Research Article

Effect of Vestibular Rehabilitation on Postural Stability in Children with Visual Impairment

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Highlights

- The vestibular system is restitute for maintaining balance in visual impairment
- Vestibular rehabilitation improves functional balance in visual impairment

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ABSTRACT

Background and Aim: Postural stability is monitored by a circuitous system, particularly visual perception, vestibular apparatus, and somatosensory organs. The ability to maintain balance is significantly compromised in children with visual impairment and has higher risks of falls than the normal sighted children. Children with visual disability reported delayed motor dexterity such as eye-hand coordination, gross and fine motor control involving struggle in gait procurement and postural control. Vestibular rehabilitation is the relevant therapy to restitute for maintaining postural control in the absence of visual information. This study aimed to find the effect of vestibular rehabilitation on postural stability in children with visual impairment.

Methods: A quasi-experimental study was done in pre and post-test type design on 30 boys in the age group of 7-16 years' children with visual impairment. Vestibular rehabilitation therapy was used as the exercise protocol to improve functional balance and reduction of falls in children with visual impairment for six weeks.

Results: Statistical analysis was done between pre-test and post-test readings with SPSS 20 and there is a significant difference between the pre-test and post-test of total score and individual scores of Pediatric Balance Scale (PBS) after the intervention, since ($p<0.05$).

Conclusion: Vestibular rehabilitation therapy improved the capability of postural controlling and reduces the risk of falls to an extent in children with visual impairment.

Keywords: Visual impairment; postural stability; vestibular rehabilitation; pediatric balance scale; high risk of falls

Introduction

Postural stability is monitored by a circuitous system, particularly visual perception, vestibular apparatus and somatosensory organs [1, 2]. The harmonious integration of these sensory organs forms the "Equilibrium Triad" in human beings which is highly reliant on postural control. The anatomical or physiological deficit of anyone of these sensory systems creates a discontinuity in the triad which ultimately results in postural instability.

Visual perception performs a crucial role in maintaining postural control [1]. Vision provides an estimation of the spatial reference system, locating barriers without movement and goal-directed activities [3]. Visual input is generated as electric potentials from the rods and cones of the retina for spatial orientation to control postural stability. It is determined by terms called visual acuity and peripheral field vision. Visual acuity is the capacity of the eyes to decide the definite shape and analyze the materials. Cone cells of the retina are enormously responsible for visual acuity (distant and near vision). Peripheral field vision (temporal, nasal, upper and lower field) is a part of the outside world seen by single eye fixed in one direction [4].

Vestibular system is present in the inner ear labyrinth which is concerned with posture and equilibrium. The vestibular system is composed of three semicircular canals and otolith organ, which works on inner ear balance. The superior semicircular canal detects the position of the head in the Antero-Posterior (A-P) plane i.e. cervical flexion and extension. The horizontal semicircular canal detects the head position in the horizontal plane i.e. cervical rotation. Posterior semicircular canal senses rotation in vertical plane i.e. cervical side flexion.

Semicircular canal senses the rotatory motions of head relative to the body and otolith is concerned with linear acceleration in both transverse and vertical planes. Vestibular apparatus is responsible for evoking statokinetic (postural) reflexes that maintain posture during locomotion concerned with both linear and rotatory motions of head and creates adjustments in head, eyeball and body during postural changes [4]. Proprioceptors are the somatosensory receptors situated in different parts of the body especially in muscle tendon, joints and soft tissues (ligaments and fascia), which provide response to changes in optimal body posture [4].

Visual perception performs an imperative role in maintaining postural stability in the early stages of developing milestone. Later in life, dominancy is taken by vestibular and proprioception. Ability to maintain balance is significantly compromised in children with visual impairment than normal children. Different studies have reported a delay in developmental milestone in children with visual disability than normally sighted children, some of the delayed motor dexterity are eye-hand coordination, visual motor control (both gross and fine motor) involving struggle in gait procurement, and postural control [5]. Colak et al. confirmed that visual disability in children can cause postural deformities, diminished ability to engage in physical activities, orientation and balance issues [6]. Body balance exists as a pre-eminent factor in children with visual loss for their Activities of Daily Living (ADL) exclusively related to walking and stair climbing [7].

Vestibular apparatus is the next relevant structure to restitute for maintaining postural control in absence of visual information [2]. The linear and angular movements of the head create potential sensory integration between vestibular apparatus and proprioceptors. The goal of vestibular rehabilitation is to enhance the functional balance status of children with visual impairment.

