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RESEARCH ARTICLE

The effect of hearing impairment and intellectual disability on children's static and dynamic balance

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Abstract
Background and Aim: Children with hearing loss and children with intellectual developmental disorders have defects in organizing and sensory integration. The aim of this study was to evaluate the effects of hearing impairment and intellectual disability on children's static and dynamic balance.
Methods: This cross-sectional comparative study was conducted on 17 boys with congenital severe to profound sensorineural hearing loss (age 10.54 with SD=2.77), 30 boys with mild intellectual disability (age 10.23 with SD=2.05) and 42 normal healthy boys (age 9.42 with SD=1.79). Balance subtest of Bruininks-Oseretsky-2 test of motor proficiency was used in order to evaluate subjects' static and dynamic balance. Statistical analysis was conducted using SPSS software through Kruskal-Wallis test and Duncan test.
Results: The results show that there is a significant difference between groups in static and dynamic balance. ($p<0.05$), the post hoc test showed that the group with hearing loss and intellectual disability group were significantly different compared to the control group, while no significant difference was observed between hearing loss and intellectual disability group ($p>0.05$).
Conclusion: Children with hearing loss and intellectual impairment compared to healthy children almost equally showed a lower balance performance and it is required to provide the children with rehabilitation programs to maintain independence.
Keywords: Hearing impairment; intellectual developmental disorder; static balance; dynamic balance; Bruininks-Oseretsky-2 test

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Introduction
Children with disabilities do not have enough activities in order to be healthy [1], and considering their gender and level of education, the type of disability may be more relevant to the intensity of the activity [2]. Therefore, the inability restrains children from involving in physical and daily activities [3]. Balance is one of the key and inseparable components of daily activities and exercises. Regarding theoretical aspect, Punakallio defines balance as both static which is the ability to maintain the center of gravity within the base of support, and dynamic which is active movement of the center of pressure during standing, walking or any other skill [4]. Postural control efficacy is closely related to the ability to understand the environment through

peripheral sensory systems; stability control is the result of the interaction of vision, vestibular, proprioceptive and neuromuscular systems [5]. Of 10% of the country's disabled population, 16.2% are hearing and speech impaired and of every one thousand children born in Iran, 5 to 6 children suffer from hearing impairment [6]. Damage to some sections of the vestibulocochlear which is one of the possible causes of sensorineural hearing defects may cause harm to not only the cochlea, but also to the vestibular afferents [7]. About half of the children with hearing loss suffer from impaired vestibular system and this problem leads to postural control and balance problem [7]. Zwierzchowska et al. suggested that hearing loss is associated with balance performance and the lowest balance score was achieved in children with central auditory defects [8]. In many cases, the auditory effect on the central nervous system emerges in general motor skills such as balance, mobility and rapid movements [9]. On the other hand, someone who does not receive acoustical or non-acoustical signals from the environment may act differently in motor functions [10]. Rine et al. reported that children with sensorineural hearing loss (SNHL) who simultaneously suffer from vestibular system, have also difficulties in sensory organization [11] and suffer from progressive delayed motor development as well [11-13]. In a study on motor skills and balance of 3-14 year old hearing-impaired children, Butterfield showed that the cause of hearing loss, the extent of it and gender have no impact on gross motor skills [14]. Martin et al. also pointed out the need for early screening of children with SNHL regarding their motor proficiency. Their study showed a significant association between SNHL and abnormal motor proficiency [15].

Intellectual disability (intellectual developmental disorder) is a disorder that begins during the growth period and includes lack of intellectual and adaptive functioning in conceptual, social and practical areas. Federal law in the United States (Public Law 111-265, Rosa's law) has replaced Mental retardation with the term intellectual disability and research publications use the term intellectual disability. The prevalence of intellectual disability in the total population is approximately one percent [16]. Children with intellectual developmental disorder have lower health and fitness level than average people their age [17]. These children show shortcomings in motor areas consistent with neurological sensory processes, motor development, muscle tone, orientation, body balance, weight shift and weight bearing from juvenility. Restrictions of motor development in these children deprive them of much success in life activities. Based on Carmeli et al (2005) those with mild intellectual disability due to impaired sensorimotor integration gain lower scores than normal people in perceptual-motor tests [18], furthermore, immobility, isolation and unwillingness to participate in group and sport activities adds to the problems of these children. According to Rine (2000) and Carmeli (2005), children with hearing loss and those with impaired intellectual development have some defects in sensory organization and integration; therefore, this study aims at investigating the effect of hearing impairment and intellectual disability on children's static and dynamic balance.

