The Effect of Vestibular Rehabilitation Therapy Program on Sensory Organization of Deaf Children With Bilateral Vestibular Dysfunction

Amir Abbas Ebrahimi[1], Ali Ashraf Jamshidi[2], Guita Movallali[3], Mehdi Rahgozar[4], and Hojjat Allah Haghgoo[5]

[1] *Department of Audiology, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran*

[2] *Department of Physical Therapy, Iran University of Medical Sciences, Tehran, Iran*

[3] *Pediatric Neurorehabilitation Research Center, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran*

[4] *Department of Biostatistics, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran*

[5] *Department of Occupational Therapy, University of Social Welfare and Rehabilitation, Tehran, Iran*

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Abstract- The purpose of this study was to determine the effect of vestibular rehabilitation therapy program on the sensory organization of deaf children with bilateral vestibular dysfunction. This cross-sectional and analytic study was conducted on 24 students between the age of 7 and 12 years (6 girls and 18 boys) with the profound sensorineural hearing loss (PTA>90 dB). They were assessed through the balance subtest in Bruininks-Oseretsky test of motor proficiency (BOTMP). For children which the total score of the balance subtest was 3 standard deviation lower than their peers with typical development, vestibular function testing was completed pre-intervention. Posturography Sensory organization testing (SOT) was completed pre- and post-intervention with SPS (Synapsys, Marseille, France). Children with bilateral vestibular impairment were randomly assigned to either the exercise or control group. Exercise intervention consisted of compensatory training, emphasizing enhancement of visual and somatosensory function, and balance training. The exercise group entered in vestibular rehabilitation therapy program for 8 weeks. The children initially participating in the control group were provided the exercise intervention following the post-test. Based on the results there was significant difference in condition 5 and 6, areas of limits of stability (LOS), vestibular ratio and global score in posturography at the end of the intervention, but there was no significant difference in the control group in posturography ($P<0.05$). The results indicated that testing of vestibular, and postural control function, as well as intervention for deficiencies identified, should be included in deaf children rehabilitation program.

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Keywords: Bilateral vestibular dysfunction; Deaf children; Hearing loss; Sensory organization test; Posturograph; Vestibular rehabilitation therapy

Introduction

In children, vestibular function plays an important role in the gross motor development and postural control. Infants and children with congenitally profound hearing loss commonly suffer vestibular dysfunction in both ears, and loss of postural control (1). However, there have been very few studies have investigated postural stability in these children (1,2).

The development and maintenance of postural stability is a multisystem process that does not depend solely on vestibular input. Maturational changes in visual and proprioceptive, central nervous system processing, and coordination of motor output are responsible for the changes in postural skills observed through adolescence (3). From the sensory systems perspective, Infants and young children are dependent on the visual system to maintain balance (4); as they grow older, begin to use somatosensory and vestibular information appropriately (3). Between the 3 sensory inputs in children, the vestibular system seems to be the least effective in postural control (4).

Children with early sensorineural hearing loss and bilateral vestibular dysfunction present with delayed gross motor development. These children stand and walk later than their peers with typical development (3).

Difficulties in maintaining balance can lead to challenges in normal childhood activities, such as riding

Corresponding Author: A. A. Jamshidi
Department of Physical Therapy, Iran University of Medical Sciences, Tehran, Iran
Tel: +98 21 22228051-2, Fax: +98 21 22220946, E-mail address: aliajamshidi@yahoo.com.

a bicycle or hopping. Reduced ability to participate in normal play with other children may result in social isolation (5). So the mechanisms responsible for the loss of postural control in children with profound hearing impairment need to be established, and holistic management including both auditory and vestibular function is needed.

Sensory organization dysfunction is more prevalent in children with hearing loss and vestibular dysfunction which may result in dependency to one modality for postural control. These children in situations which that modality is not available or not functioning properly depends that modality despite the result may be inconsistency (6).

