ORIGINAL ARTICLE

Balance Performance of Deaf Children With and Without Cochlear Implants

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Abstract- The aim of this study was to compare the static and dynamic balance performance of deaf children with and without cochlear implants. This is a cross-sectional study of 145 school children, aged between 7 and 12 years comprising 85 children with congenital or early acquired bilateral profound sensorineural hearing loss (the hearing loss group) and 60 normal hearing aged-matched control counterparts were assessed using the balance subtest of Bruininks-Oseretsky test of Motor Proficiency (BOTMP). The hearing loss group, 50 without cochlear implants (the non-implant group) and 35 of them with unilateral cochlear implants (the implant group) were recruited from schools for the deaf and normal hearing children (the control group) randomly selected from two randomly selected elementary schools of Tehran city. The scores were analyzed using one-way ANOVA. The total score of deaf children especially the implant group were significantly lower than the control group ($P<0.001$). The balance performance of the control group was better than the implant group in all of the items as well as the non-implant group except the fourth tested item (walking forward on a line) ($P<0.05$). The balance score of the implant group was significantly lower than the non-implant group except for the third tested item (standing on the preferred leg on a balance beam with eyes closed). The findings suggested that deaf children, specifically those with cochlear implants are at risk for motor and balance deficits. Thus, vestibular and motor evaluations, as well as interventions to improve balance and motor skills, should be prioritized for this population.

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Introduction

Childhood deafness is usually associated with communication difficulties. Moreover, Parents and teachers of deaf children report incoordination, clumsiness, and balance deficits as well. This is likely to further affect their communication with others and their optimal performance with their environment (1). Balance is defined as the body's ability to maintain its center of gravity over its base of support. This relies on the integration of sensory inputs coming from the vestibular, visual and somatosensory systems. Therefore, impairment in any of these systems can cause balance deficits (2). During the course of this research paper, we will be mainly focusing on balance deficits associated with damage to the vestibular system during cochlear implants in children.

The peripheral vestibular system is composed of two sub-systems that perform different tasks. Firstly, the vestibulo-ocular system responsible for gaze stabilization during head movements. Secondly, the vestibulospinal system contributes to muscle tone necessary that is necessary for the emergence of early motor milestones, as well as aiding postural control (3). There is a 20-70% prevalence of vestibular dysfunction reported in children with the sensory neural hearing loss (4). It seems that the presence and severity of peripheral vestibular deficit correlate with the severity of cochlear loss; thus, vestibular deficits may be more prevalent in deaf children and cochlear implant candidate than in children with lesser degrees of hearing loss (5).

Researchers have shown that deaf children have

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performed poorly in static and dynamic balance skills in comparison than their typically developing peers, and so are at a higher risk for developing gross motor skills and balance deficits (6). In addition, research by Maes *et al*., (7) also concludes that there is indeed a strong correlation between vestibular function and motor performance, in children with hearing impairment, and if vestibular loss superimposed to hearing loss results more motor deterioration. Ayanniyi *et al*., (8) also reported that static balance of children with hearing impairment is poorer than children with normal hearing although, there is no significant difference in their dynamic balance abilities. Walicka-Cupryś *et al*., (9) reported that static balance components of deaf children is better than children with normal hearing and related that to "sensory compensation" hypothesis which suggests that loss of one sensory modality can cause compensation in another healthy modality.

Over the past 20 years, cochlear implants have been used extensively to help deaf children with language development. However, the impact of cochlear implantation on balance performance and motor development in this population are contradictory (10). One hypothesis is that because cochlear and vestibular receptors have a close relationship, surgical trauma during electrode array insertion or indirect electrical stimulation of the vestibular nerve can cause vestibular damage and hence problems with balance (4,11-15). Another hypothesis is the positive effect of a cochlear implant on vestibular system and motor performance (16-18). A better understanding of this issue and finding further evidence for one of the two hypotheses is helpful for preoperative counseling and rehabilitation after implantation and to give the true picture of results of cochlear implantation.

As the impact of a cochlear implantation on the vestibular function and therefore balance performance and/or motor development of deaf children are not known in Iran, the aim of this study was to compare the static and dynamic balance performance of deaf children with and without cochlear implants.