Methods

The present study is a comparative cross-sectional analysis. Participants were 89 boys aged 7-12 years, including 17 children with severe to profound congenital SNHL with an average age of 10.54 (SD=2.77), 30 children with mild intellectual disability with an average age of 10.23 (SD=2.05), and 42 healthy normal children with an average age of 9.42 (SD=1.79). The study was conducted during January 2016. In order to control gender factor and puberty (mostly girls reach puberty at this period), boys were selected for the study. Subjects in the experimental group and the control group were excluded from the study in case of having musculoskeletal or neuromuscular deficiencies, visual impairment, learning disability, a history of surgery or continuous use of certain drugs based on their medical records in education centers. Inclusion criteria in the control group were having no history of hearing and balance problems as

Table 1. Bruininks-Oseretsky test -2 Balance subtest

Row	Balance subtest scores	Eyes	Score maximum
1	Standing on a straight line	Open	10 s
2	Standing on a straight line	Closed	10 s
3	Walking forward on a straight line	Open	6 S
4	Standing on one leg on a straight line	Open	10 s
5	Standing on one leg on a straight line	Closed	10 s
6	Walking forward heel -to -toe on a straight line	Open	6 S
7	Walking forward heel -to -toe on a balance beam	Open	6 S
8	Standing on one leg on a balance beam	Open	10 s
9	Standing on one leg on a balance beam	Closed	10 s

s; second, S; steps

well as general health of children. The entry criteria for group with hearing loss were congenital or early bilateral severe to profound SNHL which was determined by audiology experts using pure tone audiometry (PTA). For the group with an intellectual disability, subjects with mild mental retardation determined based on Wechsler and Raven's intelligence test (using child's medical records) entered the study. Normal healthy children were selected from among students of two primary schools, hearing impaired children from an elementary school for hard of hearing and eight integrated elementary school, and subjects with intellectual disability from an exceptional elementary school.

After completing medical history and consent form, subtest of balance of the Bruininks-Oseretsky test version 2 (BOT-2) of motor proficiency was taken from all children. Cushing et al. believe this test is highly correlated with the rotating chair test which is used for the diagnosis of under-responsive vestibular system in hearing-impaired children [19]. Also Wong et al. suggest that this test is correlated significantly with pediatric version of clinical test of sensory interaction for balance (PCTSIB) for children which is a modified clinical version of sensory organization test [20].

