

A study on the dynamic balance of schoolchildren in India with varying degrees of hearing impairments

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Abstract:

Background: The present study attempted to measure the dynamic balance of the children with varying degrees of hearing loss from a comparative stand point to establish the association of dynamic balance with degree of hearing loss. **Purpose:** It was aimed to evaluate the differences of dynamic balance of school children with different degrees of hearing loss. **Problem Statement:** The present research work is stated as a study on dynamic balance of school children in India with varying degrees of hearing impairments. **Approach:** Two hundred & fifty two (N=252) children, both Boys (N_B=126) and Girls (N_G=126) with varying degree of hearing impairments having age ranging from 13-16 years were selected as subjects. On the basis of hearing ability, they were divided into six equal sub groups for each sex, namely Profound, Severe, Moderately Severe, Moderate, Mild and Normal Groups as assessed through audiometric techniques. In each subgroup the no. of subjects was twenty one (n=21). In this study dynamic balance was measured by Modified Bass Test (BASS; maximum score = 100). Collected data on dynamic balance for different sub groups (twelve) were presented as mean and standard deviation (SD). Data normality was tested through Kolmogorov-Smirnov (K-S) Test. The values of K-S test statistic were greater than the respective p-values (not differed significantly) in all twelve cases (row × column) for raw-data set of dynamic balance, it was confirmed that the data sets were normally distributed. Therefore, groups were compared by using 2-way ANOVA as parametric statistical tools in dynamic balance. Exact differences between the pair of groups were calculated separately in row, column and interaction to be confirmed by using Tukey's LSD test- a post hoc test. The significance was tested at p<.05 level. **Results:** In dynamic balance, 1) the girls were better than the boys when all six varying degrees of hearing impaired groups were combined. 2) Significant differences were observed between most of the pairs of groups with varying degrees of hearing impairments when both sexes are combined except in the few pairs of groups. 3) No interaction was observed between degree of hearing loss and sex. **Conclusions:** The dynamic balance of the girls is better than boys and it decreases almost linearly with increasing degree of hearing impairment. Thus, in dynamic balance there is a linear increasing trend with positive gradient from profound towards the normal group.

Keywords: Balance, Static balance; Sensorinural hearing loss; Degree of hearing loss; Deaf & Dumb; Decibels of hearing loss

Introduction

Among the sensory abilities; hearing is one of the important abilities that takes a vital role for the development of cognitive, affective, & behavioral abilities through the forms of communication in the process of learning (Zittel et al., 2016). Any degree of impairment in hearing ability inhibits the sensory inputs to flow up to the brain, lack of the signal strength results misprocessing and hearing inability comes into (Bilir, S. et al., 1995; Brunt & Broadhead, 1982; Jernice et al., 2011). The hearing impairment can vary in degree from mild to profound. Previous research work suggested that motor development interrupted due to hearing inability of the children as they suffers from poor level of balance abilities – static & dynamic (Gayle G. W., & Pohlman R. L., 1990; Gail M. Dummer et al., 1990; Weiss A H & Phillips J O, 2006). Execution of any movement is highly related to static and dynamic balance.

The World Health Organization (WHO) has provided terrible statistics on the sensorineural hearing loss of the world. These were reported first in 1985 that approximately 1% of the world's population (42 million) were suffering from moderate-to-profound (disabling) hearing loss (World Health Organization., 1995). After that, it increased in geometric progression and increased to 360 million, with 32 million children below the age of 15 years (World Health Organization, 2017). The hearing loss population increased from 1.2 billion (17.2%) to 1.4 billion (18.7%) from 2008 to 2017 (James et al., 2018). Most recently (2018), WHO reported that 6.1% of the total population of the world, or approximately 466 million (adults, 432 million, and children, 34 million) were suffering from “disabling” hearing loss. It was estimated that in 2030 the number will reach 630 million and in 2050 it will touch 900 million land mark (Stepanchenko et al., 2020). It is further reported that in 2050, approximately 1 in every 10 individuals will have hearing disability (Kushalnagar, 2019). This statistics also

explains that the number of children born with or acquiring a hearing disability is relentlessly expanding. These issues related to hearing disability should be considered with ample importance at the very early age of life to ensure the proper development of millions of children with hearing impairment all over the globe.

The person who cannot hear has hearing ability less than equal 20 dB on the other hand for the normal people it is greater than 20 dB in both ears (Kushalnagar, 2019). Hearing loss can be classified according to its varying degrees as profound, severe, moderately Severe, moderate, and mild (Kushalnagar, 2019; Smith, A. W., 1998). Hearing impairment, whether in one or both ears, makes it difficult to hear speech or even louder sound frequencies. Mild to severe degrees of HL are referred to as “hard of hearing”. People having profound hearing loss who hear very little or cannot hear at all are also called “Deaf” (Kushalnagar, 2019). The auditory problem originated from vestibular damage, which affects sensorineural function and psychomotor development. Previous research has suggested that hearing impairment cause some deficits in the psychomotor development as well as delays in learning motor skill performance, balance (static or dynamic), and coordination when compared to normal-hearing children (Gheysen & Loots, 2008; Melo RD et al., 2015.; Rajendran, 2011; Wiegiersma & Velde, 1983).

On the basis of the damage in the parts of the auditory system (inner, middle, or outer ear), the *American Speech-language Hearing Association* (ASHA) has classified HL into three types: i) Conductive Hearing Loss– the inability to hear faint sound waves that cannot pass through the external (outer ear) and internal ear (middle ear). ii) *Sensorineural Hearing Loss*- due to damage in the auditory nerve pathways and innermost part of the ear, and iii) Mixed Hearing Loss- i.e. conductive as well as sensorineural hearing loss (Weber & Klein, 1999; Rajendran, 2011). Furthermore, depending on the ability to receive the sound frequency, ASHA classified the degree of hearing loss, usually expressed in decibels of hearing loss (dB HL), into the following types: profound, severe, moderately severe, moderate, mild, slight, normal (Clark J G., 1981).

Balance is the skill that keeps the line of gravity perpendicularly over the support area of the base, and it depends on the feedback that is coming from the vestibule, visual and other somatosensory organs quickly and continuously. For any smooth neuromuscular action which is coordinated too requires good balance (Winter, D. A., 1995). Sustaining the body in a particular position is called static balance, while maintaining a stable position in motion is called dynamic balance (Winter, D. A. et al., 1960). Thus, for maintaining balance postural control is very important in any activity of human beings. Balance is required while someone wants to maintain a stable position or wants to restore and achieve a stable state in a stationary position and sometimes while someone is preparing to move or stop from a stable position or from a movement (De Kegel et al., 2011). In a particular motor response, the position of the center of gravity for postural stability over the base of support is an important factor (Rong-Ju Cherng et al., 2009). Balance is a component of motor fitness and is basically of two types: i) Static Balance and ii) Dynamic Balance (Berg K., 1989). Maintaining a stable & stationary position is called static balance, while dynamic balance is the ability to maintain the equilibrium of body mass in different motions (Ayanniyi et al., 2014a). In other words, static balance refers to the steady weight-bearing position in a antigravity posture, where as the ability to alter the position for maintaining stability is called dynamic balance - the skill to maintain body balance in motion (Patel et al., 2017; Hazar F, & Taşmektepligil Y., 2008).

To maintain static or dynamic balance, it is required to send an adequate amount of afferent information to the brain accurately from the visual, vestibular, and proprioceptive systems (Brian D. Iverson, et al., 1990). Balance is an essential tool in the execution of accurate motor performance and movement. People having profound hearing loss basically suffer from vestibular problems and show poor ability in balance skills (Potter CN, & Silverman LN, 1984). The maintenance of balance depends on the postural control of the body. Balance is controlled from the Central Nervous System (CNS) that receives a signal from the somatosensory system and processes the information, consequently, the balance of the body is maintained (Alpay, C. B. & Işık, Ö., 2017). The sense of pressure, touching, pain, position of the joints and movement of joints is perceived from the somatosensory system, which is simultaneously called proprioception. It is responsible for maintaining balance and postural control arising from joint position and joint movement perception. Hearing plays an important role – detecting the direction of sound coming by adjusting its frequency, differentiating the surrounding acoustical signals, etc. However, the unbalanced gravitational forces in movement dynamics are largely controlled by the vestibular system of the inner ear. The vestibular system modulates the information originating from different systems, such as muscular, auditory, and visual. When the vestibular system stops functioning temporarily or permanently, it causes numerous troubles like movement disorientation, disruption of balance, etc. (Rong-Ju Cherng et al., 2009). Thus, balance ability is somewhat ascertained by the vestibular function of the body and determined by the CNS (Dhooge I. et al., 2016).