Materials and Methods

This is a cross-sectional study of 145 school children, aged between 7 and 12 years comprising 85 children (30 girls, 55 boys) with congenital or early acquired bilateral profound sensorineural hearing loss (>90 dB) testing by audiology and 60 normal hearing aged-matched control counterparts (29 girls, 31 boys). Children were assessed using the balance subtest of Bruininks-Oseretsky test of Motor Proficiency (BOTMP). Children with profound sensorineural hearing loss (the hearing loss group), 50 without cochlear implants (the non-implant group), and 35 of them with unilateral cochlear implants (the implant group) were recruited from Baghcheban schools for the deaf and normal hearing children (the control group) randomly selected from two randomly selected elementary schools of Tehran city. Children with any cognitive, physical, visual or neurological conditions were excluded from the study; confirmed by reviewing their medical and educational records. We did not carry out any screening procedures to analyze vestibular function.

BOTMP is a norm-referenced, standardized test which is appropriate for motor assessment in children 4.5 to 14.5-year-old. The balance subtest of BOTMP comprises 8 items. The first three items measure static balance while the last five items measure dynamic balance (19). As the balance subtest of BOTMP in comparison to BOT-2 has more dynamic items we chose the BOTMP balance subtest. The cochlear implants and hearing aids were turned on during the test.

According to the BOTMP manual, each child was asked to kick a small ball twice to determine the preferred leg, then asked to do the following tasks: 1) Standing on the preferred leg on a line while looking at a target on the wall. 2) Standing on the preferred leg on a balance beam while looking at a target on the wall. 3) Standing on the preferred leg on a balance beam with eyes closed. 4) Walking forward on a line using a normal stride. 5) Walking forward on a balance beam using a normal stride. 6) Walking forward with a heel-to-toe on a line. 7) Walking forward with a heel-to-toe on a balance beam. 8) Stepping over response speed stick on the balance beam. The raw scores were then converted into a point scores, and the point scores of the 8 items were summed to produce a total point score (range, 0-32 points). Because the BOTMP have not been normed in Iran, we used a group of normal hearing aged-matched children as our control group.

Each participant was tested individually and wore sneakers or crepe-soled shoes during the test. All the instructions were explained to the deaf children via total communication by the first author. To ensure that the instructions were understood, each child was allowed to do a practice trial for each item. The test was administered in a quiet area in the school without any distractions. Based on the test manual when the child was unable to reach the maximum of the raw scores in their first trial their errors were determined, and so it was possible for them to repeat the task again and the highest score was used for analysis.

The normality of variable was checked by one-sample of the Kolmogorov-Smirnovone test. The mean of each item, as well as total scores of 3 groups of children, were compared by the use of the one-way ANOVA. Post hoc comparisons were performed using the Bonferroni's test, with the criterion for statistical significance set at *P*<0.05 community.

Results

The mean age of the non-implant group, the implant group, and the control group were 8.7±1.5, 9.2±1.4, 8.9±1.6 years respectively (Table1). The mean age of cochlear implantation was 4.5±2.0 years. The mean scores of total balance for the control group, the non-implant group, and the implant group were 26.1±2.6, 18.5±6.8, and 10.7±7.9 respectively (Figure 1). The results showed a significant difference among mean scores for total balance (Table 2).

Table 1. Characteristics of each group: normal hearing children (the control group), children without cochlear implants (the non-implant group) and children with cochlear implants (the implant group)

Group	**N**	**Gender**		**Mean age±sd**
		Male	**Female**	
Control group	60	31	29	8.7±1.5
Non-implant group	50	31	19	9.2±1.4
Implant group	35	24	11	8.9±1.6

