Original Article

Contrast Sensitivity Abnormalities in Deaf Individuals

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Abstract

Purpose: Hearing impaired children are heavily dependent on their sense of vision to develop efficient communication skills; any contrast sensitivity defect can negatively impact their lives because they are not able to use auditory stimuli to recognize probable dangers in the world around them. The purpose of this study was to determine the contrast sensitivity abnormalities in deaf individuals.
Methods: In this cross-sectional study, contrast sensitivity of 15- to 20-year-old high-school boys with hearing disability from Tehran, Iran were evaluated. Sixty-four eyes were tested for contrast sensitivity and refractive error. All subjects had an intelligence quotient (IQ) >70. We investigated their contrast sensitivity with Vector vision CVS-1000 in 4 different spatial frequencies.
Results: Profound hearing loss was noted in 50% of the subjects. The frequency of contrast sensitivity abnormalities in 4 different spatial frequencies varied between 51.6% and 65.6%. The largest abnormalities were recorded at 18 cycles per degree. Only 12.5% of deaf students had corrected distance visual acuity (CDVA) greater than zero (in LogMAR). The abnormalities in contrast sensitivity showed no correlation with the type or severity of hearing loss.
Conclusion: Hearing impaired boys are at a greater risk for contrast sensitivity abnormalities than boys with normal hearing. The larger frequency of contrast sensitivity abnormalities in high spatial frequencies than in other frequencies may demonstrate greater defects in the central visual system compared with the periphery in individuals with hearing loss.

Keywords: Contrast Sensitivity; Deafness; Hearing Loss; Refractive Error

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INTRODUCTION

Hearing loss as a latent disability is a birth defect with a prevalence of 0.1-0.3% in newborns.[1,2] Hearing loss affects more than 20 million people in the United States (a prevalence of 9%).[3]

As the severity of hearing loss increases, the role of the remaining senses becomes progressively more significant. Thus, deaf persons may compensate by making greater use of visual perceptual cues than their hearing peers, and even a mild refractive error may reduce the visual cues available to them. Ocular and

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visual anomalies such as refractive errors, difficulty in sustaining visual attention, visual field and oculomotor abnormalities are reported more commonly in children with hearing impairment compared to those with normal hearing and the general population.[4,5] These observations emphasize the importance of early visual assessments to detect any vision related abnormalities in hearing impaired individuals.[6]

There is new evidence to show that when coping with profound sensory deprivation, processing of inputs from the intact modalities is critical. In profound hearing impairment, detection of changes in the environment and orienting of attention occurs primarily through vision and sensory deprivation is associated with crossmodal neuroplastic changes in the brain.[7-9] Maladaptive consequences are one of possibilities following visual or auditory deprivation so that brain areas normally associated with the lost sense are recruited by functional sensory modalities.[10] Early detection and appropriate management of possible maladaptive consequences and defects such as contrast sensitivity (CS) abnormality can improve people's quality of life due to its importance in distance and peripheral vision activities, driving, and a sense of independence.[11]

Most researches have focused on the prevalence of visual abnormality in deaf persons, but few studies have examined CS in the hearing impaired population. This study was designed to investigate the CS status and its association with other visual parameters in a group of patients with hearing loss.

In recent years, it has been shown that determination of the visual CS function of the patient is of considerable clinical value; this can reveal the wider effects of pathology on the visual system where visual acuity may or may not be affected. This study on CS evaluation in hearing impaired patients is important, given their greater dependence on accurate visual cues to function efficiently.

METHODS

This cross-sectional study was performed in Tehran, Iran on 64 eyes of 64 deaf high-school students. All participants were boys aged 15-20 years (mean, 17 ± 1.65).

The study team consisted of an optometrist, an ophthalmologist, a speech therapist, an audiologist, and a psychologist. The Ethics Committee at Mashhad University of Medical Sciences approved the study protocol, and the study was performed according to the tenets of the Declaration of Helsinki.

After the personal information had been documented, to ensure the accuracy of tests, all subjects completed the Wechsler intelligence quotient (IQ) test. An IQ score of >70 was set as one of the inclusion criteria.[12] Wechsler Intelligence Scale for Children-revised (WISC-R) is composed of 12 subscales and provides three IQ scores, namely, verbal, nonverbal, and total IQ. The reported reliability and validity of this test is 0.73.[13,14]

The status of hearing loss was investigated by an audiologist. Based on the published study by Hollingsworth et al, study subjects were classified into groups based on the severity [mild (20-40 dB), moderate (41-70 dB), severe (71-95 dB), and deep (more than 95 dB)] and time of onset (congenital and acquired) of hearing loss.[15]

All subjects underwent a full ophthalmic examination, including biomicroscopic evaluation and ophthalmoscopy, to exclude ocular pathologies and corneal or lenticular opacities. Refractive errors were measured objectively and the results were refined using subjective refraction. The corrected distance visual acuity (CDVA) was measured with the standard Snellen chart at a distance of 6 meters.

CS was evaluated at four different spatial frequencies by the CVS-1000 contrast sensitivity chart, the results of each spatial frequency were allocated separately with the severity of hearing loss and the time of onset.[16]

Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) version 22 for Windows (IBM Inc., Chicago, Illinois, USA). Descriptive statistics including the mean readings of the parameters along with their standard deviations were calculated. Normality of the measured data was assessed with the Kolmogorov-Smirnov test, and parametric and nonparametric tests were applied accordingly. At 95% confidence interval, a P value < 0.05 was considered statistically significant.

