Research Article

Integration of Hearing and Balance Screenings for Preschool Children Aged 4-6 Years in Tehran, Iran

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Highlights

- The positive effect of normal weight on the balance scores of preschool children
- Slight to moderate conductive HL was the most common hearing impairment
- There was an indirect relationship between the degree of HLand balance scores

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ABSTRACT

Background and Aim: Hearing impairment is the third leading cause of years lived with disability, particularly affecting children through language and speech delays, cognitive issues, and vestibular dysfunction. This study aimed to conduct both hearing and balance screenings for preschool children aged 4-6 years in Tehran, Iran.

Methods: In this study, 384 children (180 boys and 204 girls) from the east of Tehran city during spring 2023 participated. After taking the children's history and calculating their Body Mass Index (BMI), hearing screening were performed at screening, diagnostic, and intervention levels. Balance function was screened using the balance subtest of the short form of Bruininks-Oseretsky test of motor proficiency- second version (BOT-2).

Results: Among 768 ears examined, the prevalence of hearing loss (HL) was 11.2%, ranging from slight to moderate HL. Conductive HL had the highest prevalence (9.1%), followed by sensori-neural HL (1.3%) and mixed HL (0.8%). Of these, only 3% sought intervention. The mean total balance scores for age groups of 4, 5, and 6 years were 22.05±3.40, 26.02±3.72, and 28.13±4.50, respectively. Boys, children with higher BMIs, those with HL, and those with lower physical activity had significantly lower balance scores ($p<0.05$).

Conclusion: Given the type and degree of HL in preschool children and its relationship with balance scores, routine universal hearing and balance screenings for preschool children is recommended. Additionally, it is recommended to increase awareness among parents, child instructors, and pediatric healthcare providers in Iran regarding the importance of hearing and balance screenings for preschool children.

Keywords: Hearing; balance; preschool screening; bruininks-oseretsky; motor skills

Introduction

The processing and interpretation of auditory information in the auditory system are crucial for language and speech development, enabling an understanding of surrounding events and interaction with the environment. The effective listening experience is vital for decoding speech sounds, particularly during the early years of life when rapid neural plasticity occurs and gradually diminishes over time. This critical period for language acquisition spans from the fetal stage to six years [1]. Even mild hearing loss during this period can lead to delays in language and speech acquisition, reduced or absent communication abilities, economic and educational disadvantages, social isolation, and emotional and behavioral issues in children [2].

Hearing impairment is one of the most common sensory disorders. In 2018, 466 million people were reported to have hearing impairment. According to the latest reports from the World Health Organization (WHO), this number is predicted to increase to nearly 900 million people worldwide by 2050, with at least two-thirds living in developing countries [3]. The prevalence of hearing loss in preschool children has been reported to be approximately 13.2% in some provinces of Iran [4]. Currently, the implementation of hearing screening programs for preschool children in Iran is low (around 20%) and has not been implemented in all provinces.

Primary Health Care (PHC) is the foundation of the health system and is crucial for overall social and economic development within the community. One aspect of the PHC is the implementation of screening programs, including hearing screening across various age groups, especially during infancy and childhood. Although Universal Newborn Hearing Screening (UNHS) programs have proven effective in identifying hearing loss in infants and is being implemented with high coverage in Iran, their implementation for the preschool children is also necessary due to reasons such as the high prevalence of recurrent otitis media—affecting approximately 90% of preschool children, the occurrence of delayed or progressive hearing losses, and the presence of undetected mild hearing loss (In 10-15 newborns per 1000 live births, it may be missed due to limitations of hearing screening tests) [2,4].

Due to the anatomical and physiological similarities between the auditory and vestibular systems, where the vestibular system is one of the three modalities that play a role in balance and postural control, hearing loss can also cause balance disorders that significantly impact cognitive and emotional function in children, affecting their quality of life [5]. The prevalence of balance disorders in children has been reported to range from 0.7% to 15% [6]. Evaluation of gross motor skills is essential in assessing children's balance. Among gross motor assessments, the short form of the Bruininks-Oseretsky test of motor proficiency- second edition (BOT-2), due to having high reliability (0.81), validity (0.88) [7,8], sensitivity (91%), specificity (93%) [9], and being cost-effective, accessible, and time-efficient, has been recommended for children' balance screening in Iran. Its balance subtest evaluates Vestibulo-Spinal Reflex (VSR) for dynamic and static balance in individuals aged 4-21 years [10]. This test has been used in numerous studies to identify balance issues among children with hearing loss [10, 11]. Given that this test is influenced by individual characteristics such as age, gender, Body Mass Index (BMI), cultural and social factors, and economic status [9], it is necessary to conduct research in different geographical locations to determine the average score of its subtests. Therefore, this study aimed to implement integrated hearing and balance screenings for preschool children aged 4-6 years in Tehran, Iran. Hearing screening were performed to identify hearing impairment at three levels: screening, diagnosis, and intervention, while balance test was performed only at the screening level to determine the cutoff point for the balance subtest of BOT-2 short form for children aged 4-6 years.