There is increased association between visual impairment and recurrent unintentional injuries which includes falls, fractures and traffic-related injuries. Individuals with visual impairment especially children and adolescents have decreased fitness due to lack of physical activities which results in health related problems. There is a limited study to improve postural stability in children with visual impairment hence, balance conditioning is mandatory for effective participation in physical activities. Vestibular rehabilitation can be a mainstay for prevention of falls and improvement of postural control. The aim of the study was to find out the effect of vestibular rehabilitation on postural stability in children with visual impairment.

Methods

Study participants

A quasi-experimental study was conducted with 30 visually impaired male children in Victory Memorial Blind School. The subjects were selected based on inclusion and exclusion criteria. The inclusion criteria of the study were based on category of visual impairment: moderate **(**40%) and severe (75%) visual impairment according to Indian classification of visual disability, age: 7 to 16 years, duration of visual impairment>3 years, ability to walk independently within the school, previously, no motor activities aimed and performed to improve the vestibular system. The exclusion criteria were children having cortical visual impairment, presence of hearing impairment (deaf-blinded), intraocular surgeries, neurological disorders (epilepsy), intellectual limitations (autism spectrum disorder, mental retardation, and cognitive disorders), and recent orthopaedic injuries was excluded. After selection criteria an informed consent was obtained from the parents of each child after detailed explanation on the benefits of the study and had the right to insight into their medical records.

According to Indian definition, "low vision is those who suffer visual acuity between 20/200 to 70/200 in the better eye after the best possible correction" [8]. According to Indian categorization of visual disability, moderate and severe visual impairment is considered as low vision [8]. Visual acuity of 20/60-20/120 in better eye and 20/200 to nil in worse eye is considered as moderate visual impairment with 40% of visual disability. Visual acuity of 20/130-20/300 or field vision of 10°to 20° in the better eye and 20/400 to nil in the worse eye is categorized as severe visual impairment with 75% of visual disability. The causes of visual impairment in childhood are uncorrected refractive errors, congenital cataract, congenital glaucoma, congenital trachoma, conjunctivitis, retinopathy of prematurity, albinism, optic hypoplasia and others.

Assessment tool

PBS can be used for assessing the functional balance of children and adolescents [9]. PBS composed of 14 tasks which assess both static and dynamic balance and each task should be scored based on criteria 0–4 with total score of 56. Multiple trials can be allowed on many of the tasks of PBS. The scorings should be done based upon the lowest criteria, which describes the best performance of the child. If the child scores maximum score of 4 at first trial, no need of additional trials. The total test duration of PBS is approximately 15 minutes. The score between 0 and 20 indicates balance impairment, 21 and 40 indicating acceptable balance. The score between 51 and 56 implies good balance [10].

Study procedure

With reference to visual disability certificate issued by Government of Tamil Nadu, 30 subjects with moderate to severe visual impairment were qualified for the study. The subjects were evaluated with general assessment and PBS and the score was documented as pre-test scorings. As a result of pre-test scores, the subjects were considered to have high risk of fall. Then the subjects were given orientation regarding the exercises before commencement and additional assistance was obtained from the special teacher. Adequate verbal commands and physical prompts were given as instructions to clarify the tasks. Vestibular rehabilitation was given as group therapy and closely monitored whenever the exercises performed inaccurately, the movements were corrected. Vestibular rehabilitation was started with warm-up exercises such as arm circles, arm swings, leg swings (with wall support) and March in place. Each warm-up exercises performed 10 times on both the sides. Vestibular balance conditioning exercises begun with gradual and smooth movements of cervical joint with eyes closed in different positions like lying, sitting and standing [2]. Figure 1 provides a schematic illustration of the exercise sequence.

Lying position

The subjects were positioned in supine lying with hands relaxed at the sides. Cervical rotation was performed alternatively on both the sides initially for 10 repetitions. The cervical rotation movement to right side was ceased almost for a minute and similarly repeated on left side. The intention for ceasing movement for a minute was to maintain the flow of endolymph within semicircular canals of vestibular apparatus evenly [2].

Sitting position

The subjects were asked to be in crossed leg sitting with hands placed over their laps.

i) Cervical flexion and extension were performed alternatively for prescribed repetitions. Then, the movements were ceased almost for a minute in cervical flexion and extension independently.

