Auditory and Vestibular Research

The study of hearing and balance screening in preschool children in the east of Tehran city

1-**Seyedeh Fatemeh Mousavisadr** (first author), MSc in audiology
Department of Audiology, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
Email: s.fateme.moosavisadr.77@gmail.com, Orcid: 0009-0000-5507-0979
2- Fatemeh Heidari (corresponding author), Ph.D in audiology, assistant professor
Department of Audiology, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
Email: fheidari.audio@gmail.com, f.heidari@sbmu.ac.ir, Orcid: 0000-0002-7358-1008
3- **Amir-Abbas Ebrahimi** (third author), Ph.D in audiology. Special Education Organization
Email: mahyarebrahimi@yahoo.com, Orcid: 0000-0001-7072-6868

Abstract
Background and Aim: Hearing impairment is the third leading cause of years lived with disability in health systems, particularly affecting children through language and speech delays, cognitive issues and vestibular dysfunction. This study aimed to conduct hearing and balance screening for preschool children aged 4 to 6 years in the east of Tehran city during spring 2023.
Methods: In this study, 384 children (180 boys and 204 girls) were participated. After taking history and calculating the children's body mass index (BMI), hearing screening was performed leading to diagnosis and intervention levels. Balance function was screened using balance subtest of short form of Bruininks-Oseretsky test of motor proficiency second version (BOT-2) for children with entry criteria.
Results: In hearing screening**,** out of 768 ears, the frequency of hearing loss (HL) was found to be 11.2% that ranging from slight to moderate HL. Conductive HL had the highest frequency (9.1%), followed by sensori-neural HL(1.3%) and mixed HL(0.8%). Of these, only 3% sought intervention. In balance screening, the mean balance scores of subtest of BOT-2 for ages 4, 5, and 6 were respectively 22.05± 3.40, 26.02±3.72, and 28.13± 4.50. The boys, children with higher BMI, those with hearing loss and less physical activity had statistically significant lower scores ($p<0.05$).
Conclusion: Given hearing loss with its characteristics and relationship with balance scores found in this study, the necessity of routine universal screening for hearing and balance in preschool children is mentioned. Also, it's recommended increased awareness among parents, instructors and healthcare providers to maximize intervention.
Keywords: hearing; balance; preschool screening; Bruininks-Oseretsky; Motor skills

Highlights

- Slight to moderate conductive hearing loss was the most common hearing impairment
- There was an indirect relationship between degree of hearing loss and balance scores
- The positive effect of normal body mass index was observed on balance item scores

Introduction

The processing and interpretation of auditory informations in the central auditory system are fundamental for language and speech development, leading to an understanding of surrounding events and individuals' interaction with their environment. The effective listening experience is crucial 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 with hearing loss. According to the latest estimates from the World Health Organization (WHO), this number is increasing nearly 900 million people worldwide will suffer from disabling hearing loss by 2050, with at least two-thirds living in developing countries [3]. The frequency of hearing loss in preschool children has been reported approximately 13.2% in some provinces of Iran [4]. In addition, currently, the implementation of the

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hearing screening program for preschool children has a low coverage of around 20% , and is not implemented in all provinces.
Primary health care (PHC) is the core of health system and overall social and economic development in community. One aspect of PHC is implementing screening programs, including hearing screening across various age groups, especially during infancy and childhood. Although universal newborn hearing screening (UNHS) has proven effective in identifiying hearing loss in infants and is being implemented with high coverage in Iran. But, implementation the preschool hearing screening program are also necessary for the following reasons: the high prevalence of recurrent otitis media—affecting approximately 90% of children before school, the occurrence of delayed or progressive hearing losses, the presence of undetected slight and mild hearing loss (10 to 15 newborns per 1000 live births may be missed due to limitations of hearing screening tests) in UNHS [2,4].
Furthermore, due to anatomical and physiological similarity between the auditory and vestibular systems, where the vestibular system is one of the three modalities which roles in balance and postural control, hearing loss can also cause motor disorders that significantly impact cognitive and emotional function in children and affect their quality of life [5]. The prevalence of balance disorders in children has been reported to vary from 0.7 to 15% in previous studies [6]. Evaluation of gross motor skills is essential in assessing children's balance. Among gross motor assessments, the Bruininks-Oseretsky Test of Motor Proficiency Second Edition (BOT-2) short form, due to its reliability (0.81) and validity (0.88)[7,8], high sensitivity (91%) and specificity (93%) in Iran [9], cost-effectiveness, accessibility and time-efficient nature are recommended for children balance screening. It's balance subtest evaluates vestibulo spinal reflex (VSR) for dynamic and static balance in individuals aged 4 to 21 years [10] This test has been used in numerous studies to identify balance issues among the children with hearing loss [10, 11]. Given this test is influenced by individual characteristics such as age, gender, body mass index (BMI), cultural and social factors, economic status, etc [9], it is necessary to conduct research in different geographical locations to determine the average score of its subtests. This study aimed to implement integrated hearing and balance screening for preschool children aged 4 to 6 years in the east of Tehran city during spring 2023. Hearing screening was performed to identify hearing impairment at three levels: screening, diagnosis, and intervention, while balance screening was performed only at the screening level to determine the norm cutoff line for the balance subtest BOT-2 in 4- to 6-year-old kindergarten children for future balance screening studies.

