placed in standing and did not attempt to lift his legs which is improvement from previous abasia behavior. Also noted was increased tolerance to extended time in standing with feet flat for greater than 90% of the time. Static stance appeared more steady demonstrating decreased postural sway with minimal assistance to maintain. When placed behind the push toy, he attempted walking on the first attempt with no further verbal or visual encouragement needed and tactile cues only for balance. The patient ambulated 30 feet on this first attempt of walking which was the furthest distance he had covered during a therapy session. Ambulation was performed with decreased lateral sway and toe walking decreased from previous sessions. These initial improvements one week after the inclusion of vestibular therapy remained but did not progress any further for the four weeks following. Results are summarized in Table 1.

Nystagmus after directional spins followed a more linear trend with consistent improvement seen every week. At the end of the five-week period the patient demonstrated 10 beats of nystagmus with 10 spins in the clockwise and counterclockwise direction. With spinning in prone he demonstrated six beats of nystagmus with both directions which is an improvement from the four beats at the initial evaluation. From the subjective standpoint at five weeks the patient demonstrated less discomfort to spinning in the prone position and did not appear as fearful or hesitant to undergo the treatment.

Table 1. Objective measures considered before start of intervention, 1 and 5 weeks of intervention.

	Pre-intervention	1 week of intervention	5 weeks of intervention
Time spent in standing	1:30 minutes	4 minutes	4 minutes
Distance walked	20 feet	30 feet	32 feet
Percent of toe-walking	90%	50%	50%

Discussion

What was initially seen with this child is a difference in interpretation of vestibular signals between the sitting and prone positions. This patient demonstrated improvement in spinning with both positions, with more notable improvement seen in sitting than prone. He also demonstrated less discomfort and fearful behavior to the prone rotations after five weeks of treatment. Research shows that humans are unique in the larger size of the anterior-posterior canal, likely due to our bipedal nature, which demonstrates the heightened importance this semicircular canal holds for standing balance and walking skills[3]. After providing continued input to these structures through the daily spinning regimen, the response to this input improved. This could signify that with specific input to the vestibular system through rotational spins, there is improved communication between the peripheral vestibular structures and the central interpretation of their signals.

A correlation may exist for this patient between the improved vestibular function and performance related to gross motor skills, as multiple articles would support[2,4,5]. By understanding the importance of the vestibular system with balance, addressing vestibular impairments could improve standing and gait skills as these require greater balance ability with less support and more dynamic abilities required. Given the communication barrier that exists within pediatrics, this patient's fearful behavior to the initial spins could be similar to adults with vestibular dysfunction who are able to communicate feelings of nausea or dizziness. Therefore, less fearful behavior to spinning after five weeks of treatment can signify a decrease in the uncomfortable sensations commonly associated with vestibular dysfunction.

By adding this treatment then performing standing and gait skills, the patient was able to practice the gross motor skills after specific input to the vestibular system through spinning. It is possible that the spinning serves as a "primer" that increases input and activity in the vestibular system and its communication pathways to the brain. Then, by completing the task following this specific input it could help to form the connections necessary to perform the skill. Priming is supported in literature as a potential mechanism to increase response to a given treatment following an activity that has primed the brain to heightened activity[15]. Specifically, sensory priming through sensory stimulation has been found to have an effect on sensory and motor functions in stroke patients. Similarly, by providing specific sensory input to the vestibular system followed with standing or walking tasks, the treatment may be more affective and performance may be improved as a result of this heightened cortical excitability. The notable increase in standing time, gait distance and decreased toe walking could be an example of this.

If the decreased nystagmus initially indicates hypofunction of the vestibular system, how well will this system function with any challenge from a balance related task? Therefore, if increased nystagmus indicates more normal function of the vestibular system, then it is better able to provide the necessary input to maintain and adapt balance with dynamic skills like gait. If an infant is unable to learn how to call upon the necessary vestibular and cerebral structures when attempting to perform dynamic balance related tasks, either due to inefficient communication between these structures or inaccurate interpretation of the sensation, then they are at risk for further delays in gross motor skills. However, by attempting to treat this through incorporating vestibular input to tasks that test its function in young ages where these systems are still developing, such detrimental effects can potentially be lessened or prevented.

This form of treatment broadens the other pediatric vestibular treatments that more so encompassed the balance rehab commonly seen in the adult population for vestibular impairment, consisting of balance exercises involving the visual and somatosensory aspects of balance[2,3]. The subjects of these studies were school aged, much older than the patient involved in this case study. By addressing vestibular dysfunction at younger ages, it allows the patient to potentially learn motor skills at a more age appropriate level and prevent as great of a gap in motor development. In doing so, associated problems with reading and learning can possibly be addressed at an earlier age as well.

They otherwise may not be aware of these deficits until they begin school and experience greater consequences by not addressing these delays sooner.

Overall, this case study demonstrates that progress in gross motor milestones can be made in the pediatric population with the combination of general skilled pediatric therapy and vestibular therapy that is tailored to the patient's tolerance of spinning. It is clear that the vestibular system is involved in the normal development of children and when development is impaired, this system should be considered for assessment and treatment if necessary. This spinning protocol provides a simple and affordable treatment that can easily be included into the plan of care.

Limitations in this case study include the lack of MCD or MCID to compare this patient's performance to. Literature is lacking for this specific treatment and this case study appears to be one of the first and hopefully will lead to further studies with a greater number of participants. To maintain the simplicity of this study to be performed in a regular pediatric therapy clinic, the assessment for this case relied on subjective impression and lacked objective measures which would provide a greater degree of validity and reliability. Given this, it is more difficult to compare this patient's results to any other patient outcome. It is also unknown if the five-week time frame of this study was adequate to see significant changes. Further studies should include an extended time period to assess if greater change could be observed.

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