Most children with bilateral vestibular dysfunction since birth failed conditions dependent upon sensory reweighting, and somatosensory, and vision ratio scores were significantly worse than peers without vestibular dysfunction, despite no evidence of vision or somatosensory deficits. These results suggest that due to multi-modal sensory interdependence, the development of visual and somatosensory effectiveness in postural control is impaired secondary to vestibular dysfunction since birth (7).

There is ample support for the efficacy of vestibular rehabilitation therapy in adults, but very few data exist regarding its results in children (7,8,9).

In children with bilateral vestibular dysfunction at or shortly after birth, the effectiveness of visual and somatosensory cues in postural control was significantly lower than age-matched peers, although normal functioning of both of these modalities intervention must address enhancement of the development of these abilities (7,10).

In this study, the exercise intervention study was designed to enhance the visual-motor and somatosensory abilities with the purpose of improving sensory organization for postural control.

The aim of this study was to determine the effect of exercise intervention on sensory effectiveness in postural control in young children with SNHI and vestibular dysfunction.

Materials and Methods

Subjects

This qusi-experimental study was conducted on 24 students between the age of 7 and 12 years, consisting of 6 girls and 18 boys with the profound sensorineural hearing loss (PTA>90 dB). They were assessed through the balance subtest in Bruininks-Oseretsky test of motor proficiency (BOTMP) (11).

The hearing level of the children was measured by audiogram. Children who, in addition to hearing loss, suffered from visual, physical, neurological, and cognitive impairment were excluded from the study. This was confirmed by review of educational and medical records. Deaf children were selected from Baghchehban Schools for the deaf in Tehran City.

For children which the total score of the balance subtest was 3 standard deviation lower than their peers with typical development, Occulography, cervical vvestibular evoked myogenic potential (c-VEMP) test, video head impulse test (V-Hit), and sensory organization test (SOT) were completed pre-intervention.

The SOT, a computerized dynamic posturography subtest, which provides indirect functional measurement of the contribution of the sensory systems involved in postural control, was completed pre- and post-intervention with SPS (Synapsys, Marseille, France). It consisted of a static force-platform mounted on a translator which allowed for subject translation in the anteroposterior (AP) or mediolateral (ML) directions.

Children with bilateral vestibular impairment were randomly assigned to either the exercise or control group. The exercise group entered in vestibular rehabilitation therapy program for 8 weeks. The children initially participating in the control group were provided the exercise intervention following the post-test.

Prior to the test, its conditions were described in a written form to children's parents whose written consents for letting their children's participation in the study were obtained.

Sensory organization test is a standard test evaluating the coordination and interaction of visual, somatosensory, and vestibular systems during postural responses to 6 changes in sensory conditions by measuring the postural sway. This test has been designed to quantify the child's ability in using different sensory systems to maintain balance in standing position. In this test, the child calmly stands on a static platform and is tested in 6 static conditions with different visual and somatosensory inputs. In the 3 initial conditions, the child stands on a firm surface. In condition 1, eyes are open, but in condition 2 the eyes are closed. In condition 3, the visual scene moves. The moving visual scene (cob web) is created by means of a projection device in another room, which is completely dark. This polarized vision provides visual information, which does not significantly help in maintaining undisturbed standing. Condition 3 provides misleading visual clues regarding the position of the body in space. In conditions 4, 5, and 6, the somatosensory and proprioceptive information is not absent but becomes limited to standing in an upright stance by using compliant (foam) surface.

The test was performed in a room without distracting factors and during the evaluation, each child was asked to stand barefoot and as much as possible without motion while his or her hands were placed next to his or her body. At the beginning of evaluation, the first author of the article placed the child's legs at a distance of 30º from one another. In the condition with open eyes, the child should directly look forward to the visual target that was placed 2.5 meters from him or her on the surface level. In the condition with closed eyes, to ensure of no visual feedback, the blindfold was used, and children were asked to stabilize their position as much as possible in the condition that they have already memorized the target. Duration of each condition was 20 seconds. Two trials were conducted for each condition, the first of which was ignored. Also, the area of limits of stability (LOS) in the open eyes condition was assessed while the platform was fixed. The children were asked that while they were keeping their body in the upright stance, without taking a step, to sway in all directions as much as possible.