Methods

Study population

In this descriptive - analytical study, 384 kindergarten children aged 4 to 6 participated. We used probabilistic and multi-stage sampling in 12 kindergartens located in the east of Tehran city. This study has received ethical approval from Shahid Beheshti University of Medical Sciences (Code number: IR.SBMU.RETECH.REC.1402.162). Informed consent and completion of a questionnaire regarding the child's hearing status, balance, overall health, and physical activities were obtained virtually or in writing from parents. All kindergarten children within the mentioned age range were screened for hearing and balance issues, except those with neurological, orthopedic, musculoskeletal, or ocular problems.
After ensuring the calibration of the hearing screening device, coordination with the selected kindergarten managers was established and after selecting an appropriate location for screening in each kindergarten, biological check was performed. Children were divided into three age subgroups: 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).

Data collection

Screening phase

By measuring each child's height and weight, their BMI was categorized as normal, underweight, or overweigh [12]. After given instruction to children in small groups. The hearing and balance screening were conducted sequentially starting with older children in each group.

Hearing screening

First, the appearance of the auricle was observed followed by otoscopy examination for each ear. In case of structural or functional problems of the outer or middle ear, the child was referred to an otologist. Subsequently,

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hearing screening was performed using a screening audiometer. The referral criteria for pure tone screening audiometry, 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).

Balance screening

Initially, we explained to each child how to perform BOT-2 short form. The balance subtest of BOT-2 consists of nine items: six with eyes open and three with eyes closed—six performed on the ground and three on a balance beam. According to test instructions, children were permited to repeat their attempts if they did not achieve the maximum score on their first try. Mistakes made by children were pointed out to them along with explanations before retesting; only their best result from two attempts was recorded [14].

Diagnostic hearing phase

After completing the screening, referred cases from hearing screening were followed up and their results from screening level to diagnosis and intervention levels were collected to complete the hearing screening report. The degree of hearing loss was determined based on averaging the 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, two independent t-tests were used if data were normally distributed; otherwise, the non-parametric equivalent (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 equivalent (Kruskal-Wallis test) was used for non-normally distributed data. In cases where differences between groups were found, Bonferroni correction or Mann-Whitney with Bonferroni adjustment (non-parametric) served as post-hoc tests for pairwise comparisons. To assess the relationship between age and gender with the type and degree of hearing loss, Generalized Estimating Equations (GEE) were employed. A significance level of 0.05 was considered.

Results

The demographic data for the 384 preschool children screened are presented in Table 1. In this study, 180 (47%) boys and 204 (%53) girls participated. Boys had an average age of 4.90±0.81 and girls 5.02±0.79 years.

Out of a total of 384 children, 78 (20.3%) were referred for medical evaluation based on otoscopic examination findings, comprising 41 (10.7%) boys and 37 (9.6%) girls. The results of otoscopic referrals indicated that out of 768 ears examined, 122 (15.9 %) ears were referred 59 (7.7 %) right ears and 63 (8.2%)left ears), the most common etiologies for referral being the observation of bubbles behind the tympanic membrane, (18 (2.3%) right ears and 19(2.5%) left ears) and inflammation (12 (1.6%) right ears and 8 (1.04%) left ears).

In screening audiometry, out of the 384 children, 57(14.8%) were referred to the audiological centers (32 (56%) boys, and 25 (44%) girls). The highest referral rates was observed in 6 years old age group (22 (5.7%)). Of the total of 768 ears, hearing screening referrals included 48 (6.2%) right ears and 51 (6.6%) left ears.

Among the 57 (14.8%) referred children the hearing screening, 8 (2%) of them exhibited 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 details of frequency distribution of the type and degree of hearing loss obtained in diagnosic level (level II). 12 (3%) of children confirmed with 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) loss underwent ventilation tube placement surgery and 7 (1.7%) children with mild to moderate hearing loss due to otitis media began medical intervention. GEE results indicated no significant relationship between gender or age with type or degree of hearing loss ($p>0.05$).