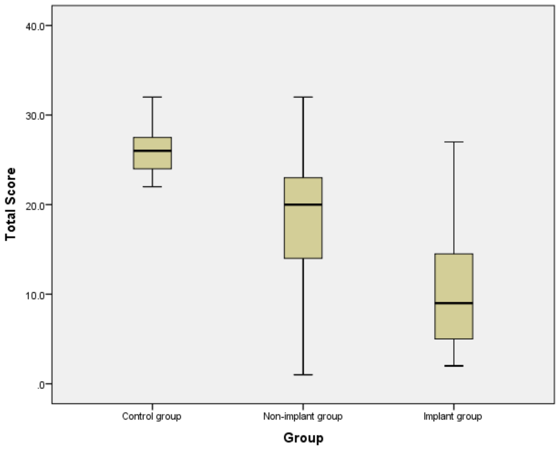

Figure 1. Box-plot of the total scores of BOTMP balance subtest of the 3 groups of children: normal hearing children (the control group), children without cochlear implants (the non-implant group) and children with cochlear implants (the implant group).

Table 2. Comparisons of the BOTMP balance subtests results among normal hearing children (the control group), children without cochlear implants (the non-implant group) and children with cochlear implants (the implant group)

	The control group (I)	**The non-implant group (II)**	**The implant group (III)**	***P*.value**
	mean±sd	**mean±sd**	**mean±sd**	
Item 1	3.98 ± 0.12	3.22±1.29	1.91±1.42	I and II (.001), I and III (.000), II and III (.000)
Item 2	5.68 ± 0.81	3.70±2.26	1.91±2.17	I and II (.000), I and III (.000), II and III (.000)
Item 3	2.02 ± 1.79	0.96±1.04	0.51±0.81	I and II (.000), I and III(.000), II and III (.425)
Item 4	3.00 ± .387	2.86±0.49	2.45±0.88	I and II (.491), I and III (.000), II and III (.002)
Item 5	3.95 ± 0.38	3.32±1.33	1.85±1.51	I and II (.010), I and III (.000), II and III (.000)
Item 6	2.90 ± 0.44	2.28±1.06	0.97±1.24	I and II (.002), I and III (.000), II and III (.000)
Item 7	3.25 ± 1.25	1.82±1.64	0.74±1.42	I and II (.000), I and III (.000), II and III (.003)
Item 8	0.98 ± 0.12	0.82±.388	0.37±0.49	I and II (.041), I and III (.000), II and III (.000)
Total Score	26.17 ± 2.61	18.54±6.88	10.77±7.93	I and II (.000), I and III (.000), II and III (.000)

The Bonferroni's test for multiple comparisons showed significant differences in mean scores between groups for the total balance score ($P<0.001$). However, this test showed no significant differences between the control group and the non-implant group for item 4 of the test, and between the non-implant group and the implant group for item 3.

Discussion

The results of our study showed that the total balance score of the hearing loss group is lower than that of the hearing group (Table 2).

Researchers have shown that deaf children have deficits in BOTMP balance subtest (20,21) and 4-5-year-old children with sensorineural hearing loss in comparison to their peers with normal hearing had lower scores in static and dynamic balance tests (22). The findings of our study are consistent with the vestibular deficit theory; one of the predominant theories regarding motor and balance deficits in children with hearing loss. Based on this theory because the cochlea and vestibular end organs are closely related, hearing loss due to an inner ear impairment may cause vestibular dysfunction and is likely to result in balance deficits (23).

However, this finding is not inconsistent with the results reported by Melo *et al*., (24). A possible cause of the difference in results may be the differences in test instruments used to measure the subject balance ability. In their study, balance ability was assessed by the Tinetti balance and mobility scale. Perhaps in this test the difficulty of balance task is not enough to challenge the peripheral vestibular system. Another possible confounding variable is the age of the participants. In the study by Melo *et al*., (24) the mean age of deaf children (12±3.2) which is an important factor in their balance ability is quite higher than the deaf participants in our study (9.2±1.4).

As mentioned before because of the close relationship of the cochlea and the vestibular receptors, surgical trauma during electrode array insertion or indirect electrical stimulation of the vestibular nerve can cause vestibular deficits. Thus, CI may have a negative impact on balance and motor performance of deaf children. The researches by Jin *et al.,* (25) and Psillas *et al*., (26) lend some support to this hypothesis as well. Their study indicated that saccule could potentially be severely damaged during cochlear implantation. The comparison of balance performance between the implant group and the non-implant group indicated that the balance scores of all items, with the exception the third item (standing on one leg with eyes closed in balance beam), were better in the non-implant group.