Methods

Participants

Three hundred eighty-four preschool children aged 4-6 participated, who were selected using probabilistic and multi-stage sampling from 12 kindergartens located in the east of Tehran city. After obtaining their informed consent, a questionnaire for measuring the children's hearing status, balance, overall health, and physical activities was completed virtually or face-to-face by the parents. The preschool children with neurological, orthopedic, musculoskeletal, or ocular problems were excluded. Children were divided into three age groups: 4 years to 4 years and 11 months (4-year-olds), 5 years to 5 years and 11 months (5-year-olds), and 6 years to 6 years and 11 months (6-year-olds).

Measures

After measuring each child's height and weight, they were categorized into normal, underweight, or overweight groups based on their BMI [12]. After giving instructions to the children, their hearing and balance screenings were also conducted, starting with the older children in each group. For hearing screening, the appearance of the auricle was first observed followed by otoscopy examination for each ear. In case of structural or functional problems of the outer or middle ear, the child would be referred to an otologist. Subsequently, hearing screening was performed using an audiometer. The referral criterion for pure tone audiometry was the response to tones greater than 20 dB HL at any frequency (500 Hz, 1000 Hz, 2000 Hz, or 4000 Hz) in each ear [13]. Referrals were introduced to the audiological center for diagnostic evaluation (level II).

For balance screening, after giving explanations to each child, they performed thes balance subtest of the BOT-2 short form. This subtest consists of nine items: six performed with eyes open and three with eyes closed, with six tasks performed on the ground and three on a balance beam. According to test instructions, children were permitted to repeat their attempts if they did not achieve the maximum score on their first try. Their mistakes were indicated to them along with giving explanations before retesting; only their best result from two attempts was recorded [14].

After completing the screening, referred cases were followed up, and their results from the screening level to the diagnosis and intervention levels were collected to complete the hearing screening report. The degree of hearing loss was determined based on averaging the results at frequencies of 500, 1000, and 2000 Hz [13].

Statistical analysis

To examine the relationship between two categorical variables, the chi-square test was employed. For comparing the means of two groups, an independent t-test was used if the data were normally distributed; otherwise, the non-parametric test (Mann-Whitney U test) was applied. For comparing means across more than two groups, one-way ANOVA was utilized for normally distributed data, while a non-parametric test (Kruskal-Wallis test) was used for non-normally distributed data. In cases of significant differences between groups, the Bonferroni test or the Mann-Whitney U test with Bonferroni adjustment (non-parametric test) was used as a post-hoc test for pairwise comparisons. To assess the relationship of age and gender with the type and degree of hearing loss, the Generalized Estimating Equations (GEE) method was employed. The significance level was set at 0.05.

Results

The demographic characteristics of 384 preschool children are presented in Table 1. In this study, 180 boys (47%) and 204 girls (53%) participated. The boys had a mean age of 4.90±0.81 years, and the girls had a mean age of 5.02±0.79 years. Out of 384 children, 78 (20.3%) were referred for medical evaluation based on the otoscopic test results, including 41 (10.7%) boys and 37 (9.6%) girls. Also, out of 768 ears examined, 122 (15.9 %) ears were referred for otoscopic tests, including 59 (7.7 %) right ears and 63 (8.2%) left ears. The most common reasons for referral were the observation of bubbles behind the tympanic membrane (18 right ears, 2.3%; 19 left ears, 2.5%) and inflammation (12 right

Table 1. Number of children passed the hearing screening or referred for further examination categorized by age group, gender, and test ear

Variables		Passed, n(%)	Referred, n(%)	Total, n(%)
Gender	Boy	148(45.3)	32(56.1)	180(47.0)
	Girl	179(54.7)	25(43.9)	204(53.0)
Age group	4 years	115(35.2)	14(24.6)	129(33.5)
	5 years	119(36.4)	21(36.8)	140(36.4)
	6 years	93(28.4)	22(38.6)	115(29.9)
Test ear	Right	336(87.5)	48(12.5)	384(100.0)
	Left	333(86.7)	51(13.3)	384(100.0)

ears, 1.6%; 8 left ears, 1.04%). For hearing screening, out of 384 children, 57(14.8%) were referred to the audiological centers, including 32 boys (56%) and 25 girls (44%). The highest referral rate was observed in the 6-year-old group (n=22, 5.7%). Out of 768 ears, 48 (6.2%) right ears and 51 (6.6%) left ears were referred for hearing screening. Among 57 (14.8%) children referred for hearing screening, 8 (2%) had normal hearing at the diagnostic level (false positive). The remaining 49 (12.7%) children, 12 (24%) had unilateral hearing loss, while 37 (76%) had bilateral hearing loss.