The children were trained that without moving their arms or bending their torso, move their bodies like a piece of wood and use only the direction of their ankles for carrying out their motions and in doing so, do not lift their ankles. Otherwise, the trial would be repeated. Considering the learning process in sequential execution limits of stability, prior to recording the data for all children, a practice trial was carried out, and the duration of LOS execution was considered for 30 seconds.

In deaf children, the manner to execute different stages of the test was explained by the first author through total communication, so that it would be ensured that the children have understood the correct manner of carrying out the test.

In this study, the evaluation included the assessment of all conditions (Conditions 1-6), calculation of the scores for overall balance, values of sensory ratios, and the area of limits of stability. Condition 1 evaluates the balance of data from all 3 sensory systems. In condition 2, visual input is absent. In condition 3, the visual input and in condition 4, the somatosensory input are inaccurate. In condition 5, the visual input is absent and somatosensory input is inaccurate. In condition 6, the visual and somatosensory input is both inaccurate. The overall score shows the general level of sensory organization function and includes the median weight of 6 sensory conditions with more emphasis on conditions 3 to 6.

Furthermore, since quantifying the relative difference of scores between 2 conditions leads to better identification of the particular nature of the child's difficulty in sensory balance, the relative difference between the scores is quantified by using the ratio. The somatosensory ratio compares condition 2 with condition 1 and measures the posture's stability when vision is absent. Therefore, it shows the ability of the child in using somatosensory input. The visual ratio compares condition 1 to condition 4 and measures the ability of the visual system function when the somatosensory input becomes limited. Next, the vestibular ratio compares condition 5 with condition 1 and measures the child's ability when both somatosensory and visual inputs are in turn limited or absent. Eventually, the vision preference compares conditions 3 and 6 with conditions 2 and 5 and measures the degree in which the child relies on visual information even when they are misleading.

Intervention

The vestibular rehabilitation therapy (VRT) program consisted of both adaptation and substitution exercises for gaze stability training and balance training (12,13) and were similar to those described for adults with vestibular dysfunction and modified based on age appropriate expectations of motor abilities, attention span and the motivational factors critical for the cooperation of children and confirmed by the ethics committee of university of social welfare and rehabilitation.

The program consisted of 3 weekly 45 min sessions over an 8-week period, with make-up sessions provided for sessions missed due to illness or school vacation/holiday to assure that each child participated in a minimum of 24 sessions within the 2 month period.

Activities for each session were based on individual progress, and the difficulty level was advanced. The control groups were provided the exercise intervention following the post-test.

The exercise group received a progressive exercise program that included adaptation, eye-head coordination, and substitution exercises to improve gaze and postural stability.

Adaptation exercises program designed to perform at different head positions or frequencies for optimal effects. Duration began with 1 min and progressed to 2 min. Background and distraction began with simple background and progressed to the conflicting background. Distance started with near target (3 feet) and progressed to far target (8 feet). Speed began slowly and progressed to faster speed. Position began with standing position and progress to challenging position (e.g., Standing in balance board). Vestibular substitution employs alternative strategies including reliance on the visual and somatosensory cues to replace the lost vestibular function (15,16).

Statistical analysis

To examine whether the data are normal, the Kolmogorov-Smirnov test and for analyzing the static balance data, the Independent t-test was completed. The significant level was set at $P<0.05$.

Results

The mean chronological age of control group was 9.75±1.28, and the mean age of exercise group of our study was 10.08±1.62 years (Table 1).

In Tables 2, 3 and 4, respectively, the mean numbers and standard deviations of pressure center displacement for conditions of sensory organization test, limits of stability area, and sensory balance scores and overall scores of two groups of children pre and post training are shown.