The results of balance screening using 9 items of BOT-2 according to age and gender are reported in Table 3. Based on the Kruskal-Wallis test for comparing multiple groups among three groups of children aged 4, 5, and 6 years, there were statistically significant differences in overall balance performance and subscales 3 and 5 to 9 between the groups under investigation ($p<0.001$). The results of pairwise comparisons based on post-hoc tests with Bonferroni correction indicated that children aged 5 and 6 years compared to those aged 4 years, the overall balance and subscales scores 3 and 5 to 9 were higher statistically significant ($p<0.001$). Additionally, children

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aged 6 years compared to those aged 5 years, the overall balance and subscales scores 3 and 6 to 9 were also higher statistically significant ($p<0.05$).
The overall balance scores of children who passed hearing screening (Mean=25.79, SD=4.654) was statistically significant higher than the balance scores of children with confirmed hearing loss (Mean=22.08, SD=2.29) ($p<0.001$). No significant difference was found between the mean balance score of children who passed hearing screening and those with unilateral hearing loss ($p>0.05$). The mean balance score of children with unilateral hearing loss (Mean=23.75, SD =3.14) was statistically significant higher than those with bilateral hearing loss (Mean=21.54, SD =1.66) ($p<0.05$). Balance subscale scores, except for items 1, 6, and 7 were higher statistically significant in children who passed hearing screening compared to those confirmed hearing loss ($p<0.001$). Based on the Kruskal-Wallis test, three groups of children with different types of hearing loss, the overall balance performance differences among the groups were statistically significant ($p<0.001$). Additionally, the results of post-hoc test with Bonferroni correction revealed that children with CHL had higher statistically significant balance scores compared to those with SNHL and MHL($p<0.05$).
Comparing the mean scores of balance subtest of BOT-2 short form of children with different degree of hearing loss across three categorization of slight, mild, and moderate hearing loss, in the right ear revealed statistically significant differences ($p<0.001$). Bonferroni post-hoc test 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 statistically significant lower than those with slight ($p<0.05$) and mild hearing loss ($p<0.001$).
Comparing balance performance 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 left ear scored higher statistically significant balance scores than those with mild ($p<0.05$) and moderate hearing loss ($p<0.001$), also those with mild hearing loss scored higher statistically significant balance scores than those with moderate hearing loss ($p<0.05$).
The Bonferroni post hoc test revealed that the balance performance of children with normal BMI and those with underweight BMI were statistically significant better than overweight children ($p<0.05$) **.** Table 4 shows the statistical data related to the scores of the BOT-2 balance subtest items and BMI.
According to the history form results, the balance scores of children who engaged in routine physical activities (Mean=26.86, SD=3.50) was higher statistically significant than children who did not participate in physical activities (Mean=23.32, SD=4.18) ($p<0.001$).

Discussion

The aim of this study was to implement integrated hearing and balance screening in children aged 4 to 6 years in the eastern regions of Tehran city. In hearing screening**,** out of 384 children, 85 (22%) were referred in otoscopic examination and screening audiometry. Among of 57 (14.84%) referred for screening audiometry (level II), 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 only 3% of children with hearing loss sought intervention. In balance screening**,** the mean balance scores of subtest of BOT-2 short form for ages 4, 5, and 6 were respectively 22.05± 3.40, 26.02±3.72, and 28.13± 4.50. The boys, children with higher BMI, those with hearing loss and less physical activity had statistically significant lower total balance scores ($p<0.05$).
In a study by Baradaranfar et al. in Yazd, Iran, involving 577 children aged 3 to 6 years, the prevalence of slight to profound hearing loss was reported 13.4%, with CHL (11.5%) , SNHL (1.5%), and MHL (0.5%) [15]. In study by Heidari et al. in Hamadan, Iran, involving 345 children aged 3 to 6 years, the prevalence of slight to moderate hearing loss was reported 11.9% which 10.3% of them with CHL, 1.3% with SNHL, and 3% with MHL[16]. Comparing the findings of the present study with preschool hearing screening reports in other cities and provinces of Iran, similarity in the frequency rate of hearing loss is observed. In study by Kam et al. in China using automated auditory screening on 6,231 children aged 3 to 7 years; the overall referrals was reported %10.38, in which 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 mentioned is that the highest prevalence rate of hearing loss is related to 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 programs in preschool children.