Table 2 shows the frequency of hearing loss based on the type and degree obtained at the diagnosic level (level II). Tweleve (3%) children with confirmed hearing loss sought intervention (level III(; two children (0.5%) with bilateral moderate Sensorineural Hearing Loss (SNHL) received hearing aids, 3 (0.8%) children with moderate Conductive Hearing Loss (CHL) underwent ventilation tube placement surgery, and 7 (1.7%) children with mild to moderate hearing loss due to otitis media began medical intervention. The GEE results indicated no significant relationship of gender or age with type or degree of hearing loss (p>0.05).

The scores of balance screening for nine items of the BOT-2 short form based on age and gender are reported in Table 3. Based on the Kruskal-Wallis test results

Table 2. Number of referrals categorized by type and degree of hearing loss in their right and left ears

Test ear	Degree	Type			
		CHL n(%)	SNHL n(%)	MHL n(%)	Total, n(%)
Right	Slight	7(1.8)	0(0.0)	0(0.0)	7(1.8)
	Mild	11(2.9)	1(0.3)	0(0.0)	12(3.2)
	Moderate	15(3.9)	4(1.0)	3(0.8)	22(5.7)
Left	Slight	11(2.9)	1(0.3)	0(0.0)	12(3.2)
	Mild	16(4.2)	0(0.0)	1(0.3)	17(4.5)
	Moderate	10(2.6)	4(1.0)	2(0.5)	16(4.1)

CHL; conductive hearing loss, SNHL; sensorineural hearing loss, MHL; mixed hearing loss

Table 3. Mean scores for each item of the balance test categorized by gender and age group

Items	Mean(SD) Gender			Mean(SD) Age group			
	Girl	Boy	p*	4 years	5 years	6 years	p**
Item 1	3.99(0.07)	4.00(0.00)	0.35	3.99(0.09)	4.00(0.00)	4.00(0.00)	0.37
Item 2	3.90(0.38)	3.84(0.50)	0.19	3.82(0.54)	3.91(0.33)	3.88(0.44)	0.40
Item 3	3.24(0.86)	2.94(1.02)	0.004	2.53(0.98)	3.25(0.83)	3.56(0.70)	<0.001
Item 4	3.85(0.40)	3.79(0.44)	0.17	3.78(0.47)	3.86(0.37)	3.83(0.42)	0.41
Item 5	3.37(1.02)	2.95(1.21)	<0.001	2.56(1.24)	3.40(1.00)	3.59(0.84)	<0.001
Item 6	2.12(0.92)	1.80(0.99)	0.001	1.35(0.75)	2.10(0.83)	2.52(0.95)	<0.001
Item 7	2.08(1.15)	1.63(1.10)	<0.001	1.19(0.89)	2.00(1.01)	2.49(1.16)	<0.001
Item 8	3.40(2.38)	2.82(1.17)	<0.001	2.71(1.08)	3.10(1.10)	3.64(3.05)	<0.001
Item 9	0.62(0.82)	0.40(0.98)	0.001	0.22(1.02)	0.48(0.59)	0.90(0.95)	<0.001
Total	26.45(4.28)	24.04(4.61)	<0.001	22.05(3.40)	26.02(3.72)	28.1(4.50)	<0.001

* Mann-Whitney U test, ** Kruskal-Wallis test with Bonferroni correction

for comparing three age groups of 4, 5, and 6 years, there were statistically significant differences in total balance score and in items 3 and 5-9 among the groups ($p<0.001$). The results of pairwise comparisons using the Bonferroni test indicated that the total balance score and the scores of items 3 and 5-9 were significantly higher in children aged 5 and 6 years compared to those aged 4 years ($p<0.001$), and in children aged 6 years compared to those aged 5 years ($p<0.05$).