The comparison of balance performance between the implant group and the non-implant group indicated that the balance scores of all items, with the exception the third item (standing on one leg with eyes closed in balance beam), were better in the non-implant group. A different set of studies conducted by Gheysen *et al*., (10) and Shall *et al*., (27) found contradictory results, as their research did not find any significant differences in balance performance between children with and without cochlear implants. These studies were conducted using the Movement Assessment Battery for Children (M-ABC) test. Perhaps the balance tasks, used in this test were not difficult enough to challenge the subject's peripheral vestibular system. The BOTMP used in our study reaches this goal by reducing their base of support and eliminating vision in various items. Our results showed that the omission of visual cues caused severe impairments in the balance skills of the hearing loss group, compared to the normal hearing subjects. These results are consistent with the postulation that deaf children are more dependent upon visual cues when it comes to balance control, in comparison to children with normal hearing. Bernard-Demanze *et al*., (28) concluded that postural function of adults with cochlear implants in static and dynamic balance with eyes closed is less than normal hearing subjects and they were more dependent on vision.

Saurez *et al*., (5) evaluated postural control of 36 children with profound hearing loss (13 of them had unilateral cochlear implants) and compared it to their normal hearing peers. They suggested that visual omission can cause severe postural control loss in vestibular dysfunction group. In such cases instability results from an inability to effectively organize and select appropriate sensory inputs for postural control.

Sensory organization dysfunction can manifest as an inflexible weighting of sensory information for orientation. This means that a person may depend heavily on one particular modality for postural control. When presented with a situation in which that modality is either not available or not functioning properly, the person will still continue to rely on that modality even if instability may be a consequence (29). Therefore, the role of visual cues in balance control for individuals with auditory problems is highly crucial, and this may be the cause of there being no significant difference between the scores from the non-implant group and the implant group for the third tested item. In addition, the hearing loss group contained kids with and without vestibular function.

Studies have shown that people with vestibular dysfunction walk with short steps, using a wide support base (30). This may explain why the cochlear group in this study had poor performance in the fourth tested item (walking forward on a line using a normal stride).

On the other hand, some investigators suggested that motor problems of deaf children may not simply result from a vestibular deficit but may be dependent on motor experience and these children do not experience, for example, as much physical play as typically developing children so, motor delays can be attributed to auditory deprivation and indirect result of language and communication delays (10,23). Therefore, the auditory inputs obtained from the cochlear implants by improving self-reliance and self-confidence have a positive effect on motor development (16).

Cushing *et al.*, (31) investigated 41 children with a cochlear implant and measuring balance with the implant "on" and "off" and demonstrated that their balance performance improved when they were wearing their implants. They concluded that the possible mechanism of improvement in balance function was the spread of the electrical current from implanted electrode array to the vestibular system.

On the other hand, Suarez *et al.*, (5) compared deaf children when their cochlear implants were turn on and off and concluded that auditory information from the unilateral cochlear implant is not contributing factor for postural control. Brand-Demanze *et al.*, (28) also indicated that auditory cues do not have any significant sensory substitution role in the improvement of postural control.

In the present study despite more auditory information that the cochlear implant provides, the balance skills of the implant group in all of the items except the third tested item were poorer than the non-implant group. Therefore, it does not seem that auditory stimulation obtained from cochlear implantation has a positive effect on motor development and balance performance. Thus, the results do not agree with the hypothesis that cochlear implant has a positive effect on vestibular function and balance performance.

Due to the cross-sectional nature of this study, the pre-operative vestibular function of the implant group was not available, so it was not possible to compare the scores before and after cochlear implant surgery. As we don't measure vestibular function, the children with hearing impairment comprise of those with and without vestibular hypofunction. This was the predominant limitation in our study, and so it is recommended that deaf children undergo vestibular function evaluations in future studies. Consequently, any hypothesis suggesting a connection between cochlear implant surgery and vestibular dysfunction would need prospective and longitudinal studies.

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