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Original Article

To Observe the Dynamic Balance Problem in Deaf Children`s Via Four Square Step Test

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ABSTRACT

Background: Hearing loss is often associated with challenges in dynamic balance among children, impacting their daily activities and quality of life. This study aims to explore the relationship between varying degrees of hearing loss and dynamic balance capabilities among children, addressing a gap in current research on the physiological impacts of auditory impairments.

Objective: To assess and compare the dynamic balance of children with different severities of hearing loss and to establish if there is a linear relationship between hearing loss severity and balance performance.

Methods: A total of 302 children aged 4 to 15 years with varying degrees of hearing loss were recruited for this study. Participants were categorized into subgroups labeled as profound, severe, moderate, and minor hearing loss based on stop-watch tests. The Four Box Step Test was employed to measure each participant's dynamic balance. Data normality was verified using the Kolmogorov-Smirnov test, and differences among groups were analyzed using two-way ANOVA and Tukey's post hoc test.

Results: This study assessed the dynamic balance in children with varying degrees of hearing loss, analyzing data from 172 participants aged 4 to 15 years. The analysis revealed significant gender differences in dynamic balance, with males generally outperforming females. The age-based assessment demonstrated a negative linear trend, indicating that dynamic balance decreases as age increases, with significant variances across different age groups ($F(2, 166) = 3.91$, $p = 0.022$). Two-way ANOVA confirmed no significant interaction between gender and age on dynamic balance ($F(2, 166) = 2.82$, $p = 0.062$), highlighting that while age significantly affects balance, gender alone does not show a substantial impact.

Conclusion: Dynamic balance decreases as the severity of hearing loss increases, with males generally outperforming females. This study underscores the importance of incorporating balance training in rehabilitation programs for children with hearing loss to enhance their motor performance and safety.

Keywords: Balance, Deaf, Degree of hearing loss, Decibels of hearing loss, Dynamic balance, Sensorineural hearing loss, Static balance.

INTRODUCTION

Deafness, a multifaceted condition, has evolved in its definition across both cultural and medical realms. Medically, it is characterized by a loss of hearing severe enough to hinder the comprehension of spoken language in a clinical setting (1). Culturally, it extends to those who predominantly communicate through sign language, which may include individuals with varying levels of hearing ability. Historically, terms such as "mute" and "dumb" were used to describe individuals who, due to profound congenital or early deafness, could not use spoken language. These terms, while once neutral, have shifted in connotation over time(2, 3).

Advancements in medical technology, such as cochlear implants (CI), have significantly altered the landscape of treatment for early-stage deafness. It is recommended that cochlear implantation occur before the age of 12 months to optimize auditory development (1). This early intervention, supported by universal newborn hearing screening, has enhanced the potential for successful outcomes, including determining CI candidacy. Deafness results from dysfunction in one or more of the ear's sensory components, classified into degrees from mild (21-40 dB) to profound (over 95 dB)(4, 5).

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Environmental factors, along with genetic predispositions, contribute to hearing impairment in infants, with conditions such as maternal illnesses during pregnancy and complications post-birth accounting for approximately 25% of cases (6). Various forms of hearing impairment include sensorineural, conductive, mixed, and auditory neuroma spectrum disease (ANSD), each presenting unique challenges in diagnosis and management(7, 8).

Interestingly, hearing loss has been linked to challenges in maintaining balance, a connection not widely documented in young children (9). The vestibular system, crucial for balance, often remains under-assessed in pediatric settings despite its importance. Vestibular hypo function can lead to significant balance issues and falls, particularly as children develop complex motor skills. The interconnectedness of the ear and vestibular system suggests that hearing impairments could contribute to difficulties in postural stability (10, 11).

The Four Square Step Test (FSST) has been developed as a clinical tool to assess dynamic balance and mobility, crucial for navigating physical environments safely (12). This test measures the ability to traverse obstacles and change direction swiftly, providing valuable insights into motor planning and the ability to maintain stability while moving. Recognizing the significance of balance and mobility, the FSST has become an essential component in evaluating the risk of falls, particularly in populations with sensory deficits such as those experienced by deaf children(13, 14).