Table 1. Characteristics of each group

Group	N	Age (mean±sd)	Gender	
			Male	Female
Control	12	9.75 ± 1.28	10	2
Exercise	12	10.08 ± 1.62	11	1

Table 2. Comparison of pre- and post-test posturography scores: results of paired *t*-test by group

Group	Condition		Test	Mean	sd	*P*
control	AP	1	pre	76.71	8.28	0.74
			post	76.01	8.76	
		2	pre	69.66	13.26	0.42
			post	70.60	12.67	
		3	pre	48.47	16.17	0.34
			post	49.95	16.17	
		4	pre	57.72	15.68	0.31
			post	58.61	15.33	
		5	pre	23.10	14.01	0.47
			post	25.45	11.42	
		6	pre	10.86	11.60	0.40
			post	13.12	9.93	
	ML	1	pre	81.30	6.49	0.64
			post	81.04	6.40	
		2	pre	77.53	8.21	0.40
			post	77.46	7.64	
		3	pre	60.68	13.48	0.05
			post	59.96	12.37	
		4	pre	62.43	17.19	0.13
			post	63.22	16.99	
		5	pre	20.47	20.61	0.88
			post	23.26	19.38	
		6	pre	12.16	14.60	0.16
			post	15.20	15.96	
exercise	AP	1	pre	77.05	5.31	0.83
			post	77.47	7.49	
		2	pre	70.29	10.09	0.65
			post	71.65	7.83	
		3	pre	51.94	12.80	0.57
			post	54.36	11.69	
		4	pre	53.00	17.86	0.16
			post	61.55	8.69	
		5	pre	12.97	14.78	0.00***
			post	47.53	8.02	
		6	pre	6.47	9.06	0.00***
			post	31.57	13.02	
	ML	1	pre	81.61	6.51	0.83
			post	82.04	5.29	
		2	pre	78.54	7.76	0.80
			post	77.82	7.40	
		3	pre	65.40	9.86	0.64
			post	63.27	13.46	
		4	pre	61.97	14.74	0.36
			post	65.53	8.56	
		5	pre	15.98	18.27	0.00***
			post	56.84	9.39	
		6	pre	9.61	12.15	--
			post	35.66	9.44	

Table 3. Values of limits of stability (LOS) area of the 2 groups of children between pre- and post-tests

group	LOS	Mean	Sd	*P*
control	pre	94.75	40.25	0.22
	post	98.91	36.85	
exercise	pre	108.08	31.98	0.00***
	post	144.00	36.81	

Table 4. Values of sensory balance scores and total scores of the 2 groups of children between pre- and post-tests

group	Ratio		test	Mean	sd	*P*
control	AP	som	pre	0.90	0.13	0.32
			post	0.93	0.06	
		vis	pre	0.74	0.19	0.21
			post	0.78	0.19	
		ves	pre	0.30	0.17	0.43
			post	0.31	0.18	
		pref	pre	0.72	0.21	0.85
			post	0.73	0.19	
		Glob	pre	44.20	9.25	0.87
			post	44.71	9.11	
	ML	som	pre	0.94	0.14	0.35
			post	0.98	0.11	
		vis	pre	0.77	0.22	0.39
			post	0.78	0.22	
		ves	pre	0.25	0.25	0.24
			post	0.28	0.23	
		pref	pre	0.78	0.29	0.26
			post	0.72	0.23	
		Glob	pre	47.03	8.68	0.42
			post	47.77	9.13	
exercise	AP	som	pre	0.91	0.14	0.79
			post	0.93	0.11	
		vis	pre	0.69	0.24	0.21
			post	0.79	0.10	
		ves	pre	0.16	0.18	0.00***
			post	0.61	0.07	
		pref	pre	0.72	0.22	0.09
			post	0.73	0.13	
		Glob	pre	39.61	6.00	0.00***
			post	53.92	6.99	
	ML	som	pre	0.96	0.08	0.65
			post	0.94	0.08	
		vis	pre	0.76	0.19	0.46
			post	0.80	0.10	
		ves	pre	0.19	0.23	0.00
			post	0.69	0.09	
		pref	pre	0.82	0.23	0.22
			post	0.70	0.24	
		Glob	pre	46.61	6.62	0.00***
			post	60.25	6.69	