The total balance score of children who passed hearing screening was significantly higher than that of children with confirmed hearing loss (25.79±4.654 vs. 22.08±2.29; $p<0.001$). No significant difference was found between the mean total balance score of children with normal hearing and those with unilateral hearing loss ($p>0.05$). The mean total balance score of children with unilateral hearing loss was significantly higher than that of those with bilateral hearing loss (23.75±3.14 vs. 21.54±1.66; $p<0.05$). Regarding the balance test items, the scores were significantly higher in children with normal hearing compared to those with confirmed hearing loss ($p<0.001$), except for items 1, 6, and 7. Based on the Kruskal-Wallis test results, the total balance score difference among the three groups of children with different types of hearing loss was statistically significant ($p<0.001$). The results of post-hoc test with Bonferroni correction revealed that children with CHL had significantly higher balance scores compared to those with SNHL and Mixed Hearing Loss (MHL) ($p<0.05$).

In comparing the mean total score of balance among children with different degrees of hearing loss in the right ear (slight, mild, and moderate), the results showed a statistically significant difference ($p<0.001$). Bonferroni post-hoc test results indicated no significant difference in balance scores between children with slight and mild hearing loss in the right ear ($p>0.05$), while the mean balance score of children with moderate hearing loss was significantly lower than that of those with slight ($p<0.05$) and mild ($p<0.001$) hearing loss. The comparison of balance score among children with slight, mild, and moderate hearing loss in the left ear also showed statistically significant differences ($p<0.001$). Children with slight hearing loss in the left ear had significantly higher balance scores than those with mild ($p<0.05$) and moderate ($p<0.001$) hearing loss, and those with mild hearing loss had significantly higher scores than those with moderate hearing loss ($p<0.05$).

The Bonferroni post hoc test results revealed that the total balance score of children with normal weight and underweight children was significantly higher than that of overweight children ($p<0.05$). Table 4 shows the

Table 4. Mean scores for each item of the balance test categorized by body mass index

	Mean(SD)			
	BMI			
Items	**Underweight**	**Normal weight**	**Overweight**	**p***
Item 1	4.00(0.00)	3.99(0.07)	4.00(0.00)	0.56
Item 2	3.95(0.22)	3.88(0.43)	3.85(0.47)	0.64
Item 3	3.48(0.75)	3.17(1.01)	2.99(0.90)	0.01
Item 4	3.86(0.48)	3.83(0.39)	3.81(0.44)	0.74
Item 5	3.67(0.73)	3.28(1.09)	3.02(1.18)	0.01
Item 6	2.24(1.04)	2.06(1.08)	1.86(0.82)	0.08
Item 7	2.14(1.35)	2.01(1.28)	1.71(0.95)	0.07
Item 8	3.14(0.96)	3.29(2.58)	2.98(1.12)	0.36
Item 9	0.57(0.75)	0.68(0.83)	0.36(0.96)	<0.001
Total	26.86(4.13)	25.99(5.02)	24.50(4.05)	0.002

BMI; body mass index
* Kruskal-Wallis test with Bonferroni correction

statistical data related to the scores of the balance items based on BMI. According to the history of physical activity, the balance score of children engaged in routine physical activities was significantly higher than that of children with no participation in physical activities (26.86±3.50 vs. 23.32±4.18; p<0.001).

Discussion

The purpose of this study was to implement integrated hearing and balance screenings in children aged 4-6 years. In the hearing screening of 384 preschool children, 85 (22%) were referred for otoscopic examination and audiometry. Among the 57 children (14.84%) referred for audiometry, 8 (2%) were reported as false positives. The CHL had the highest frequency (9.1%), followed by SNHL (1.3%) and MHL (0.8%). Follow-up data revealed that only 3% of children with hearing loss sought intervention. In balance screening, the mean total scores of the balance subtest of the BOT-2 short form for age groups of 4, 5, and 6 were respectively 22.05±3.40, 26.02±3.72, and 28.13±4.50. The male children, those with higher BMI, those with hearing loss, and those with low physical activity had significantly lower total balance scores (p<0.05).