The discourse around deafness, both culturally and medically, highlights its complexity and the varied interpretations it can evoke. Deafness, as defined in audiological terms, denotes a level of hearing loss that severely impedes the understanding of spoken language, affecting various groups including those born with profound deafness, who are typically unable to use spoken language (15). These individuals often rely on sign language for communication, irrespective of their auditory capability, which culturally aligns them with the Deaf community—a group with its own rich cultural practices, history, and values (1, 16).

The concept of deafness extends to include not only those with a clinical diagnosis of severe hearing loss but also individuals who, although not profoundly deaf, engage primarily in sign language communication. This broader definition encompasses children of deaf adults and other members of the Deaf community who maintain sign language as their primary mode of communication. Misconceptions persist in mainstream society about the capabilities of Deaf individuals, often underestimating their potential and contributions. Efforts by NGOs around the world have sought to rectify this by supporting educational and technological access for the Deaf and hard of hearing in underserved regions, enhancing their integration and providing them with platforms to express their aspirations and experiences (17, 18).

Hearing loss, categorised into sensorineural, mixed, and conductive types, alongside auditory neuropathy, presents varying challenges in diagnosis and management. It impairs the ability to hear to varying degrees, from mild difficulties with soft sounds to profound deafness where only very loud sounds are perceivable (15). The impacts of hearing loss extend beyond auditory challenges, influencing cognitive and developmental trajectories in children. Early interventions, such as cochlear implants, have shown significant benefits in allowing children to gain spoken language skills, although disparities in outcomes remain a concern (19, 20).

This study aims to delve into how different degrees of hearing loss affect dynamic balance in children, utilizing the Four Square Step Test (FSST) as a diagnostic tool to evaluate their motor skills and balance. By understanding these dynamics, the research seeks to illuminate the correlation between auditory capacity and physical stability, thereby aiding in the future design and prescription of assistive devices. The ultimate goal is to enhance the understanding of balance performance in hearing-impaired children, paving the way for improved intervention strategies that cater to their unique needs. This endeavor not only aims to expand scientific understanding but also to contribute to the societal inclusion and enhanced quality of life for these children.

MATERIAL AND METHODS

In this observational cross-sectional study, a total of 302 children aged between 4 to 23 years, diagnosed with varying degrees of hearing loss, were initially recruited from a local organization in Sukkur. The participants, comprising 232 boys and 76 girls, were sourced from the Family Education Foundation School for the Deaf. Although 302 subjects were initially considered, the data of only 172 subjects were ultimately collected and analyzed, due to the requirements of the statistical program used in the study (10 November 2022–24 November 2022)(21).

The study was conducted following ethical approval from the appropriate regulatory committee, ensuring adherence to ethical standards and protocol compliance. Before the commencement of the research activities, informed consent was obtained from each participant's legal guardian, as well as assent from the children themselves where appropriate(10).

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Participants were stratified into subgroups based on the severity of their hearing impairment, assessed using the Stop Watch method. The division into groups took into consideration the age and gender of the participants. Boys and girls were included in the study and were assigned to three age-based groups: 4 to 7 years, 8 to 11 years, and 12 to 15 years. No subgroup for children with slight hearing loss was considered due to challenges in assessing balance in this group using the Stop Watch method(22).

The data collection involved administering the Four Square Step Test (FSST), a validated tool designed to assess dynamic balance. The test requires a stopwatch and four single-point sticks arranged in a cross formation on the floor. Participants began in one square and were instructed to move sequentially to each of the four squares, execute a turn, and return to the starting square. The sequence included steps forward, backward, and laterally to the right and left. The time to complete the sequence, termed the Full Sequence Time (FSST), was measured in seconds. Each participant was allowed two attempts, with the faster of the two times recorded. Any errors or losses of balance were noted, and trials were repeated if necessary(23).