Bruininks-Oseretsky test of motor proficiency (BOTMP) is a norm-referenced measure for gross and fine motor skills of children aged 4.5 to 14.5 years old. This test has been widely used in the evaluation of motor impairment of children with cerebral palsy, intellectual disability, developmental disorders and autism and its result on 800 children was reported in 1978 by Bruininks [21]. In 2005, the test was revised and the second version was called BOT-2 test, complete sets of the new version has 53 articles which is divided into eight sub-tests and subtest of balance consists of nine sections which starts with easy tasks and then examines balance performance of individuals by creating difficulty in somatosensory and visual inputs. The reliability value and the validity were reported 0.87 and 0.84, respectively [19]. In present study, in order to measure the subjects' balance, the second edition of the test was used. In this test, stages 1, 2, 4, 5, 8 and 9 are used to assess static balance and stages 3, 6 and 7 are used to assess the dynamic balance (Table 1). During stages 1 and 2, subject -once with eyes open and once with eyes closed -stands on a straight line for 10 seconds with his arms resting on his hips, in case of sliding or moving or splitting hands off hips, test is stopped and the recorded time is considered as the participant's record. In stage 3, subject takes 6 steps on a straight line with his arms resting on his hips. If before taking six steps, one or both feet completely go out of the line or subject's hands are removed from his hips, the test stops and the number of correct steps is recorded. In stages 4 and 5, subject stands on a straight line for 10 seconds with one leg (dominant leg) while arms resting on the hips, once with eyes open and once with eyes closed, in case of stumbling or moving or splitting hands off hips or if the free leg touches the floor or the other leg or drop below a 45 angle or shift the supporting foot out of place, test stops and duration of keeping balance is recorded. In stages 6 and 7, subject with hands resting on his hips takes six heel-to-toe steps on a straight line on the floor or on a balance beam. If before taking six steps, one or both feet completely go out of the line or subject's hands are removed from his hips, or the heel of the front foot is placed on the toe of the back foot or the toe of the back foot touches the heel of the front foot, the test stops and the number of correct steps is recorded. In stages 8 and 9, subject stands on in the midline of a balance beam for 10 seconds with one leg (dominant leg) while arms resting on the hips, once with eyes open and once with eyes closed, in case of sliding or moving or splitting hands off hips or if the free leg touches the ground or the other leg or places lower than 45 degrees, test stops and duration of keeping balance is recorded [22]. It should be noted that during all the stages, subject should not be wearing any shoes or socks in order to eliminate the interference of the type of the shoes and socks on the validity of the test.

If subjects did not achieve maximum points in the first trial, they were allowed to repeat the test two more times and the best result was considered. The test was conducted by the first author of the present article in the occupational therapy room or an empty class in subjects' schools. The correct manner of doing each stage was explained to children either by the examiner or sometimes their teacher using all types of general communication, including speech, sign language, body language, facial expressions or displaying the act and then after confirming the understanding of the child regarding how to the test, the test was conducted.

Table 2. Comparison of the mean (standard deviation) of age and body mass index in the three studied groups

Variable	Group	Mean (SD)	p
Age			
	Hearing impaired	10.54 (2.77)	
	Intellectual disability	10.23 (2.05)	0.11
	Normal	9.42 (1.79)	
BMI			
	Hearing impaired	17.49 (2.77)	
	Intellectual disability	15.91 (1.80)	0.08
	Normal	16.84 (2.56)	

BMI; body mass index

For mean comparison, ANOVA, Kruskal-Wallis non-parametric test, and Duncan's post hoc test were used. All statistical analysis was performed using SPSS 23 with a significance level of 0.05.

Results

Demographic features regarding age and body mass index of subjects in all three groups are shown in Table 2. ANOVA test results showed that the three groups have no significant difference in mean age and body mass index. Kolmogorov-Smirnov test showed that the scores of the subtest of balance are not normally distributed in three groups ($p<0.001$), so Kruskal-Wallis nonparametric analysis was used to compare the three groups.

Table 3 shows the results of BOT-2 balance subtest in stages 1 to 9 from dynamic balance subtest and static balance subtest separately, and also statistical results of Kruskal-Wallis test. Results revealed that there is a significant difference between the groups in mean balance scores in all stages except for stages 3 and 8. Duncan post hoc test was used in order to compare and find the difference among each two pairs. Results showed in stages 1 and 2, hearing

Table 3. Comparison of the mean (standard deviation) of balance subtest scores, static and dynamic balance in the three studied groups

Balance subtest	Hearing impaired	Intellectual disability	Control (Normal)	p
1 s	8.8 (2.7)	10 (0)	10 (0)	0.002
2 s	6.8 (3.2)	8.5 (2.4)	9.4 (1.8)	0.005
3 S	5.7 (1.2)	6 (0)	6 (0)	0.12
4 s	9.1 (2.6)	9.3 (1.2)	10 (0)	0.015
5 s	4.4 (2.7)	5.2 (2.6)	7.5 (2.9)	0.000
6 S	5.2 (1.6)	5.4 (1.1)	5.9 (0.2)	0.007
7 S	5.3 (1.6)	5.3 (1.5)	6 (0)	0.002
8 s	9.2 (2.5)	9 (2.2)	9.8 (0.7)	0.225
9 s	5.7 (2.9)	5.6 (3.2)	7.5 (2.6)	0.020
Static balance	44.1 (13.9)	47.6 (9.5)	54.2 (6.3)	0.000
Dynamic balance	16.3 (4.2)	16.7 (2.3)	17.9 (0.2)	0.001

s; second, S; steps

impaired group has a significant difference with other two groups while the intellectual disability group has no significant difference with healthy one.