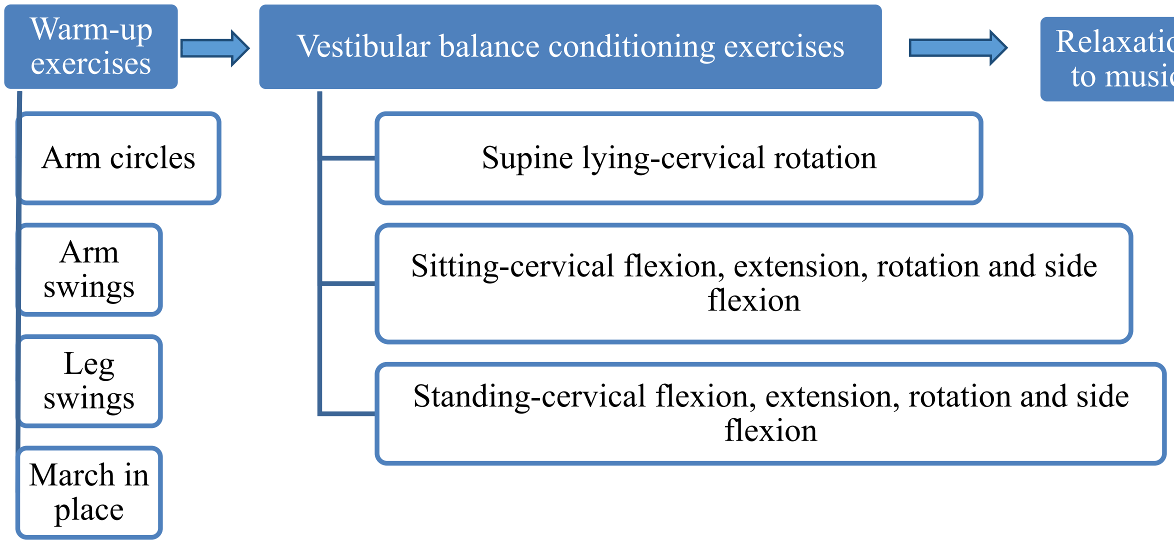

Figure 1. Schematic representation of procedure of the study

ii) Cervical lateral flexion was performed on both the sides alternatively for prescribed repetitions. Later, the movement was ceased for a minute on both the sides independently.

iii) Likewise, cervical rotation also performed alternatively and movement ceased on both the sides.

Standing position

The subjects were asked to stand erect with hands relaxed at the sides. Cervical flexion and extension were performed alternatively for prescribed repetitions. Then, the movements were ceased almost for a minute in cervical flexion and extension independently. Cervical lateral flexion was performed on both the sides alternatively for prescribed repetitions. Later, the movement was ceased for a minute on both the sides independently. Likewise, cervical rotation also performed alternatively and movement ceased on both the sides. After all the repetitions were performed, participants stopped moving for approximately three minutes while lying on their right side. The purpose of this halting of movement for about three minutes after performing each simple exercise movement was to equalize the flow (following head movement) of endolymph in the semicircular canals and the otoliths of the saccule and utricle of the vestibular organ.

Relaxation to music

Finally, the subjects were made to lie down with hands relaxed at the sides. Head and neck should be maintained in neutral position with eyes closed; the soothing music was played to relax the whole body for about 10 minutes. The purpose of playing music was to enhance the relaxation, as the auditory impulses were the most commonly used therapeutic stimuli in visual impairment [2]. Fortunately, all 30 subjects successfully completed the six weeks' exercise protocol. Then, PBS score was taken as post-test scorings. The protocol of intervention is presented in Table 1.

Data analysis

The collected data was tabulated and the International Business Machine (IBM) Statistical Package for Social Science (SPSS) version 20 for windows was used for data analysis. The statistical tool used in this study was paired t-test for analysis of pre-test and post-test value of PBS. The result $p<0.05$ implies a significant difference between the pre-test and post-test values.

Results

According to the Table 2, PBS score was improved from pre-test average of 39.63 to post-test of 44.63 with the mean difference –5.00 at 95% confidence interval.