Statistical analysis was conducted using one-way analysis of variance (ANOVA) to assess differences among age groups and an independent t-test to compare genders. Two-way ANOVA was employed to explore any significant interactions between age and gender in terms of dynamic balance performance. The normality of data distribution was verified using the Kolmogorov-Smirnov and Shapiro-Wilk tests. The significance threshold was set at $p > 0.05$ for all tests(24).

The study's findings were processed and analyzed with the collaboration of a statistician, ensuring robust and reliable data interpretation, and the results were documented for further scientific and clinical reference. This methodology not only facilitated a detailed assessment of dynamic balance in children with hearing impairments but also provided insights into the potential impacts of age and gender on balance performance.

RESULTS

Table 1 presents the subject's descriptive data broken down by subgroup. The table shows that there were a total of 172 participants in the study. One hundred sixteen guys participated in various subgroups. The total number of females across all categories was 56. One nineteen ninety (N=172) volunteers were used to ensure an equal number of males and females. In Table 1, the ages (in years) of the individuals are broken down by gender into several categories.

Figure No 1: Bar chart of age categories of Respondent in study

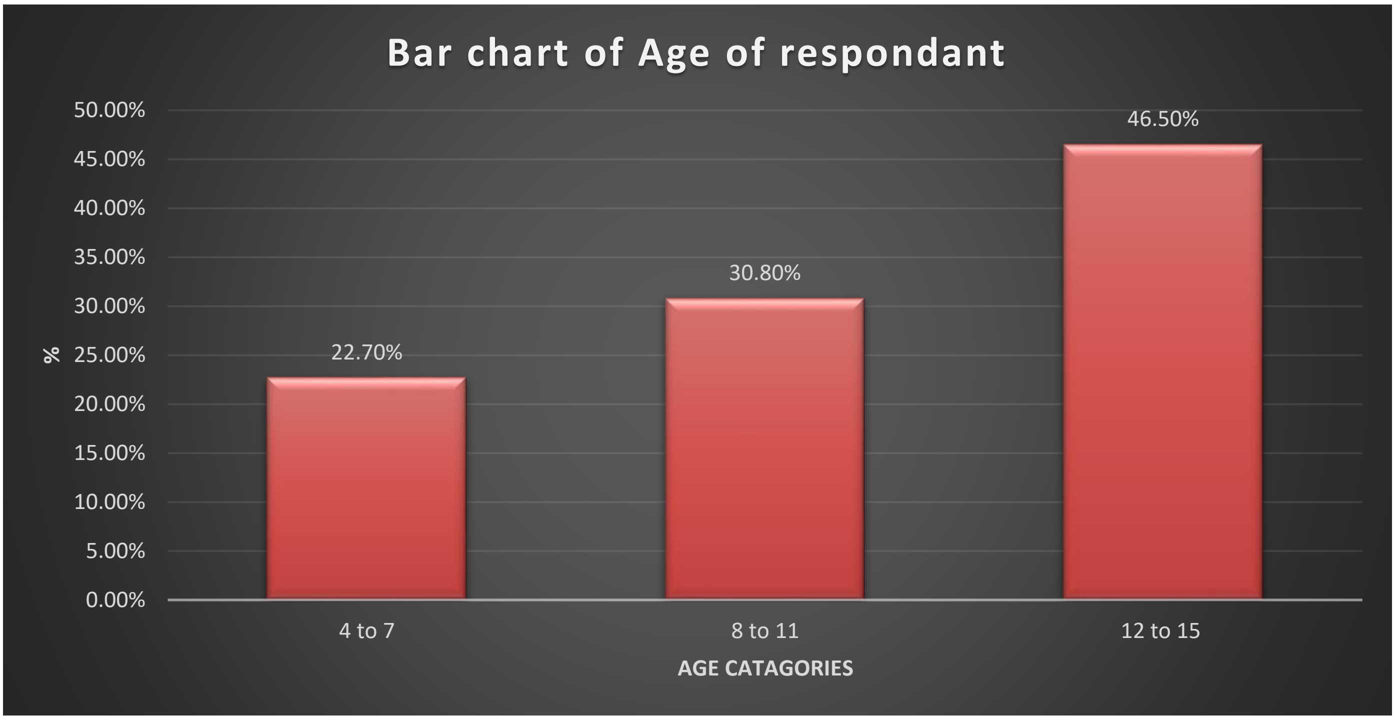

Figure 1 is bar chart of age wise categories of respondents here bar 1 shows that there were 39(22.70%) children of age four to seven years, second bar shows that there were 53(30.80) children of age 8 to 11 years in research study. In bar chart 3rd bar shows that there were 80 (46.50%) children between age twelve and fifteen in our research study

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Table no 1: Descriptive statistics basic characteristics/ variable in study

Variable	Categories	Frequency	Percentage
Gender	Male	116	67.4
	Female	56	32.6
	Total	172	100.0
Age	4-7	39	22.7
	8-11	53	30.8
	12-15	80	46.5
	Total	172	100.0
	Mean ±SD		Range
Age (years)	10.78±3.38		4-15
Trail 1 time (sec)	12.51±5.71		5-32
Trail 2 time (sec)	11.39±5.42		4-30
Best trail time (sec)	10.75±5.09		4-30

Table 1: show the descriptive characteristics of different variable in study. Table shows that there were 39(22.70%) children of age four to seven years and there were 53(30.80) children of age 8 to 11 years in research study.

Table shows that there were 80 (46.50%) children between age twelve and fifteen in our research study. For gender variable table shows that there were 56(32.60%) female children in research study and there were 116(67.4%) male children's in research study.