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In the current study, the balance screening using balance subtest of BOT-2 short form performed for children aged 4 to 6 years old. The lower overall mean balance scores obtained from younger children was align with study conducted by Hong et al. in korea which used BOT-2 on 81 children aged between 4 to 6 years[18] and study by Yoon et al. in korea that performed BOT-2 on 283 children aged between 7 to 12 [8]. Human balance development is gradual and continues until age 12 [19], also attention and concentration for skill acquisition increase with age[20].

The findings of this study demonstrated the superiority of girls in the balance subtest of BOT-2 short form, which aligns with the results of Hong et al. in korea, who reported girls' advantages in fine motor skills and balance in the BOT-2[18]. Similary, it is consistent with Rehagen et al. in the United States, who studied 30 children aged 4 to 8 using oculomotor tests and the balance subtest of BOT-2[10]. However, it contradicts the findings of Gaul et al. in Ireland, that performed completely BOT-2 on 139 children and found that boys exhibited higher motor skill proficiency than girls [21]. It should be noted that the current study exclusively utilized the balance subtest of BOT-2, and during evaluation, the examiner observed generally girls exhibited greater focus than boys while learning each items of the balance subtest of BOT-2 short form. This observation is supported by findings from Naglieri et al. in the United States study involving 2,200 children aged 5 to 17 years [22] and Alavi et al. in Malaysia on cognitive test batteries involving 270 children, which indicated that girls have more focus than boys [23].

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

In this study, it was observed that as the average BMI of children increase, the balance performance of them decrease. This finding aligns with the results of Gazbare et al. [28]. in India and Awad et al. in Egypt [29]but is inconsistent with the findings of Mülazimoglu et al. in Turkey [30]. 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]. Collectively, these factors may contribute to poorer motor skills in overweight children.

In addition to the effects of age, gender, BMI, and hearing loss on the overall mean balance score of BOT-2 which was observed in this study, another finding from the history form indicated that children who reguarly engaged in physical activity achieved higher overall mean balance score compared to their peers. This is consistent with Gauchard et al. [31]and Patti et al. [32]. Balance maintenance relies on the integration of proprioception, vestibular receptors, and vision inputs; regular exercise enhances these sensory inputs and consequently improves balance performance [33].

The limitation of this study include a lack of awareness among some managers, parents and caregivers regarding the necessity of hearing and balance screening and follow-up of cases that were referred. Additionally the young children required more time for training and implementing hearing and balance screening, as well as a lack of access to tympanometer during hearing screening.

Conclusion

The most common type of hearing loss (CHL) and the degree of hearing loss (slight to moderate) found in this study highlights the need for routine and regular preschool hearing screening programs. The balance subtest results of BOT-2 short form demonstrate the impact of factors such as gender, hearing loss, BMI, and physical activities on children's motor abilities. Therefore, universal hearing and balance screening for preschool children should be accompanied by increasing awareness among target communities including families, kindergarten teachers, and caregivers regarding the prevalence and consequences of hearing impairments in children to achieve maximum implementation from screening to intervention in PHC programs.

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Conflicts of interest

No conflict of interest in this study.

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Credit authorship contribution statement

SFMS: Review, Writing original draft, Resourses, Data collection, Formal analysis; FH: Writing and editing, Project administration, Methodology, Formal analysis, conceptualization; AAE: Project consultant, Methodology, Editting.

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Table 1. Presents demographic data about children based on pass or referral status in hearing screening by age, gender, and test ear.

Variables		Pass/N (%)	Refer/N (%)	Total/N (%)
Gender	Boy	148 (45.3)	32 (56.1)	180 (47)
	Girl	179 (54.7)	25 (43.9)	204 (53)
Age	4 years	115 (35.2)	14 (24.6)	129 (33.59)
	5 years	119 (36.4)	21 (36.8)	140 (36.46)
	6 years	93 (28.4)	22 (38.6)	115 (29.95)
Ear	Right	336 (87.5)	48 (12.5)	384 (100)
	Left	333 (86.7)	51 (13.3)	384 (100)

Table 2. Distribution data for referrals from right and left ears during diagnostic hearing assessment categorized by type and degree of hearing loss.

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

HL: Hearing loss, CHL: Conductive hearing loss, SNHL: Sensorineural hearing loss, MHL: Mixed hearing loss

Table 3. The Mean scores and standard deviations for each items of balance subtest of BOT-2 categorized by gender and age.

Items	Gender		P value *	Age			P value **
	Girl	Boy		4 year	5 year	6 year	
	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)	Mean (SD)	
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

Table 4. The mean and standard deviation of scores of 9 items of the balance subtest of BOT-2 by BMI.

Items	BMI			P value *
	Underweight	Normal range	Overweight	
	Mean (SD)	Mean (SD)	Mean (SD)	
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

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