The Table 3 shows the mean value of individual tasks of PBS that there was relatively significant improvement obtained from individual task including task number 2, 3, 6, 7, 8, 9 and 11. There was a significant difference

Table 1. Prescribed repetitions of vestibular balance conditioning exercises (thrice a week in alternate days)

Position	Exercises	Weeks					
		1	2	3	4	5	6
Lying	Cervical rotation	10	15	20	20	25	30
Sitting	Cervical flexion and extension	10	15	20	20	25	30
	Cervical lateral flexion	10	15	20	20	25	30
	Cervical rotation	10	15	20	20	25	30
Standing	Cervical flexion and extension	5	10	15	20	25	30
	Cervical lateral flexion	5	10	15	20	25	30
	Cervical rotation	5	10	15	20	25	30

Table 2. Comparison on total score of pre and post-test of pediatric balance scale

Outcomes		Mean	SD	Mean difference	t	p
PBS Total	Pre-test	39.63	5.19	-5.00	–36.9	<0.001
	Post-test	44.63	4.90			

PBS; pediatric balance scale

between the pre-test and post-test of above individual tasks of PBS with p<0.001. Task 1 (sitting to standing) of PBS score was improved from pre-test average of 3.67 to post-test average of 3.97 with mean difference –0.30 and p=0.001. Task 4 (standing unsupported) of PBS score was improved from pre-test average of 3.80 to post-test average of 3.97 with mean difference –0.17 and p=0.023. Task 5 (sitting unsupported) of PBS score was improved from pre-test average of 3.87 to post-test average of 4.00 with mean difference –0.13 and p=0.043. Task 10 (turning 360°) of PBS score was improved from pre-test average of 2.10 to post-test average of 2.17 with mean difference –0.07 and p=0.161. There was no significant improvement obtained from pre and post-test of task 10 of PBS. Task 12 (retrieving object from the floor) of PBS score was improved from pre-test average of 3.37 to post-test average of 3.60 with mean difference –0.23 and p=0.006. Task 13 (placing alternate foot on stool) of PBS score was improved from pre-test average of 2.73 to post-test average of 3.00 with mean difference –0.27 and p=0.009. Task 14 (reaching forward with outstretched arm) of PBS score was improved from pre-test average of 2.50 to post-test average of 2.70 with mean difference –0.20 and p=0.012.

Discussion

The present study was done to determine the effectiveness of vestibular rehabilitation on postural stability in children with visual impairment. This study supports the concept that there was an enhancement of maintaining postural stability after performing the vestibular and balance rehabilitation therapy. Authors like Wiszomirska et al. found that the vestibular rehabilitation was proved to be effective in maintaining postural stability among individuals with visual impairment with the mean age of 19 years and proven that there was improvement after three months of intervention with approx. 20 minutes per day and twice a week [2]. Bakke et al. reported that children with visual disability had delayed motor development such as gait procurement and postural stability than normal sighted children [5]. Children with partial or complete blindness were in need of specific therapeutic interventions including postural correction and balance training as suggested by Slavoljub et al. [7].

Legood et al. found that recurrent unintentional injuries which include falls, fractures and traffic-

Table 3. Comparison on individual tasks of pre and post-test of pediatric balance scale

Task		Mean	SD	Mean difference	t	p
Sitting to Standing	Pre-test	3.67	0.55	−0.30	−3.530	0.001
	Post-test	3.97	0.18			
Standing to sitting	Pre-test	3.57	0.81	−0.37	−4.1	<0.001
	Post-test	3.93	0.25			
Transfers	Pre-test	3.07	0.58	−0.63	−7.07	<0.001
	Post-test	3.70	0.53			
Standing unsupported	Pre-test	3.80	0.48	−0.17	−2.41	0.023
	Post-test	3.97	0.18			
Sitting unsupported	Pre-test	3.87	0.34	−0.13	−2.11	0.043
	Post-test	4.00	0.00			
Standing with eyes closed	Pre-test	3.47	0.57	−0.43	−4.71	<0.001
	Post-test	3.90	0.30			
Standing with feet together	Pre-test	3.27	0.94	−0.37	−4.10	<0.001
	Post-test	3.63	0.85			
Standing with one foot in front	Pre-test	0.60	0.72	−0.50	−5.39	<0.001
	Post-test	1.10	0.66			
Standing on one foot	Pre-test	0.53	0.81	−0.93	−14.00	<0.001
	Post-test	1.47	0.68			
Turning 360°degrees	Pre-test	2.10	0.88	−0.07	−1.44	0.161
	Post-test	2.17	0.98			
Turning to look behind	Pre-test	2.93	0.94	−0.43	−4.71	<0.001
	Post-test	3.37	0.81			
Retrieving object from floor	Pre-test	3.37	0.61	−0.23	−2.97	0.006
	Post-test	3.60	0.56			
Placing alternate foot	Pre-test	2.73	0.78	−0.27	−2.80	0.009
	Post-test	3.00	0.90			
Reaching forward	Pre-test	2.50	0.82	−0.20	−2.70	0.012
	Post-test	2.70	0.79			

related injuries were higher in individuals with visual impairment than normal individuals [11].