Table also shows that the Mean ±SD of overall age of respondents was 10.78±3.38 with range 4-15. Mean ±SD of overall Trail 1 time (sec) of respondents was 12.51±5.71 with range 5-32. Mean ±SD of Best trail time (sec) of respondents was 11.39±5.42 with range 4-30 Mean ±SD of overall Best trail time (sec) was 10.75±5.09 with range 4-30

Table 2: Gender wise comparison of best trail timing (Second), independent t test with bootstrapping

	Type	Mean±SD	95% CI for mean	P value
Grouping variable Gender	Male	10.51±5.12	9.63-11.58	0.367
	Female	11.25±5.05	10.0004-12.65	

Table 2: is showing the results of independent t test to compere the male and female average best trail time in seconds. To test the hypothesis that there is no difference of averages of best trail time in seconds in male and female, the data score was not normally distributed, therefore, the p-value may not be reliable and more weight should be placed on the bootstrapped 95% confidence interval that will be provided. On average, best trail time in seconds for male (M = 10.51, SD= 5.12) was lower than female (M = 11.25, SD = 5.05). This difference was not significant (Mdif = 0.7727, t(170) =-0.88, p = 0.367).

Therefore, it can be concluded that hypothesis that there is no difference of averages of best trail time in seconds in male and female is supported by the data.

Table3: Scores of Children by Age Groups Based on the best Assessment Trail. (One-way ANOVA)

Age Group	n	Mean ± SD	95% CI for mean	Min-max	F value	P value
4-7	39	8.59±4.45	7.23-10.1	4-24	7.45	0.001
8-11	53	10.20±5.23	8.90-11.59	4-27		

12-15	80	12.15±4.90	11.05-11.30	4-30		

Table 3 To test whether the mean of best trail in higher of age group 12 years to 15 years is higher than the age group 8 years to 11 years and 4 years to 7 years, one-way ANOVA was performed, the assumption of normality is not present so we perfume bootstrap

On average, dependent variable best trail time in seconds for age group 12 to 15 years had a mean of 12.15 (SD = 4.90). dependent variable best trail time in seconds for age group 8 to 11 years had a mean of 10.20 (SD = 5.23), dependent variable best trail time in seconds for age group 4 to 7 years had a mean of 8.59 (SD = 4.45). The pattern of means is displayed in table 3. The overall ANOVA was significant, indicating that there are differences in the mean of best trail in higher of age group 12 years to 15 years is higher than the age group 8 years to 11 years and 4 years to 7 years, F (2, 169) = 7.45, p =0.001)