While framing the idea of the study, the researchers went through intensive reviews related to this study that can be summarised as below. A large number of studies have already been conducted on the balance ability of hearing impaired populations in comparison with normal hearing groups (Banerjee & Ghosh, 2021; Ghosh & Banerjee, 2015; Jernice et al., 2011; Gayle G W & Pohlman R L., 1990; Ayanniyi et al., 2014; Patel et al., 2017; Ghosh S. S., 2014; Ayanniyi et al., 2014). Again few studies were also conducted to measure the level of static & dynamic balance of the players of different games (Alpay C B & Işık Ö, 2017; Coşkun, B. et al., 2019; Eliöz et al., 2013; Halil et al., 2015; Bressel, E. et al., 2007; Nunomura, M., & Oliveira, M. S., 2013; Caglar et al., 2013). A few different studies have also been conducted on hearing impaired populations to find out the effect of

age, gender, etiology, etc. on static and dynamic balance abilities, and most of those studies showed that balance was affected negatively in terms of age, gender, etiology, etc. (Rajendran, 2011; Weiss, A. H. & Phillips, J. O., 2006; Berg K., 1989; Siegel, J. C., Marchetti, M., & Tecklin, J. S., 1991; Tetik, S., Koç, H., & Atar, Ö., 2016; Caglar et al., 2013; Butterfield & Ersing, 1986). Some researchers also conducted a few randomised control trials with a view to developing the balance ability of the hearing impaired population (Rong-Ju Cherng et al., 2009; Hazar F., & Taşmektepligil Y., 2008; Kaya & Sarıtaş, 2019; Fotiadou, E. et al., 2002; Nacaroglu & Karakoc, 2018; Arumugam, 2015; Sanjari & Qasemi, 2016). However, only a few studies have looked into the relationship between hearing loss and balance ability: static or dynamic balance (Rajendran, 2011; Maes, Leen; et al., 2014; Dhooze I. et al., 2016; Banerjee, S., & Ghosh, S. S., 2021).

Considering the research work already done in this area to find out the impact of varying degrees of hearing loss on balance, it was felt that those efforts were not sufficient enough to reach an exact conclusion in this dimension of knowledge. Hence, it was felt by the researchers that a scientific study should be planned to obtain further information on this surprisingly less attempted area of research on the hearing impaired population, and accordingly, the present study was planned to investigate the association between degree of hearing loss and dynamic balance in Indian children with varying degrees of hearing loss. Therefore, the purpose of the study was deemed to investigate the dynamic balance among different degrees of hearing impairment among school boys and girls in India. It was also felt by the researcher that the result would be useful to future researchers, educationists, and movement and sports scientists for further investigation into this relatively new area of research interest. It will also help the trainers and the adapted physical educationist to be aware while planning a physical activity program for those special needs children. It will also help the future researchers in the field of adapted physical activity to plan further advanced research on the special population with varying degrees of hearing loss.

Material and Methods

Participants

For the present study, two hundred & fifty two ($N=252$) children, both Boys ($N_B=126$) and Girls ($N_G=126$) with varying degrees of hearing impairments having age ranging from 13-16 years were purposely selected as subjects. The degree of hearing loss was measured using an audiometric technique. The subjects were selected from three separate districts of West Bengal – a state of eastern India. On the basis of their hearing loss, the subjects were grouped into the following sub groups: At the start of the research work, a total of three hundred eighty-four ($N=384$) subjects were recruited, but the researchers were able to collect complete data from only two hundred ninety-six ($N=296$) subjects because some of the subjects were not present at the venue (Gymnasium/hall of the respective schools) at the date (12th January 2020 to 28th January 2020) of data collection. Due to equating the number of subjects in each subgroup for the sake of statistical software, finally, the researchers considered two hundred fifty-two subjects for this study. The subjects in this study were recruited on the basis of self willingness. A written consent form for each subject was taken prior to the commencement of the work, where the consent of their guardians was also confirmed. The research work has been approved by the Departmental Research Committee (DRC) from the Department of Physical Education; University of Kalyani; India, where the study was registered after satisfying the requirements related to the research objectives and issues like ethical considerations, research aims, and procedures of implementations.

Group Division

Among the total subjects, one hundred and twenty-six were boys ($N_B=126$), and one hundred and twenty-six were girls ($N_G=126$). In the present study, according to the guidelines of ASHA both boys and girls were selected on the basis of their dB HL (frequency receiving ability as measured by the audiometer). They were divided into six sub-groups; viz. (1) Profound Group (91+ dB HL), (2) Severe Group (71 to 90 dB HL), (3) Moderately Severe Group (56 to 70 dB HL), (4) Moderate (41 to 55 dB HL), (5) Mild Group (25 to 40 dB HL) and (6) Normal Group (0 to 20 dB HL) purposively (Clark J G., 1981). Due to the difficulty of detecting this type of hearing loss by audiometer, no Slight Group was considered. Thus, both for boys and girls, a total of twelve sub-groups were considered where each group consisted of twenty-one subjects. Twenty-one ($n = 21$) subjects in each sub group were finally considered.

Data Collection Procedure

For this study the only variable i.e. dynamic balance was measured through Modified Bass Test (BASS; maximum score = 100) was used (Ruth I. Bass., 1939; Barry L. Johnson & Jack K. Nelson, 1986; Wood, R. J., 2010). The test was developed to measure the dynamic balance of high school students, both boys and girls. The equipment and materials needed are: flag and stopwatch, 3 balance judges, and 2 spot judges. Eleven (10+1) markers (shown in Fig. 1) dimension (5cm²), on the floor (pasted) in a standardised manner (Wood, R. J., 2010; Ghosh, S. S., & Majunder, S., 2012; Ghosh, S. S., & Majumder, C., 2013). At the starting mark, the participants stand on their right feet. They then leap or hop to the first marker and try to stand and maintain balance for up to 5 seconds on their left foot. After five seconds, the participants leaps/hops to the second marker and tried the same on their right foot, and so on. After landing, if the participant fails to maintain balance, error points will be counted. To regain balance, it requires subsequent hops. The feet (metatarsal) of the participants will completely cover the marker (so that it cannot be seen). If the participant touch the floor by hand or any other part, a point

will be deducted from total score (maximum score of 100). For a successful landing on each mark, five points are given to the participants. The participants should try to remain on each marker for as many seconds as possible, up to a maximum of 5 seconds. For spending each second on the mark, one point is awarded. In this way, a performer may earn ten points (maximum) for each marker and a total of 100 points (10×10) may earn in a trial for this test. Three trials will be provided to each participant, and the best attempt will be recorded as the score. (Bloomfield, J., R. Polman, P. O'Donoghue, and L. McNaughton., 2007; Troy Blackburn et al., 2000).

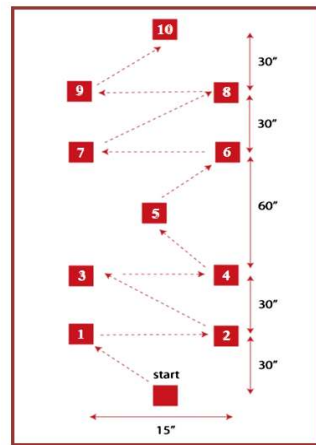


Fig. 1 Measurement of Court for Modified Bass Test of Dynamic Balance
Statistical Analysis

At first data normality was tested through Kolmogorov-Smirnov (K-S) Test. The values of K-S test statistic were greater than the respective p-values (not differed significantly) in all twelve cases (row × column) for raw-data set of dynamic balance, it was confirmed that the data sets were normally distributed. Therefore, groups were compared by using 2-way ANOVA as parametric statistical tools in dynamic balance. Exact differences between the pair of groups were calculated separately in row, column and interaction to be confirmed by using Tukey's LSD test- a post hoc test. The significance was tested at $p < .05$ level. A popular software package known as social science statistics was used to calculate data normality through the Kolmogorov-Smirnov test. Vassar Stats software package was used to calculate F-value through 2-Way ANOVA. In Microsoft Windows office version 10, excel spreadsheets were used to calculate Tukey's LSD test and other statistical calculations.