Zylka et al. found that PBS can be taken as outcome measure to find out the functional balance status of children with visual impairment. This study reported that PBS score was in range of 47 and 56 among girls with visual impairment with the age group of 10 and 15 years, had difficulties in one leg standing, turning 360°, standing with foot in front and reaching forward [10].

In current study, the pre-test of PBS among boys with visual impairment with the age group of 7 and 16 years shows difficulties in one leg standing, turning 360° and tandem standing. The general assessment of subjects shows that postural deformities like forward head posture were found to be more common with deviations from the walking line. Analysis pre-test scorings, subjects had more difficulties while performing the dynamic tasks of PBS. The general assessment of coordination implies moderate to severe coordination impairment that may also affect the PBS scorings of subjects.

Whitney et al., proved that vestibular physiotherapy can be administrated to all the age groups, hence vestibular rehabilitation has been applied to children with visual impairment in order to improve the functional balance [12]. The exercise protocol consists of warm ups, vestibular balance conditioning exercises and relaxation to music. Children were given general warm up exercises like arm swings, arm circles, leg swings and march in place before vestibular balance conditioning protocol in order to activate the proprioceptors. Repeated movements of the head involving cervical flexion, extension, lateral flexion and rotation impacts on postural control and create formation of new vestibular perception in the central nervous system [13]. Relaxation to music was done in accordance with the fact that vestibular and auditory organs present together in the inner ear [14].

Since the exercise protocol used in this study has proved to be accessible it can be included in the rehabilitation programme for children with visual impairment. In this study, outcomes of vestibular rehabilitation are affected by neither degree of visual disability (moderate and severe visual impairment) nor origin (congenital and acquired). The present study, vestibular rehabilitation with head movements and relaxation to music was simple intervention protocol appropriate for children and no need of physical exertion. We assume that vestibular rehabilitation with particular patterns of head movements evoked vestibular functioning and integration with proprioceptors. The improved postural stability empowers child to carry out their ADL efficiently. This study supports that standing on one foot presented significant difference between visually impaired children and normal children demonstrated by Slavoljub et al. [7].

Rutkowska et al. found that capacity to control postural stability during static and dynamic tasks attained maximum at the age of 17 in girls and 15 in boys with normal development [3]. Schmid et al. suggested that vestibular and proprioception conditioning intervention starting early in life enhances postural stability by enduring central nervous system plasticity [14]. Hence, vestibular training should be started early in childhood as to prevent the fall injuries in children with visual impairment.

The result of our study with vestibular rehabilitation as intervention protocol goes in hand with Norris [15], Han et al. [16] that vestibular training with eyes closed in narrow base of support can improve postural stability and interventions comprising auditory stimuli can switch dominancy from vision.

The current study achieved maximum mean value 4 in post-test of task 5 (sitting unsupported) i.e. the subjects able to sit for longer duration without definite use of hands. As the total score of PBS was 56, there is in need to continue the intervention protocol to attain maximum score since the mean of post-test of total score of PBS obtained in this study was 44.63.

Limitations of the study was sample small size, there was no control group, no long term follow-up has been conducted, group therapy in children was laborious. And the recommendations of the study were a comparative study can be done within control group and the experimental group with same exercise protocol, future studies can be done in children with all categories of visual impairment as different groups with same exercise protocol, comparison can be done between boys and girls, studies can be done with long term follow-up to bring out rate of fall injuries, future studies can use colour coding and braille system in visually impaired individuals.

Conclusion

Vestibular rehabilitation therapy improved the capability of postural control and reduces the risk of falls to an extent in children with visual impairment.

Ethical Considerations

Compliance with ethical guidelines

The study protocol complies with the recommendations of the Declarations of Helsinki and Tokyo for humans and approved by Scientific Committee of Sri Ramaswamy Memorial Institute of Science and Technology.

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Authors' contributions

GK: Study design, acquisition of data, statistical analysis, interpretation of the results and drafting the manuscript; YIG: Study design, critical revision of the manuscript, and supervised the study; HS: Study design, statistical analysis, interpretation of the results and drafting the manuscript.

Conflict of interest

The authors declared no conflicts of interest.

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