AP: Anteroposterior, ML: Mediolateral, Som: Somesthetic, Vis: Visual, Ves: vestibular, Pref: preferential, Glob: Global, ***P < 0.001

The results of this study indicated that after intervention there was significant difference in condition 5 and 6, areas of LOS, vestibular ratio and global score (*P*<0/05), but there was no significant difference in the control group in posturography after intervention (*P*<0/05).

Discussion

Hearing loss is usually diagnosed early in life (8), but children are typically not screened or evaluated for vestibular deficits. The vestibular system is critical for gaze stabilization and postural control or balance. Damage to this system results in functional impairments of gaze and balance abilities (14). Documentation of vestibular dysfunction in children with SNHL indicates 20 % to 70% of children with SNHL demonstrate an element of vestibular end-organ dysfunction (15). Consequently, children with sensory neural hearing loss and vestibular impairment should participation in exercise intervention. Reports suggest that functional improvement can be achieved via participation in VRT focused on substitution and adaptation exercises (14). VRT is an exercise-based treatment program designed to promote vestibular adaptation and substitution. The goals of VRT are to enhance gaze stability, to enhance postural stability, and to improve activities of daily living (16).

Studies have shown that exercise programs that enhance the visual-motor and somatosensory abilities that enable substitution is more effective in improving the vestibular related deficits in children with hearing-impairment (17).

The results of our study showed that at the end of intervention program the sensory organization of exercise group improved which indicated that the VRT program for 8 weeks could cause significant improvement in exercise group parameters which attributed to the vestibular training program, enhancement of substitution strategies and progress of visual and somatosensory abilities.

Significant difference in condition 5 and 6, areas of LOS, vestibular ratio and global score in posturography at the end of intervention supported this idea. The visual and somatosensory ratio scores observed in the exercise group was not significant. A possible confounding variable is the age at testing. In our study, the mean age of deaf children were (10 years). Thus, the children in our study were beyond the critical period of balance development and it is possible that age at the time of intervention affected results.

The findings of our study were consistent with the previous studies which have shown that participation of children with SNHI and concurrent vestibular impairment in exercise intervention improved sensory organization for postural control (8,18-20).

Lewis *et al.,* (18), found that participation in balance and body awareness program for 6 weeks resulted in improved balance skills in 6-8-year-old children with the profound sensorineural hearing loss.

Rine *et al*., (8), indicated that exercise intervention focused on substitution strategies may halt the progression of motor development delay and enhance postural control abilities of children with SNHI and vestibular impairment.

Venkadesan Rajendran *et al*., (19), suggested that vestibular-specific neuromuscular training program may improve the motor skills, balance in children with hearing impairment. Shah *et al*., (20), suggested that motor control program, balance training and general co-ordination exercises can be useful to maintain gross motor skills and postural control in children with sensorineural hearing loss.

This finding was not inconsistent with the results reported by Effgen *et al*., (21), She investigated the effect of a 10-day exercise program of static balance activities on the static balance ability of deaf children and found no significant difference in static balance ability. A possible cause of the difference in results may be due to nature of exercise program. She provided the traditional exercises for a total of 10 sessions. Thus the traditional exercise and the insufficient duration of the exercise program might have led to the lack of improvement in the results.

Longitudinal studies with larger population of hearing impaired children with vestibular dysfunction over longer intervals of intervention are warranted to fully examine the provision of intervention and to determine if gains achieved persist.

Vestibular rehabilitation therapy focused on adaptation and substitution has shown to improve vestibular function and postural control ability in children with sensorineural hearing loss and vestibular dysfunction. Also vestibular and postural control function testing is warranted in these children.