Results

In the following sections the descriptive statistics of the subjects and findings of the study has been presented as obtained through the statistical analysis of the data.

Descriptive Statistics of the Subjects

The descriptive statistics of subjects for different sub-groups have been presented in **Table 1**. From the table it is evident that no. of subjects for each sub group were twenty one ($n = 21$). In different sub-groups for boys total no of subjects were one hundred twenty six. Likewise, total no of girls in different sub-groups were also one hundred twenty six. Thus, a total two hundred fifty-two ($N = 252$) subjects represented both sexes as a whole. In Table 1, age (years), height (cm), and weight (kg) for all subjects have been presented group wise both for boys and girls.

Table 1 Descriptive Statistics of Different Hearing Impaired Groups both for Girls and Boys

Sl. No.	Name of the Group	dB HL	No. of Subjects in different Groups		Girls			Boys		
					Age (years)	Height (cm.)	Weight (kg.)	Age (years)	Height (cm.)	Weight (kg.)
			Boys	Girls	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
1.	Normal	0 - 20	21	21	14.92±1.05	151.23 ±5.81	45.42±7.41	13.98±0.82	156.54±5.88	51.48±6.74
2.	Mild	26 - 40	21	21	14.77±1.20	147.62±5.89	39.52±6.15	14.81±0.93	156.81±4.84	45.11±6.93
3.	Moderate	41 - 55	21	21	14.26±1.25	155.43±6.81	47.57±6.00	14.24±0.99	164.90±6.79	50.71±4.60
4.	Md. Severe	56 - 70	21	21	13.51±0.61	151.04±4.45	46.19±6.82	14.29±1.02	160.81±7.59	50.86±4.73
5.	Severe	71 - 90	21	21	14.02±0.86	154.14±3.85	49.05±3.02	14.91±0.77	160.14±6.77	48.57±7.24
6.	Profound	91+	21	21	14.71±0.67	150.19±7.59	44.62±6.38	14.19±1.11	160.81±8.91	51.71±5.98
No. of Subjects in each Sex			126	126						
Total No. of Subjects			(N = 252)							

Data on Dynamic Balance

In **Table 2**, mean values and the SD of dynamic balance have been presented for different hearing loss groups of both sexes, and they have been depicted graphically in **Fig. 2** and **Fig. 3** as well.

Table 2 Mean & SD of dynamic balance (Score) for different sub-groups both for Boys and Girls

Name of The Group	Name of the group having different degree of hearing loss					
	Profound	Severe	Md. Severe	Moderate	Mild	Normal
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD
Boys	14.71 $\pm$ 6.68	17.33 $\pm$ 8.13	23.29 $\pm$ 11.59	29.43 $\pm$ 12.68	34.62 $\pm$ 13.54	43.52 $\pm$ 12.60
Girls	16.95 $\pm$ 11.60	21.34 $\pm$ 13.05	27.62 $\pm$ 15.17	35.43 $\pm$ 19.98	41.67 $\pm$ 21.62	48.62 $\pm$ 24.74

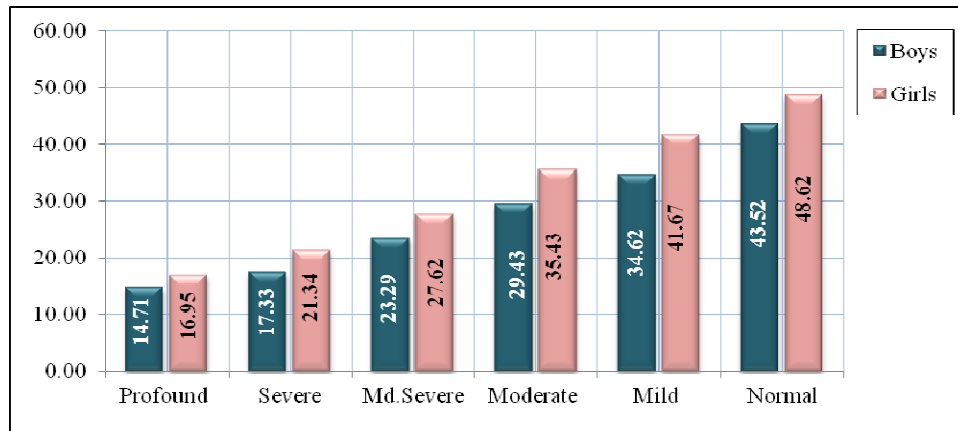


Fig. 2 Mean Values of dynamic balance between Boys and Girls for different hearing loss sub-groups

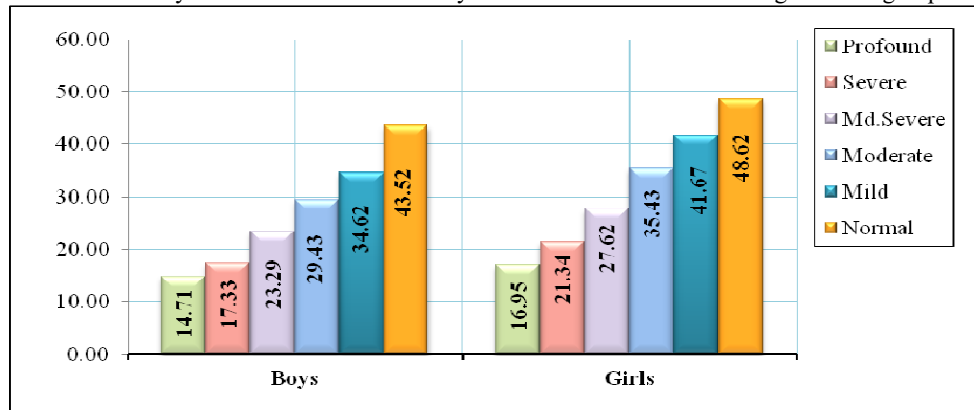


Fig. 3. Mean Values of dynamic balance among the groups with varying degree of hearing loss in boys & girls

Two-Way ANOVA on Dynamic Balance

In **Table 3**, 2-Way ANOVA has been presented for the data in Dynamic Balance (Score) of different sub-groups.

Table 3. Two Way Analysis of Variance (2-way ANOVA) for Dynamic Balance (Score)

Source of Variation	Sum of squares (SS)	df	Mean squares (MS)	F-value	p-value	Table Value of F	At
Sex (Row)	1442.8929	1	1442.8929	6.2701*	.013	3.88	F _{0.05} (1, 240)
Hearing Loss Group (Column)	27904.7341	5	5580.9468	24.2518*	.00001	2.25	F _{0.05} (5, 240)
Interactions (Row $\times$ Column)	146.9881	5	29.3976	0.1277	.99	2.25	F _{0.05} (5, 240)
Error (Residual)	55229.9048	240	230.1246				
Total	84724.5198	251					

* Sign indicates that the value is statistically significant

The table shows that the F-value for row analysis ($F=6.2701$, $p=.013$) & column analysis ($F=24.2518$, $p=.00001$) had statistically significant, but the F-value ($F=0.1277$, $p=.99$) between the interaction (Sex $\times$ Degree of Hearing Loss) had not found significant. Therefore, a significant difference existed in the dynamic balance between both sexes (row), i.e., between the boys and girls. It was also found that the girls were significantly superior in dynamic balance than the boys. Again, a significant difference was observed among subjects belonging to different degrees of hearing loss groups (column), namely the Profound, Severe, Md. Severe, Moderate, Mild, and Normal groups. It was also found that dynamic balance increased with a decreasing degree of hearing impairment. To find out the intergroup mean difference, both for rows as well as columns, pairwise comparison analysis was done separately through Tukey's LSD test (Table 4).