In stages 4, 5, 6, 7, 9 and in the overall scores of static and dynamic balance, there is a significant difference between both disabled groups and the healthy group; whereas, there is no significant difference between the two disabled groups.

Discussion

Children with hearing loss and intellectual disability obtained nearly perfect scores and performed similar to healthy children in stage 3 of BOT2 balance subtest (normal walking on a straight line). Since walking speed and step length are not considered in this test, the lack of difference can be attributed to the use of compensatory mechanisms such as walking slow and taking short steps in these children. Myklebust (1965) supports the idea that deaf children walk with short steps which is due to the need to learn more details about the base of support in order to maintain the balance; furthermore, speed of motor performance of the deaf in compare to those of normal hearing is at a lower level (9). Chiba et al. reported that children with intellectual disabilities in order to compensate for the lack of balance and stabilize their posture benefit from strategies such as shorter step length and walking at a slower pace [23].

The two groups of children with disabilities were similar to healthy ones in stage 8 as well (Standing with one leg on the balance beam with open eyes). When this stage was compared with stage 4 (standing with one foot on a straight line with open eyes) which showed significant difference between healthy children with other two groups, results revealed that lack of difference in stage 8 can be due to the poor performance of healthy children in this level in compare with stage 4 which led to similar performance among all groups in stage 8. In other words, when subjects had to stand on the balance beam instead of the floor with one leg, healthy ones did not obtain the complete score unlike stage 4.

In other stages (1, 2, 4, 5, 6, 7, 9) and in the static and dynamic balance test in general, children with hearing loss had poorer performance than healthy children. The results of this comparison is consistent with the results of Zwierzchowska et al. [8], Jafari et al. [24], Wong et al. [20] and Ahmad pour et al. [25] that hearing damage is associated with balance disorder. In this regard, vestibular deficit theory suggests that vestibular and auditory systems have close anatomical and functional relationship with one another. Damage to the inner ear which can cause hearing loss is likely to harm the vestibular organs [26]. While Hosseini et al. and Aali and Rezazadeh reported that hearing damages are ineffective on balance [27,28]. This contradiction can be attributed to the type of subjects of Hosseini et al. (elderly) and the type of balance test used in Aali and Rezazadeh (Berg test for static balance and timed get up and go test for dynamic balance). Many different tasks are required to be performed in the test used for the current study (BOT-2 balance subtest) and sensory manipulation is used in different situations which might lead to revealing the difference between groups more evidently.

Children with intellectual developmental disorder had poorer performance than healthy children in static and dynamic balance test in general and all the stages except for stages 1, 2, 3 and 8. Findings are consistent with the results of Carmeli et al. and Pahlevanian et al. regarding the impact of intellectual developmental disorder on the balance [18,29].

Comparing children with hearing loss and children with intellectual disabilities using BOT-2 balance subtest revealed that children with hearing loss had significantly poorer performance only in the first two stages since children with intellectual disabilities obtained complete score similar to healthy ones in stages 1 and 2. Children with hearing loss in compare to other disabled group had lower scores in static and dynamic balance subtest but the difference was not significant.

Conclusion

Findings of the current study show that children with hearing loss and children with developmental intellectual disorder have poorer performance than healthy ones their age. In other words, severe to profound hearing loss and mild intellectual disability almost equally affect children's balance performance and cause a drop in their performance. Since the balance is very important to achieve a better life and functional independence, it is recommended that physical activities and proper rehabilitation are considered for these children to improve their performance, particularly at younger ages that movement patterns are forming.

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