Table 4: Bootstrap for Multiple Comparisons by Tukey HSD for age wise categories

(I) Age group	(J) Age group	Mean Diff (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
4-7	8-11	-1.62	1.03	.266	-4.06	0.83
	12-15	-3.58	0.95	.001	-5.85	-1.31
8-11	4-7	1.61	1.03	.266	-0.83	4.06
	12-15	-1.96	0.87	.064	-4.02	0.090
12-15	4-7	3.58	0.95	.001	1.31	5.85
	8-11	1.96	0.87	.064	-0.090	4.02

Table 4 shows that between comparison of age categories Post hoc tukey HSD test is used for this purpose, Post hoc turkey HSD test reveals that age group between 4 years to 7 years and 12 years to 15 years differ significantly, Mdif =-3.58, p = =0.001, 95% CI [-5.85, -1.31]., Post hoc turkey HSD test reveals that age group between 4 years to 7 years and 12 years to 11 years not differ significantly, Mdif =-1.62, p = =0.266, 95% CI [-4.07,-0.83]. Post hoc turkey HSD test reveals that age group between 8 years to 11 years and 12 years to 15 years not differ significantly, Mdif =-1.96, p = 0.064, 95% CI [-4.02,-0.090].

Table no 5: Mean and standard deviation of best trail with 6 condition of independent variable gender and age categories in two-way ANOVA

	Age categories				
Gender		4-7	8-11	12-15	Mean gender
	Male	8.25(4.60) N=24	9.36(4.65) N=38	12.33(5.9) N=54	10.51(5.12) N=116
	Female	9.13(4.30) N=15	12.53(5.53) N=28	10.92(4.13) N=13	11.25(5.05) N=54
	Mean age wise	8.60(4.45) N=39	10.71(5.24) N=66	12.05(4.92) N=67	10.75(5.02) N=172

Table no 5 shows the descriptive (Mean± SD) of 6 possible conditions of independents variables for Two Way ANOVA. Table shows that the Mean± SD of best trail in seconds of 24 male children with age group 4 years to 7 years is 8.25±4.60. Mean± SD of best trail in seconds of 38 male children with age group 8 years to 11 years is 9.36±4.65, Mean± SD of best trail in seconds of 54 male children with age group 12 years to 15 years is 10.51±5.9.

Table shows that Mean± SD of best trail in seconds of 15 female children with age group 4 years to 7 years is 9.13±4.30.Mean±SD of best trail in seconds of 28 female children with age group 8 years to 11 years is 12.53±5.53.Mean±SD of best trail in seconds of 13 male children with age group 12 years to 15 years is 12.05±4.92.

Table shows that the overall Mean± SD of best trail in seconds of age group 4 year to 7 year, 8 year to 11 year and 12 year to 15 year is 8.60±4.45, 10.71±5.24 and 12.05±4.92 respectively. Table also shows that overall mean ±SD of best trail in seconds of male and female is 10.51±5.12 and 11.25±5.05 respectively.

Table no 6: Two-way ANOVA table of response variable (best trail in second) with gender and age categories as independent variable

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Source	Type of Squares	df	Mean Square	F	Sig.
Gender	26.23	1	26.228	1.101	.296
Age categories	186.61	2	93.307	3.916	.022
Gender * age categories	134.65	2	67.325	2.826	.062
Error	3954.963	166	23.825		

Table no 6 shows the best trail in seconds was not normally distributed for both group male and female because Kolmogorov–Smirnov test p value <0.0001 for male and female). Additionally, the data was also not normally distributed for 3 group of age because Kolmogorov–Smirnov test p value <0.0001 for 3 groups of age the assumption of normality is violated. Bootstrap was performed given that the two-way ANOVA. The ANOVA showed no significant main effect of Gender, F (1, 166) = 1.101, p =0.296. Dependent variables best trail in seconds for age groups 12 t0 15 year (M = 12.05, SD = 4.92) were higher than for 8 to 11 year (M = 10.71, SD = 5.24) and age group 4 year to 7 year (M=8.60, SD=4.45).