Row Analysis -Tukey's LSD test for both Sexes (When all hearing impaired groups are combined):-

Table 4. Mean value of Dynamic Balance (Score) MD and CD for both sexes (when all hearing impaired groups are combined)

Mean Scores of Rows		Mean Difference (MD)	Critical Difference (CD) ($P=.05$)
Boys	Girls		
27.15	31.94	4.79*	3.77

* Sign indicates that the value is statistically significant

In **Table 4** the mean value of the dynamic balance (score) for both the boys (27.15) and girls (31.94) groups has been presented when all six different-degree hearing-loss sub-groups were combined. The value of the critical difference ($CD=3.77$) was computed by employing Tukey's LSD test for ($df=240$, $k=6$, $n=21$ and $p=.05$). This table also included the value of the combined mean difference (4.79) between the boys and girls groups. It was observed that the mean difference was greater than the critical value, making it statistically significant. Thus, it may be concluded that the dynamic balance of hearing impaired girls is better than that of hearing impaired boys when all six degrees of hearing impairment are combined. These mean values were depicted graphically in **Fig. 4**.

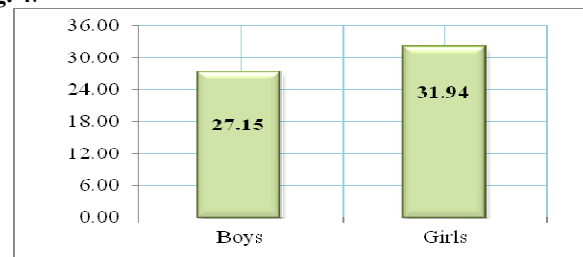


Fig. 4. Comparisons for the Mean Value of Dynamic Balance between Boys and Girls groups when all hearing impaired groups are combined

Column Analysis - Tukey's LSD test for different groups with varying degrees of hearing loss (When both Sexes are combined):- In **Table 5** the mean values of dynamic balance (score) for six different hearing-impaired groups (i.e., profound, severe, md. severe, moderate, mild, and normal groups) have been presented as 15.83, 19.34, 25.45, 32.43, 38.14, and 46.07, respectively, when both sexes, i.e., boys and girls, were combined. The value of the critical difference ($CD=6.52$) was computed by employing Tukey's LSD test for ($df=240$, $k=2$, $n=21$ and $p=.05$).

Table 5. Mean values of Dynamic Balance (Score), mean diff and critical diff for different hearing impaired groups (when both sexes i.e. Boys & Girls are combined)

Mean Scores of Column						Mean Difference (MD)	Critical Difference (CD) ($P=.05$)
Profound	Severe	Md. Severe	Moderate	Mild	Normal		
15.83	19.34					3.51	6.52
15.83		25.45				9.62*	6.52
15.83			32.43			16.60*	6.52
15.83				38.14		22.31*	6.52
15.83					46.07	30.24*	6.52
	19.34	25.45				6.11	6.52
	19.34		32.43			13.09*	6.52
	19.34			38.14		18.80*	6.52
	19.34				46.07	26.73*	6.52
		25.45	32.43			6.98*	6.52
		25.45		38.14		12.69*	6.52
		25.45			46.07	20.62*	6.52
			32.43	38.14		5.71	6.52
			32.43		46.07	13.64*	6.52
				38.14	46.07	7.93*	6.52

* Sign indicates that the difference is statistically significant

It was observed from **Table 5** that the mean difference of the profound group differed significantly from four other groups (md. severe, moderate, mild, and normal), i.e., the mean difference between profound and md. severe (MD = 9.62), profound vs. moderate (MD = 16.60), profound vs. mild (MD = 22.31), and profound vs. normal (MD = 30.24) was greater than the critical value (CD = 6.52), therefore, statistically significant. In all cases, the profound group was weaker in dynamic balance than the respective four other groups. Again, it was also observed that the mean difference of the severe group differed significantly from the three other groups (moderate, mild, and normal). The mean differences between severe and moderate (MD = 13.09), severe and mild (MD = 18.80), and severe and normal (MD = 26.70) were greater than the critical value (CD = 6.52). Therefore, the differences among these groups were statistically significant. In all cases, the severe group was weaker in dynamic balance than the four other groups, and the normal group had a better dynamic balance score. It was further observed that the mean difference of the md. severe group differed significantly from the three other groups (moderate, mild, and normal). The mean differences between md. severe vs. moderate (MD = 6.98), md. severe vs. mild (MD = 12.69), md. severe vs. normal (MD = 20.62) were greater than the critical value (CD = 6.52). Therefore, the differences among these groups were statistically significant. In all cases, the md. severe group was weaker in dynamic balance than the respective three other groups, where the normal group had the best dynamic balance score. It was further observed that the mean difference of the moderate group differed significantly from the normal group. The mean difference between moderate and normal (MD = 13.64) was greater than the critical value (CD = 6.52). Therefore, the difference between the moderate and normal groups was statistically significant. In this case, the normal group had a better dynamic balance score than the moderate group. It was also observed that the mean difference of the mild group differed significantly from the normal group. The mean difference between mild and normal (MD = 7.93) was greater than the critical value (CD = 6.52). Therefore, the difference between the mild and normal groups was statistically significant. In this case, the normal group had a better dynamic balance score than the mild group.

It was further observed that the mean difference among the profound vs. severe groups (MD = 3.51), the severe vs. md. severe group (MD = 6.11) and moderate vs. mild group (MD = 5.71) were not statistically significant as the MD values in these cases were not greater than the critical value (CD = 6.52). Therefore, the difference between these pairs of groups was statistically insignificant.

From the findings of the column analysis, it may be concluded that there are significant differences between most of the pairs of groups with varying degrees of hearing impairments when both sexes are combined, except in the above three pairs of groups. The mean values of dynamic balance (score) for different hearing impaired groups have been presented in **Fig. 5** when both sexes are combined.

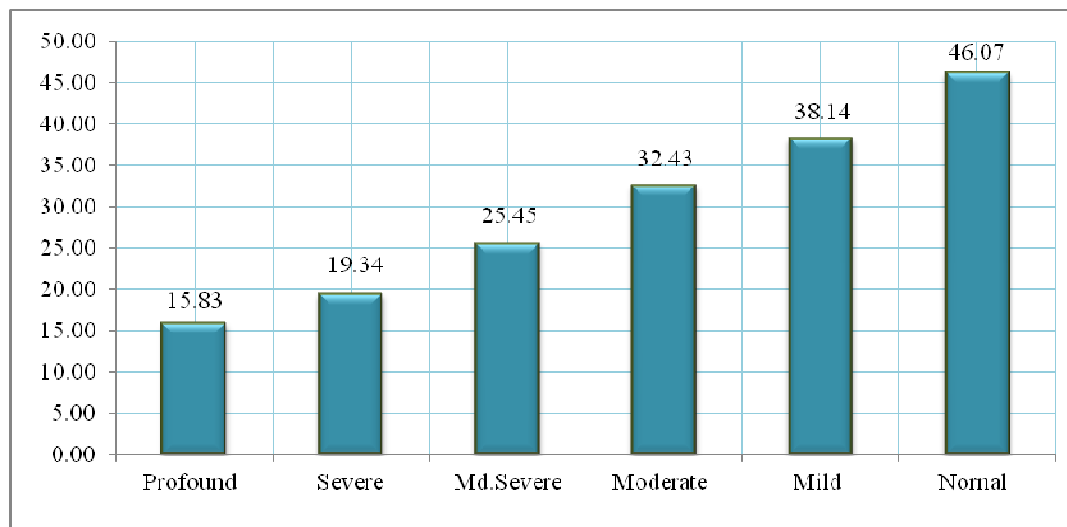


Fig. 5. Comparisons for the Mean Value of dynamic balance among different hearing impaired groups when both Sex are combined

From **Fig. 5**, it was seen that with the increasing degree of hearing ability the dynamic balance also increases when both sexes combined. Therefore, when moving from the profound hearing loss group towards normal group dynamic balance increases. Thus with decreasing hearing loss dynamic balance increases almost linearly. In this case a positive gradient was observed between the relationship of degree of hearing ability and dynamic balance.

In **Fig. 6**, Dynamic Balance vs. Degree of Hearing Loss has been depicted for both boys and girls. From the figure it was evident that with decreasing degree of hearing loss, i.e. from profound to normal group the dynamic balance increased for boys as well as girls. In this case trend lines have also been drawn and the equations of the trend line both for the boys and girls groups have also been provided in the diagram.