In a study by Baradaranfar et al. in Yazd, Iran, on 577 children aged 3-6 years, the prevalence of slight to profound hearing loss was 13.4% (11.5% CHL, 1.5% SNHL, and 0.5% MHL) [15]. In the study by Heidari et al. in Hamadan, Iran, on 345 children aged 3-6 years, the prevalence of slight to moderate hearing loss was reported as 11.9% (10.3% CHL, 1.3% SNHL, and 3% MHL) [16]. This suggests a similarity in the prevalence of hearing loss among preschool children in various cities and provinces of Iran. In the study by Kam et al. in China using automated auditory screening on 6231 children aged 3-7 years, the overall referral rate was 10.38% and 162 children had confirmed hearing loss, 15 (9.26%) with SNHL and 147 (90.47%) with CHL [17]. An important finding in the present study and other studies is the highest prevalence of CHL. Since the degree of CHL is less than moderate hearing loss and can occur frequently in children, it is often undetectable by parents, indicating the need for regular hearing screening in preschool children. In the current study, the lower total balance score observed in younger children is consistent with the findings of Hong et al. on 81 children aged 4 to 6 years [18] and Yoon et al. on 283 children aged 7-12 years [8], both in Korea, using the BOT-2. Human balance development is a gradual process that continues until age 12 [19]. The attention and concentration for skill acquisition also increase with age [20].

The findings of this study demonstrated the superiority of girls in the balance test, which is in agreement with the results of Hong et al. in Korea, who reported girls' advantages in fine motor skills and balance in the BOT-2 [18]. Rehagen et al. who studied 30 children aged 4 to 8 in the United States using oculomotor tests and the balance subtest of BOT-2 also reported similar results [10]. In contrast, Gaul. in a study in Ireland using the BOT-2 on 139 children found that boys exhibited higher motor skill proficiency than girls [21]. It should be noted that we only utilized the balance subtest of the BOT-2 short form, and during evaluation, the examiner observed that girls had greater focus than boys on learning each item of the balance subtest. This observation is supported by the findings of Naglieri and Rojahn in the United States involving 2,200 children aged 5-17 years [22] and Alavi et al. in Malaysia for cognitive test batteries involving 270 children [23], They also indicated that girls had more focus than boys.

In this study, the balance performance of children with confirmed hearing loss was poorer than that of children who passed the hearing screening. This finding is consistent with the results of Carpenter and Campos [24] and Zarei et al. [25]. Furthermore, it was observed that as the degree of hearing loss increased, the balance scores of children with hearing loss decreased, which is consistent with the results of Melo et al.'s study conducted in Brazil [26]. Due to structural proximity between the vestibular and auditory systems, when the degree of hearing loss increases, the likelihood of vestibular system dysfunction increases [5]. Since the vestibular system is one of the three systems that contribute to balance, damage to this system can reduce the balance score. In addition, as hearing loss increases, the sounds that provide cues for orientation and awareness of events diminish significantly [24]. Moreover, due to physical limitations, individuals with hearing loss tend to engage in fewer physical activities and are less active compared to people with normal hearing [27].

In this study, it was observed that children with higher BMI had poorer balance performance. This finding is supported by the results of Gazbare et al. [28]

in India and Awad and Aneis [29] in Egypt, but is against the findings of Mülazimoglu Balli [30] in Turkey. High weight disrupts the center of gravity and body geometry, preventing children from actively participating in daily sports and increasing the risk of orthopedic issues [29]. These factors contribute to poorer motor skills in overweight children. In addition to the effects of age, gender, BMI, and hearing loss on the balance score of preschool children in this study, the results showed that the children who reguarly engaged in physical activity achieved higher balance score compared to their non-active peers. This is consistent with the findings of Gauchard et al. [31] and Patti et al. [32]. Balance maintenance relies on the integration of proprioceptive, vestibular, and visual signals, which can be enhanced by regular physical activity and consequently improves balance performance [33].

One of the limitation of this study was the lack of awareness of some managers, parents and caregivers regarding the necessity of hearing and balance screenings and the follow-up of referred cases. Additionally the young children required more time for training and performing the hearing and balance tests. There was also a lack of access to tympanometer during hearing screening.

Conclusion

The most common type conductive hearing loss and degree (slight to moderate) of hearing loss in preschool children highlights the need for routine and regular hearing screening for preschool hearing in Iran. The results demonstrated the impact of factors such as age, gender, hearing loss, body mass index, and physical activities on children's balance. The universal newborn hearing screening programs should be integrated with balance screening and implemented by the parents and kindergarten teachers for preschool children to achieve maximum profit from screening to intervention in primary health care programs.

Ethical Considerations

Compliance with ethical guidelines

This is a descriptive-analytical study conducted in spring 2023, having ethical approval from Shahid Beheshti University of Medical Sciences (Code: IR.SBMU.RETECH.REC.1402.162).

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Authors' contributions

SFM: Review, writing original draft, resourses, data collection, formal analysis; FH: Writing and editing, project administration, methodology, formal analysis, conceptualization; AAE: Project consultant, methodology, editting.

Conflict of interest

No conflict of interest in this study.

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