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References

1. Kaga K, Shinjo Y, Jin Y, Takegoshi H. Vestibular failure in children with congenital deafness. Int J Audiol 2008; 47:590-9.
2. Mickle KJ, Munro BJ, Steele JR. Gender and age affect balance performance in primary school-aged children. J Sci Med Sport 2011; 14:243-8.
3. Suarez H, Angeli S, Suarez A, Rosales B, Carrera X, Alonso R. Balance sensory organization in children with profound hearing loss and cochlear implants. Int J Pediatr Otorhinolaryngol 2007; 71:629-37.
4. O'Reilly R, Grindle C, Zwicky EF, Morlet T. Development of the vestibular system and balance function: differential diagnosis in the pediatric population. Otolaryngol Clin North Am 2011; 44:251-71.
5. Martin W, Jelsma J, Rogers C. Motor proficiency and dynamic visual acuity in children with bilateral sensorineural hearing loss. Int J Pediatr Otorhinolaryngol

2012; 76:1520-5.

6. Shumway Cook A, Wollacott MH, eds. Motor Control-Translating Research into Practice. 4th ed. 2012, China: Lippincott Williams and Wilkins, 2012.
7. Rine RM, Wiener-Vacher S. Evaluation and treatment of vestibular dysfunction in children. NeuroRehabilitation 2013; 32:507-18.
8. Rine RM, Braswell J, Fisher D, Joyce K, Kalar K, Shaffer M. Improvement of motor development and postural control following intervention in children with sensorineural hearing loss and vestibular impairment. Int J Pediatr Otorhinolaryngol 2004; 68:1141-8.
9. Medeiros IR, Bittar RS, Pedalini ME, Lorenzi MC, Kii MA, Formigoni LG. Evaluation of the treatment of vestibular disorders in children with computerized dynamic posturography: preliminary results. J Pediatr 2003; 79:337-42.
10. Braswell J, Rine RM. Preliminary evidence of improved gaze stability following exercise in two children with vestibular hypofunction. Int J Pediatr Otorhinolaryngol 2006; 70:1967-73.
11. Ebrahimi, A-A., et al., *Balance Performance of Deaf Children With and Without Cochlear Implants.* Acta medica Iranica, 2016. 54(11).
12. Bernard-Demanze L, Dumitrescu M, Jimeno P, Borel L, Lacour M. Age-related changes in posture control are differentially affected by postural and cognitive task complexity. Curr Aging Sci 2009; 2:135-49.
13. Tee L, Chee N. Vestibular rehabilitation therapy for the dizzy patient. Ann Acad Med Singapore 2005; 34:289-94.
14. Rine RM. Growing evidence for balance and vestibular problems in children. Audiol Med 2009; 7:138-42.
15. Cushing SL, Chia R, James AL, Papsin BC, Gordon KA. A test of static and dynamic balance function in children with cochlear implants: the vestibular olympics. Arch Otolaryngol Head Neck Surg 2008; 134:34-8.
16. Han BI, Song HS, Kim JS. Vestibular rehabilitation therapy: review of indications, mechanisms, and key exercises. J Clin Neurol 2011; 7:184-96.
17. Rajendran V, Roy FG, Jeevanantham D. Effect of exercise intervention on vestibular related impairments in hearing-impaired children. Alexandria J Med 2013; 49:7-12.
18. Lewis S, Higham L, Cherry DB. Development of an exercise program to improve the static and dynamic balance of profoundly hearing-impaired children. Am Ann Deaf 1985; 130:278-84.
19. Rajendran V, Roy FG, Jeevanantham D. A preliminary randomized controlled study on the effectiveness of vestibular-specific neuromuscular training in children with hearing impairment. Clin Rehabil 2013; 27:459-67.
20. Shah J, Rao K, Malawade M, Khatri S. Effect of motor control program in improving gross motor function and postural control in children with sensorineural hearing loss-A pilot study. Pediatr Therapeut 2013;3:2161-665
21. Effgen SK. Effect of an exercise program on the static balance of deaf children. Phys Ther 1981; 61:873-7.