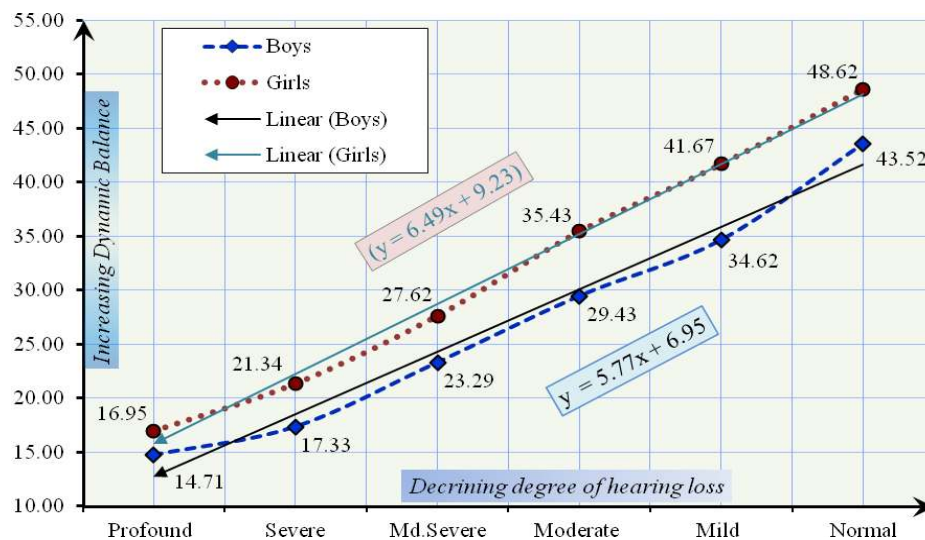


Fig. 6. Dynamic Balance vs. Degree of Hearing Loss Graph with trend line and its Equation (Mean Value of Dynamic Balance in Score)

In this case the trend lines were Oblique or Slanted lines. The general nature of both trend lines follows the general equation $y = mx + c$, which is actually an equation of straight line in slope-intercept form, where 'm' is the slope or gradient of the line and 'c' is a constant called the y-intercept. For girls the equation was $y = 6.49x + 9.23$, where slope $m=6.49$ and intercept $c = 9.23$. Again, for boys the equation was $y = 5.77x + 6.95$, where slope $m = 5.77$ and intercept $c = 6.95$. Thus, it was seen that the slope of the trend line for the girls ($m=6.49$) were more slanted than boys ($m=5.77$) but for both cases the slope was positive which also indicated that the rate of increment of dynamic balance of the girls groups were more than the boys with the decrement of degree of hearing loss. For both sexes, the two most extreme groups were profound group and normal group for minimum & maximum values of dynamic balance respectively. In all respects, lowering the position of the trend line for boys indicated that the dynamic balance of the boys was poorer than the respective girls groups. Even in the extremely poor condition of hearing impairment the value of the intercepts for boys ($c=6.95$) is lower than girls ($c=9.23$) indicating that in no way the boys could be superior to its pair girls groups in reality. It can also be explained that irrespective of the difference in the score of dynamic balance between boys and girls the nature of the curve and its trends were almost identical. Irrespective of sex, this continuous line diagram (DB vs. HL) also provides an opportunity to find out the value of dynamic balance (DB) in any required db HL (Decibel Hearing Loss) over the continuum from profound to normal i.e. from (0 – 100) dB HL and vice versa at any point on the curve simply by drawing two perpendicular on X axis and Y axis respectively. Nevertheless, at any given db HL the value of dynamic balance for boys and girls can be easily calculated and compared from this graph. Likewise, at any particular value of DB the respective value of db HL can also be calculated and compared for the boys and girls. In this way this graph can be used as a nomogram for dynamic balance (DB) with respect to degree of hearing loss (db HL) and vice versa.

Interaction Analysis:-

From Table-4 it was evident that the F-value (0.1277) was not statistically significant [$p < 0.986$, table value of $F=2.25$ at $df(5,240)$], therefore the null hypothesis was accepted. It indicates that there are no interactions between the row (sex) and column (degree of hearing impairment) as analysed through 2-way ANOVA statistics. Therefore, no post hoc LSD was performed to find the exact location of interactions between the row and column.

Discussion

From the above results, as obtained from the statistical analysis of the study, it was observed that there was a significant difference in row analysis as well as in column analysis. But no significant difference was observed in interaction analysis. Thus, the result of the present study can be explained in two ways, i.e. discussion on row analysis and the discussion on column analysis.

Discussion on Row Analysis

From the findings of the study, it was evident that the dynamic balance of girls was significantly better than boys when all hearing impaired groups were combined. From the mean values, it was also reflected that in dynamic balance, different hearing impaired girls' groups were better than the respective boys' groups. These results can be explained by the fact that due to the uneven distribution of body mass and the over accumulation of body fat in the waist-hip-and pelvic region for girls (Bird, P. J., 2006) there may be a chance of lowering the

center of gravity (CG) for them in comparison to boys (Kelly, 1974). In the later phase of adolescent growth, suddenly accelerated, the fat deposition rate for girls' increases and it becomes almost double that of boys. It is caused by an excess of fat cells, primarily in the buttocks and thighs, as well as the gluteal and femoral areas of the pelvis and, to a lesser extent, in the breasts (Bird, P. J., 2006). This is attributed mainly for the starting of the secretion of female hormones in an enhanced rate. Again, for girls due to the over accumulation of fat after the onset of adolescence the abdominal adiposity increases rapidly (Azadbakht & Esmailzadeh, 2011) that caused structural changes that is reflected through a wider and heavier pelvic region in comparison to the boys (Burbano, J. C., Vanegas, P. F., Rodríguez, J. R., & Estévez, K. P., 2016). It is conventional that the center of gravity (CG) of the girls is comparatively lower than the boys (Roger Barlett, 2007; Bussey, M., 2002; Hall S. J., 2012). Lower the CG, higher is the balance and stability (Özkaya, N., Nordin, M., Goldsheyder, D., & Leger, D., 2012; Knudson, D. V., & Knudson, D. V., 2007; Hamilton, N. P., 2011). Balance is attributed with the center of gravity (CG) of our body when remains on the base of support (Hay, J., 1978; Luttgens, Kathryn., 1997). With the growth of the child, their body develops and consequently their position of center of gravity (CG) also changes. The position of the center of gravity greatly varies in each child because different body parts, like the legs, trunk, and head, do not grow proportionately, a difference that existed between females and males also (Hamilton N, & Weimar W, & Luttgens K(Eds.), 2011). Again, one of the most important factors of balance and stability is the height of the center of gravity (CG) from the base of support, which indicates that the higher the CG Consequently, the lower the stability, and consequently, the lower the balance also (Hall S. J., 2012; Hay, J. G, 1978; Roger Barlett, 2007; Hamilton N, & Weimar W, & Luttgens K(Eds.), 2011). Thus, balance is inversely proportional to the height of the center of gravity from the base of support (Hamilton N, & Weimar W, & Luttgens K(Eds.), 2011). Again, the higher the stature, the higher the chance of the position of CG, and consequently, the lower the chance of balance and stability (Roger Barlett, 2007; Bussey, M., 2002; Hall S. J., 2012). In the present study, the standing stature of the hearing impaired boys was comparatively greater than their girl's counterpart. As a result, the different boy groups may have a higher center of gravity (CG) than the respective girl groups. That reason, the dynamic balance of different girls' groups might have been higher than the boy's groups in all respects, whether considered a group separately or when all hearing impaired groups were combined during the comparison. The above findings were supported by a few other studies also in the case of balance, whether in static or dynamic conditions (Steindl, R., Kunz, K., Schrott-Fischer, A., & Scholtz, A. W., 2006; Wong, T. P. S., Leung, E. Y. W., Poon, C. Y. C., Leung, C. Y. F., & Lau, B. P. H., 2013; Melo, R. D. S., Marinho, S. E. D. S., Freire, M. E. A., Souza, R. A., Damasceno, H. A. M., & Raposo, M. C. F., 2017; Banerjee, S., & Ghosh, S. S., 2021) .

Discussion on Column Analysis

Again, the findings of the study indicated that dynamic balance increases with decreasing hearing loss when both sexes were combined, therefore, an increasing tendency of dynamic balance with a positive gradient was observed from the profound group towards the normal group. It indicated that there was a linear relationship between decreasing hearing loss and dynamic balance. The findings of the study also indicated that dynamic balance increases with decreasing hearing loss when both sexes, i.e. boys & girls were considered separately.