There was also significant main effect of independent variable age groups, F (2, 166) = 3.91, p=0.022. Finally, there was no significant interaction effect, F (2, 166) = 2.82, p= 0.062.

DISCUSSION

The statistical analysis of the present study elucidated significant differences in dynamic balance across age and gender groups among deaf children. Notably, boys demonstrated superior dynamic balance compared to girls when the data from all hearing impairment groups were aggregated. This gender disparity in balance abilities might be attributed to physiological differences, particularly in the distribution of body mass and the resultant center of gravity (CG). During puberty, boys experience a higher rate of fat deposition around the waist, hips, and pelvis, leading to a lower CG compared to girls (25). A lower CG is generally associated with enhanced balance and stability, potentially explaining the superior performance observed in boys.

The findings suggest that dynamic balance is inversely related to the severity of hearing loss, reinforcing the notion that lesser degrees of hearing impairment correlate with better balance outcomes. This pattern held true across both genders, with improvements in dynamic balance noted as the degree of hearing loss decreased. The vestibular system, responsible for maintaining balance, is often compromised in individuals with hearing loss, particularly if the inner ear structures are affected. Vestibular dysfunction can disrupt balance as it impairs the body's ability to orient itself in space, process sensory information effectively, and maintain postural control(26).

The research also highlighted that dynamic balance varies with age, with younger children showing less balance control compared to older children. This finding aligns with developmental expectations, as balance control typically improves with age due to the maturation of sensory and motor systems. The Four Square Step Test (FSST) demonstrated high discriminative validity in this study, effectively categorizing children into appropriate age groups based on their balance capabilities(27).

However, the study has several limitations that need consideration. First, the sample size, while substantial, is drawn from a single educational institution, which may limit the generalizability of the findings to wider populations. Additionally, the assessment of balance using the FSST, although validated, does not capture all dimensions of balance and may overlook subtle nuances in dynamic and static balance abilities. Future research could benefit from incorporating a broader range of balance assessments and a more diverse demographic profile to enhance the robustness and applicability of the findings(28).

The study contributes valuable insights into the relationship between hearing loss and dynamic balance in children, with clear distinctions observed across different levels of hearing impairment and between genders. These findings underscore the complexity of balance as a multifaceted sensorimotor skill influenced by physiological, developmental, and possibly pathological factors. Enhanced understanding of these dynamics can inform targeted interventions aimed at improving balance and overall functional mobility in children with hearing impairments, ultimately fostering better quality of life and greater independence.

CONCLUSION

The study elucidates a clear relationship between hearing capacity and dynamic balance among children with varying degrees of hearing impairment. It was observed that males generally exhibited superior dynamic balance compared to females across all categories of hearing loss. This gender disparity in dynamic balance performance might be influenced by physiological differences in body mass distribution and center of gravity. Furthermore, the research highlights a positive linear relationship between the degree of hearing loss and dynamic balance, with improvements in hearing correlating with enhancements in balance. This suggests

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that as hearing loss decreases, dynamic balance tends to improve, indicating a progressive improvement from profound hearing impairment towards normal hearing conditions.

These findings imply that interventions aimed at improving hearing capacity might also enhance dynamic balance among hearing-impaired children. However, the study's scope was limited by its focus on a single institution, and the inclusion of only published research, which may affect the generalizability and comprehensiveness of the conclusions. Future research should consider a broader demographic and include unpublished studies to provide a more inclusive analysis. Additionally, rehabilitation strategies such as balance exercises, yoga, and muscle-strengthening activities could be beneficial in enhancing both the vestibular function and overall balance for children with varying degrees of hearing loss.

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