Hearing ability is determined and controlled by the vestibular mechanism in the human body. Along with the control in hearing ability, the vestibular mechanism also controls the balance of the human body both in static and dynamic conditions. In the result of the present study an increasing tendency in dynamic balance with decreasing degree of hearing loss was observed. This result may be explained by the fact that the normal functioning of the vestibular system is highly responsible for determining the balance ability. As an abnormal function in the vestibular mechanism restricts the hearing ability, simultaneously, it restricts the balance ability of humans. Moreover, balance is a function of three biomechanical signal systems, namely, vestibular damage, visual perception and proprioception ability of the joints. It is observed that problems in any one of the above three systems or more systems simultaneously or an abnormality in the central nervous system (CNS) can cause balance problems (Casselbrant & Mandel, 2005). In the way of maintaining balance, the eyes play the role to receive visual clues from light receptors and send it to the brain to be aware about the spatial confirmation of the body relative to its surroundings, and it controls the postural position simultaneously. On the basis of the postural control, balance is maintained. 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 (Malekabadizadeh, Z., Barati, A., & Khorashadizadeh, M., 2016). The receptors that are located in the muscles and joints are known as proprioceptors that also receive the signals in different conditions and position of the head and neck and joints (Melo, R. D. et al., 2015). The normal function in the vestibular system is the most important thing to maintain the balance. 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 afferent (Effgen, S. K., 1981). Damage in the inner ear harms the vestibular organs, likely it causes hearing loss. Thus vestibular and auditory systems have close anatomical and functional relationships with one another (Livingstone, & Mcphillips, 2011). The vestibular system is situated in the inner ear. It has two main parts: three semicircular canals and the vestibule. Together they are called the vestibular labyrinths which are always filled with a fluid. The change of position of the head shifts the fluid

within the labyrinth that stimulates the auditory nerve endings and an impulse is generated. This impulse moves to the brain through the auditory nerves from both the ear (right & left) in equal magnitude. But when the vestibular mechanism is not functioning properly this signal magnitude from both ears differs and is no longer equal. This inequality of signal amplitude causes distortion and discomfort that results in an off balance. In this distorted condition the brain sends a signal to the eyes that informs it to move back and forth, making the surroundings appear to spin. The eye movement in this situation creates a sensation of things spinning that affect the balance and coordination while executing any motor task. In this way malfunctioning in the vestibular mechanism plays the most crucial role for the balance mechanism. Thus, the damage in the vestibular mechanism also causes hearing loss that is associated with balance disorder. From the above discussion it is clear that greater the degree of hearing loss lesser is the dynamic balance which is observed in the present study. Thus, from the result it may be generalized that dynamic balance is inversely proportional with the degree of hearing loss i.e. if the degree of hearing loss increases then the dynamic balance decreases. This finding was in consonance with few other studies also (Ayanniyi, et al., 2014); (Banerjee, S., & Ghosh, S. S., 2021); (Jernice, et al., 2011b); (Shah, & Dar, 2019).

Conclusions

On the basis of the findings it can be concluded that the dynamic balance of the girls is significantly superior to their boy's counterparts when all degree of hearing loss groups are combined. The mean values of dynamic balance also showed that the girls are better than the boys belonging to respective hearing impaired groups. There are significant differences in dynamic balance for most of the pair of hearing impaired groups when both sexes are combined except in few cases. It is also seen that the dynamic balance increases with decreasing hearing loss for different hearing impaired groups when both sexes are combined. From the findings of the study it was observed that the mean value of dynamic balance increases with increasing hearing ability. Thus, in dynamic balance there is a linear increasing trend with positive gradient from profound towards the normal group. It indicated that there may be a linear relationship between hearing ability and dynamic balance that need further investigation and analysis.

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References:

- Alpay C B & Işık Ö. (2017). *Comparison of body components and balance levels among hearing-impaired wrestlers and healthy wrestlers*. 11(1), 79–84. [Cited on Feb, 04, 2022] Available from: [file:///E:/C.BerkanALPAY%20\(4\).pdf](file:///E:/C.BerkanALPAY%20(4).pdf)
- Arumugam, D. S. (2015). *Impact of specific balance training on static balance and dynamic balance among hearing impaired students*. 1(4), 5. [Cited on Feb, 04, 2022] Available from: <https://bit.ly/37NhkFz>
- Ayanniyi, O., Adepoju, F. A., & Mbada, C. E. (2014b). *Static and dynamic balance in school children with and without hearing impairment*. 4(4), 5. <https://doi.org/10.5455/jeim.040814.or.109>
- Azadbakht, L., & Esmailzadeh, A. (2011). Dietary diversity score is related to obesity and abdominal adiposity among Iranian female youth. *Public Health Nutrition*, 14(1), 62–69. <https://doi.org/10.1017/S1368980010000522>
- Banerjee, S., & Ghosh, S. S. (2021). A study on static balance of school children in India with different degrees of hearing impairment. *Journal of Physical Education and Sport*, 21(5), 2722–2729. <https://doi.org/10.7752/jpes.2021.05362>.
- Banerjee, S., & Ghosh, S. S. (2021). Sociability of different degree hearing impaired school girls. In *International Edited Book: Human Movement, Vol. I* (pp. 63–68). Khel Sahitya Kendra. https://www.academia.edu/49641261/Human_Movement_Journal_2021_final?email_work_card=interaction-paper
- Barry L. Johnson & Jack K. Nelson. (1986). *Practical Measurements for Evaluation in Physical Education*. Edina, MN: Burgess Publishing, 1986. New Delhi: Surjeet Publications. [Cited on Feb, 05, 2022] Available from: <https://eric.ed.gov/?id=ED048380>
- Berg K. (1989). *Balance and its measure in the elderly: A review*. 41(5), 240–246. <https://doi.org/10.3138/ptc.41.5.240>
- Bilir, S. et al. (1995). *A Comparison Study of Gross Motor Development Skills of Normal, Hearing-Impaired and Down Syndrome Children*. [Cited on Feb, 05, 2022] Available from: <https://files.eric.ed.gov/fulltext/ED390210.pdf>
- Bird, P. J. (2006). *Why does fat deposit on the hips and thighs of women and around the stomachs of men?* Scientific American. [Cited on Feb, 05, 2022] Available from: <https://bit.ly/3vM4rmQ>

- Bloomfield, J., R. Polman, P. O'Donoghue, and L. McNaughton. (2007). Effective speed and agility conditioning methodology for random intermittent dynamic type sports. *J. Strength Cond. Res.*, 21(4), 1093-1100. <https://doi.org/10.1519/R-20015.1>
- Bressel, E., Yonker, J. C., Kras, J., & Heath, E. M. (2007). Comparison of Static and Dynamic Balance in Female Collegiate Soccer, Basketball, and Gymnastics Athletes. *Journal of Athletic Training*, 42(1), 42–46. [Cited on Feb, 05, 2022] Available from: <https://bit.ly/3vXWrQ5>
- Brian D Iverson, Marilyn R Gossman, Shirley A Shaddeau, & Malcolm E Turner, Jr., (1990). *Balance Performance, Force Production, and Activity Levels in Noninstitutionalized Men 60 to 90 Years of Age.*, 70(6), 348–355. <https://doi.org/10.1093/ptj/70.6.348>
- Brunt, D., & Broadhead, G. D. (1982). *Motor proficiency traits of deaf children.*, 53(3), 236–238. <https://doi.org/10.1080/02701367.1982.10609346>
- Burbano, J. C., Vanegas, P. F., Rodríguez, J. R., & Estévez, K. P. (2016). Relationship between dietary calcium intake and adiposity in female adolescents. *Endocrinología y Nutrición (English Edition)*, 63(2), 58–63. <https://doi.org/10.1016/j.endoen.2016.02.007>
- Bussey, M. (2002). *Sports biomechanics: Reducing injury and improving performance*. Routledge. <https://doi.org/10.4324/9780203474563>
- Butterfield, S. A., & Ersing, W. F. (1986). Influence of Age, Sex, Etiology, and Hearing Loss on Balance Performance by Deaf Children. *Perceptual and Motor Skills*, 62(2), 659–663. <https://doi.org/10.2466/pms.1986.62.2.659>
- Caglar, O., Uludag, A., Sepetci, T. & Caliskan, E. (2013). Evaluation of physical fitness parameters of hearing impaired adolescents who are active and non-active in sports. *Turkish Journal of Sport and Exercise*, 15 (2), 38-44. [Cited on Feb, 05, 2022] Available from: <https://dergipark.org.tr/en/pub/tsed/issue/21503/230636>
- Casselbrant, M. L., & Mandel, E. M. (2005). *Balance Disorders in Children*. 23(3), 807–829. <https://doi.org/10.1016/j.ncl.2005.03.003>
- Clark J G. (1981). *Uses and abuses of hearing loss classification*. ASHA, 23(7), 493–500. [Cited on Feb, 05, 2022] Available from: <http://europepmc.org/abstract/MED/7052898>.
- Coşkun, B., Unlu, G. Ü. R. C. A. N., Golshaei, B., Kocak, S., & Kirazci, S. (2019). Comparison of the Static and Dynamic Balance Between Normal-Hearing and Hearing- Impaired Wrestlers. *Montenegrin Journal of Sports Science and Medicine*, 8(1), 6. <https://doi.org/10.26773/mjssm.190302>
- De Kegel, A., Kegel, A. D., Dhooge, I., Cambier, D., Baetens, T., Palmans, T., & Waelvelde, H. V. (2011). *Test–retest reliability of the assessment of postural stability in typically developing children and in hearing impaired children | Tanneke Palmans—Academia.edu Gait & posture*, 33(4), 679-685. <https://doi.org/10.1016/J.GAITPOST.2011.02.02>
- Dhooge, I., De Kegel, A., Dhondt, C., Van Waelvelde, H., & Maes, L. (2016). Association between vestibular function and motor performance in hearing impaired children. In European Society of Pediatric Otorhinolaryngology, 13th International congress, Abstracts. Lisbon, Portugal. [Cited on Feb, 05, 2022] Available from: <http://hdl.handle.net/1854/LU-8507376>
- Effgen, S. K. (1981). *Effect of an exercise program on the static balance of deaf children. Physical therapy*, 61(6), 873-877. <https://doi.org/10.1093/ptj/61.6.873>
- Eliöz, M., Sitti, S., Koç, M. C., Murt, Z., & Koç, H. (2013). *A Study on Static Balance Performance of Healthy and Hearing—Impaired Football Players*. 5. <https://doi.org/10.5829/idosi.ejas.2013.5.1.66225>
- Fotiadou, E., Giagazoglou, P., Kokaridas, D., Angelopoulou, N., Tsimaras, V., & Tsorbatzoudis, C. (2002). Effect of rhythmic gymnastics on the dynamic balance of children with deafness. *European Journal of Special Needs Education*, 17(3), 301-309. <https://doi.org/10.1080/08856250210162211>
- Gail M. Dummer, John L. Haubenstricker, & David A. Stewart. (1996). *Motor Skill Performances of Children Who Are Deaf*. 13, 400–414. <https://doi.org/10.1123/apaq.13.4.400>
- Gayle G W & Pohlman R L. (1990). Comparative Study of the Dynamic, Static, and Rotary Balance of Deaf and Hearing Children. *SAGE Publications*, 70(3), 883-888. <https://doi.org/10.2466/pms.1990.70.3.883>
- Gheysen, F., & Loots, G. (2008). *Motor Development of Deaf Children With and Without Cochlear Implants*. 13(2), 215–224. <https://doi.org/10.1093/deafenednm053>
- Ghosh S. S. (2014). A comparative study on selected physical fitness components between deaf & dumb and normal school boys of West Bengal. *International Journal of Physical Education*, 3(2), 52-59. <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.683.5518&rep=rep1&type=pdf>
- Ghosh, S. S., & Majumder, C. (2013). *A Study on Agility and Dynamic Balance of Kho-Kho Handball and Basketball Players*. *International Journal of Scientific Research*, ISSN No. 2277—8179, 2(7), 442-444. <https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.685.2059&rep=rep1&type=pdf>
- Ghosh, S. S., & Majunder, S. (2012). *A Comparative Study on Agility and Dynamic Blance of Football Volleyball and Hockey Players*. *International Journal of Health, Physical Education and Computer Science in Sports*, 8(1), 48-50. [Cited on Feb, 05, 2022] Available from: <https://bit.ly/3rYtlyv>

- Ghosh, S. S., & Banerjee, S. (2015). A comparative study on selected physical fitness components and personality traits between deaf & dumb and normal school girls of West Bengal. *International Journal of Physical Education, Sports and Health*, 1(5), 59–63. <https://bit.ly/3GpgV8Z>
- Halil, T., Ayla, K. O., & Aziz, G. (2015). *Analysis of reaction time, balance performance and some anthropometric features of hearing impaired and healthy badminton players*. 6(2), 6. <https://doi.org/10.7813/jhst.2015/6-2/9>
- Hall S. J. (2012). *Basic Biomechanics, 6th Edition*, WCB McGraw-Hill. New York. [Cited on Feb, 05, 2022] Available from: <https://bit.ly/3F30fTZ>
- Hamilton N, & Weimar W, & Luttgens K(Eds.). (2011). *The Center of Gravity and Stability | Kinesiology: Scientific Basis of Human Motion, Twelfth Edition*. McGraw Hill. <https://bit.ly/38Hsiws>
- Hay, J. G. (1978). *The biomechanics of sports techniques*. Prentice-Hall. [Cited on Feb, 05, 2022] Available from: https://openprairie.sdstate.edu/prairiestriders_pubs/251/
- Hazar F, & Taşmektepligil Y. (2008). *The effects of balance and flexibility on agility in prepuberte period*. *Spormetre Sci*. 2008;6:9-12. 6, 9–12. <https://doi.org/10.13189/ujer.2019.070110>
- James, S. L., Abate, D., Abate, K. H., Abay, S. M., Abbafati, C., Abbasi, N., Abbastabar, H., Abd-Allah, F., Abdela, J., Abdelalim, A., Abdollahpour, I., Abdulkader, R. S., Abebe, Z., Abera, S. F., Abil, O. Z., Abraha, H. N., Abu-Raddad, L. J., Abu-Rmeileh, N. M. E., Accrombessi, M. M. K., ... Murray, C. J. L. (2018). Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990–2017: A systematic analysis for the Global Burden of Disease Study 2017. *The Lancet*, 392(10159), 1789–1858. [https://doi.org/10.1016/S0140-6736\(18\)32279-7](https://doi.org/10.1016/S0140-6736(18)32279-7)
- Jernice, T. S. Y., Nonis, K. P., & Yi, C. J. (2011b). The balance control of children with and without hearing impairment in singapore – a case study. *International journal of special education*, 26(3), 16. [Cited on Feb, 05, 2022] Available from: <https://files.eric.ed.gov/fulltext/EJ959018.pdf>
- Kaya, M., & Sarıtaş, N. (2019). A Comparison of the Effects of Balance Training and Technological Games on Balance in Hearing-Impaired Individuals. *Journal of Education and Training Studies*, 7(3), 6. : <https://doi.org/10.11114/jets.v7i3S.4055>
- Kelly, D. L. (1974). Kinesiology. *Journal of Health, Physical Education, Recreation*, 45(8), 61–62. <https://doi.org/10.1080/00221473.1974.10618722>
- Knudson, D. V., & Knudson, D. V. (2007). *Fundamentals of biomechanics (Vol. 183)*. New York: Springer.
- Kushalnagar, R. (2019). Deafness and Hearing Loss. *Springer, London., In Web Accessibility*, 35–47. https://doi.org/10.1007/978-1-4471-7440-0_3
- Livingstone, N., & McPhillips, M. (2011). Motor skill deficits in children with partial hearing. *Developmental Medicine & Child Neurology*, 53(9), 836–842. <https://doi.org/10.1111/j.1469-8749.2011.04001.x>
- Luttgens, Kathryn. (1997). *Kinesiology Scientific Basis Of Human Motion*. Boston, Massachusetts: McGraw-Hill. [Cited on Feb, 05, 2022] Available from: <https://bit.ly/3y0nigZ>
- Maes, Leen;, De Kegel, Alexandra;, Van Waelvelde, Hilde;, & Dhooge, Ingeborg. (2014). *Association Between Vestibular Function and Motor Performance in Hearing-impaired Children*. 35(10), 343–347. <https://doi.org/10.1097/MAO.0000000000000597>
- Malekabadizadeh, Z., Barati, A., & Khorashadizadeh, M. (2016). *The Effect Of Hearing Impairment And Intellectual Disability On Children's Static And Dynamic Balance*. [Cited on Feb, 05, 2022] Available from: <https://www.sid.ir/en/Journal/ViewPaper.aspx?ID=511898>
- Melo, R. D. S., Marinho, S. E. D. S., Freire, M. E. A., Souza, R. A., Damasceno, H. A. M., & Raposo, M. C. F. (2017). Static and dynamic balance of children and adolescents with sensorineural hearing loss. *Einstein (São Paulo)*, 15, 262–268. <https://doi.org/10.1590/S1679-45082017AO3976>
- Melo RD, Lemos A, Macky CF, Raposo MC, & Ferraz KM. (2015). *Postural control assessment in students with normal hearing and sensorineural hearing loss*. <https://doi.org/10.1016/j.bjorl.2014.08.014>
- Nacaroglu, E., & Karakoc, O. (2018). Effects of Eight Week Plyometric Study on the Balance Performance of Hearing Impaired Athletes. *International Education Studies*, 11(6), 7. <https://doi.org/10.5539/ies.v11n6p1>
- Nunomura, M., & Oliveira, M. S. (2013). Parents' support in the sports career of young gymnasts. *Science of Gymnastics Journal*, 5(1), 5–18. [Cited on Feb, 05, 2022] Available from: <https://bit.ly/3Kz0UOa>
- Özkaya, N., Nordin, M., Goldsheyder, D., & Leger, D. (2012). *Fundamentals of biomechanics (Vol. 86)*. New York: Springer. [Cited on Feb, 05, 2022] Available from: <https://bit.ly/38C9YEC>
- Patel, H., Malawade, M., Butte-Patil, S., Khairnar, P., & Gawade, S. (2017). *Comparison of balance in children with and without hearing impairment*. 05(02), 9. [Cited on Feb, 05, 2022] Available from: <https://bit.ly/3kxZc4Z>
- Potter CN, & Silverman LN. (1984). *Characteristics of vestibular function and static balance skills in deaf children*. 64(7), 1071–1075. <https://doi.org/10.1093/ptj/64.7.1071>
- Rajendran, V. (2011). *An overview of motor skill performance and balance in hearing impaired children*. 37(33), 5. <https://doi.org/doi:10.1186/1824-7288-37-33>
- Roger Barlett. (2007). *Introduction to Sports Biomechanics Analysing human movement patterns*. Abingdon, UK: Routledge, [Cited on Feb, 05, 2022] Available from: <https://bit.ly/3OLbGEI>

- Rong-Ju Cherng, Hui-Chen Lin, Yun-Huei Ju, & Chin-Shan Ho. (2009). *Effect of seat surface inclination on postural stability and forward reaching efficiency in children with spastic cerebral palsy*. 30(6), 1420–1427. <https://doi.org/10.1016/j.ridd.2009.07.002>
- Ruth I. Bass. (1939). *An Analysis of the Components of Tests of Semicircular Canal Function and of Static and Dynamic Balance*. 10(2). <https://doi.org/10.1080/10671188.1939.10625750>
- Sanjari, A., & Qasemi, G. (2016). *The effects of 8 weeks of yoga on postural control and the quality of life in 15-17 years old female hearing impaired adolescents*. 12. [Cited on Feb, 05, 2022] Available from: <https://bit.ly/3LA4dWE>
- Shah, M. A., & Dar, A. A. (2019). *A Study of Psychomotor Abilities of Hearing Impaired Children*. 2(1), 7. [Cited on Feb, 06, 2022] Available from: <https://www.noiseandhealth.org/text.asp?1998/1/1/6/31782>
- Siegel, J. C., Marchetti, M., & Tecklin, J. S. (1991). *Age-Related Balance Changes in Hearing-Impaired Children | Physical Therapy | Oxford Academic*. [Cited on Feb, 06, 2022] Available from: <https://academic.oup.com/ptj/article-abstract/71/3/183/2728743>
- Smith, A. W. (1998). *The World Health Organisation and the prevention of deafness and hearing impairment caused by noise Smith AW - Noise Health*. [Cited on Feb, 06, 2022] Available from: <https://bit.ly/3F0uxH0>
- Steindl, R., Kunz, K., Schrott-Fischer, A., & Scholtz, A. W. (2006). Effect of age and sex on maturation of sensory systems and balance control. *Developmental Medicine and Child Neurology*, 48(6), 477–482. <https://doi.org/10.1017/S0012162206001022>
- Stepanchenko, N. I., Hrybovska, I. B., Danylevych, M. V., & Hryboskyy, R. V. (2020). Aspects of psychomotor development of primary school children with hearing loss from the standpoint of Bernstein's theory of movement construction. *Pedagogy of Physical Culture and Sports*, 24(3), 151–156. <https://doi.org/10.15561/26649837.2020.0308>
- Tetik, S., Koç, H., & Atar, Ö. (2016). An Analysis of Selected Motor Characteristics According to Age Groups in Hearing-impaired Individuals. *Studies on Ethno-Medicine*, 10(3), 295–300. <https://doi.org/10.1080/09735070.2016.11905500>
- Troy Blackburn, Kevin M. Guskiewicz, Meredith A. Petschauer, & William E. Prentice. (2000). *Balance and joint stability: The relative contributions of proprioception and muscular strength*. 9(2), 315–328. <https://doi.org/10.1123/jsr.9.4.315>
- Weber, P. C., & Klein, A. J. (1999). Hearing Loss. *Medical Clinics of North America*, 83(1), 125–137. [https://doi.org/10.1016/S0025-7125\(05\)70092-4](https://doi.org/10.1016/S0025-7125(05)70092-4)
- Weiss A H & Phillips J O. (2006). *Congenital and Compensated Vestibular Dysfunction in Childhood: An Overlooked Entity*. 21(7), 572–579. <https://doi.org/10.1177/08830738060210071501>
- Wiegersma, P. H., & Velde, A. V. (1983). Motor development of deaf children. *Journal of Child Psychology and Psychiatry*, 24(1), 103–111. <https://doi.org/10.1111/j.1469-7610.1983.tb00107.x>
- Winter D A. (1995). *Human balance and posture control during standing and walking*. 3(4), 193–214. [https://doi.org/10.1016/0966-6362\(96\)82849-9](https://doi.org/10.1016/0966-6362(96)82849-9)
- Winter, D. A., Patla, A. E., & Frank, J. S. (1990). Assessment of balance control in humans. *Med prog technol*, 16(1-2), 31–51. [Cited on Feb, 06, 2022] Available from: [https://file:///E:/WinterPatlaFrank-1990-Assessmentofbalancecontrolinhumans%20\(2\).pdf](https://file:///E:/WinterPatlaFrank-1990-Assessmentofbalancecontrolinhumans%20(2).pdf)
- Wong, T. P. S., Leung, E. Y. W., Poon, C. Y. C., Leung, C. Y. F., & Lau, B. P. H. (2013). *Balance performance in children with unilateral and bilateral severe-to-profound-grade hearing impairment*. *Hong Kong Physiotherapy Journal*, 31(2), 81–87. <https://doi.org/10.1016/j.hkpj.2013.07.001>
- Wood, R. J. (2010). *Complete Guide to Fitness Testing*. *Topendsports.com*. [Cited on Feb, 08, 2022] Available from: <https://www.topendsports.com/testing/>. <https://www.topendsports.com/testing/tests/balance-bass.htm>
- World Health Organization. (1995). *Forty-eighth World Health Assembly: Complete collection of documents. Resolutions and decisions, annexes*. Geneva: World Health Organization, [Cited on Feb, 08, 2022] Available from: <https://bit.ly/37VCjWH>
- World Health Organization. (2017). Prevention of deafness and hearing loss, Seventieth World Health Assembly, WHA 70.13, Agenda item 15.8. [Cited on Feb, 08, 2022] Available from: https://apps.who.int/gb/ebwha/pdf_files/WHA70/A70_R13-en.pdf
- Zittel, L., Pyfer, J., & Auxter, D. (2016). Principles and methods of adapted physical education & recreation. Jones & Bartlett Publishers. Inc. [Cited on Feb, 08, 2022] Available from: <https://bit.ly/3s1Djil>