RESULTS

The mean IQ of the subjects was 97.8 (range, 61–129). Table 1 shows the frequency of hearing loss by severity and the time of onset of the defect.

If moderate and severe defects were considered as group 1 and the deep defect as group 2, Fisher's exact test showed no statistically significant difference in the two groups based on the time of onset of hearing loss (P = 0.78).

The mean (±SD) CDVA in the study was 0.03 ± 0.07 LogMAR (0.0-0.30). With optical correction in place, 86% of the hearing impaired subjects had a best CDVA of 0.0 LogMAR. Hyperopia and astigmatism were

Table 1. The frequency of hearing loss by severity based on the time of onset of defect (*n*=64)

Severity Time of onset	Moderate *n* (%)	Severe *n* (%)	Deep *n* (%)	Total *n* (%)
Congenital	6 (9.4)	20 (31.2)	31 (48.4)	57 (89.1)
Acquired	-	6 (9.4)	1 (1.5)	7 (10.9)
Total	6 (9.4)	26 (40.6)	32 (50.0)	64 (100.0)

the leading refractive anomalies in severe and profound hearing loss students. The frequency distribution of different types of refractive errors in the 4 groups is presented in Table 2.

According to the standard normal range of CS, 3 cycles per degree (cpd) frequency data which values are more than 1.83 are normal; any value less than this is abnormal. CS for 6, 12, and 18 cpd is considered normal when the score obtained is more than 2.07, 1.79, and 1.30, respectively; values less than this are considered as abnormal [16].

In congenital hearing loss students, the most common type of CS abnormalities was in the spatial frequency of 18 cpd with 37 (64.9%) and the least common was in the spatial frequency of 6 cpd with 25 (47.4%), while in acquired hearing loss students, the frequency of CS abnormalities was equal in spatial frequencies of 3, 6, and 18 cpd.

As shown in Table 3, Fisher's exact test showed no statistically significant difference between CS in 4 different spatial frequencies based on the type of hearing loss.

DISCUSSION

Earlier studies have reported a high incidence of visual impairments such as refractive error and strabismus among the hearing-impaired population, but none of them have reported on CS abnormalities in different spatial frequencies.

In this study, even though we performed a perfect CS test on all 64 cases, for more accurate evaluation of hearing anomalies and their effects on vision and the frequency of visual factors, an audiometry test was conducted for all cases even if they had previously been tested. To further ensure the accuracy of the tests, all cases underwent a Wechsler IQ test, because some researchers have reported a higher prevalence of low IQ in deaf people than in normal hearing people.[7] In order to preclude any possible effect of low IQ on test performance, subjects were included in the study only if their IQ was >70.

None of the subjects tested reported mild hearing defect. This is likely due to the subject selection from schools for the hearing impaired; subjects with mild deafness can potentially study in normal schools.

In this study, the mean CDVA in deaf people was 0.955 ± 0.145 LogMAR. A total of 12.5% of cases could not reach a VA of 0 LogMAR even after correcting their refractive errors; this finding is similar to Arming's study that observed that even after refractive correction, 10.8% of the cases did not reach a VA of 0 based on the LogMAR scale.[9]

Our results showed that the most common type of refractive errors were hyperopia and astigmatism, with a frequency of 37.5%; myopia had the lowest frequency of 1.6%. In a study by Khorrami-Nejad et al conducted in Iran, the frequency of hyperopia was reported as 13.2%, which is less than what was observed in the current study; they also reported a frequency of 12.6% for myopia among deaf students while we found the frequency of myopia as 1.6%; there is a large variance between the findings of these two studies.[17] Some other researchers have also found a low prevalence of myopia in deaf people compared with the normal population. On the other hand, people with various eye pathologies were excluded from our study; this could be one of the reasons for the lower prevalence of myopia in our study because some eye pathologies are associated with a higher prevalence of myopia. There was no significant relationship between the type of visual defects and the severity of the hearing impairment in our study ($P = 0.72$). This finding is consistent with the studies by Sharma et al[18] and Mafong et al[19] which reported no correlation between the severity of hearing defect and abnormal vision in deaf people.

In previous studies, the prevalence of ocular abnormalities has been reported between 8-61%. This relatively higher range is more related to age, visual anomalies, and selection bias in deaf populations.[15-18] In this study, 87.5% of the deaf population who underwent the study had a CDVA of 10/10 and only 12.5% of them had best corrected visual acuity less than 10/10, while the frequency of CS abnormality was 43.5% to 65.6%. Notably, in our study, there is a significant difference between the prevalence of VA abnormalities and CS abnormalities in different frequencies. In a similar study on CS in deaf people,[20] even though only 25.6% of the subjects had a VA less than 10/10, CS abnormality was reported in 64.1% of the subjects; one of the reasons for this is that the CS test is more sensitive in the initial diagnosis of defects. In this study, we measured CS in

Table 2. The frequency of refractive error types based on the severity of defect (*n*=64)

Refractive error type Severity of defect	Emmetropia Number (%)	Hyperopia Number (%)	Hyperopia & Astigmatism Number (%)	Myopia Number (%)	Myopia & Astigmatism Number (%)	Astigmatism Number (%)	Total Number (%)
Mild	0 (0)	3 (4.7)	2 (3.1)	0 (0)	0 (0)	1 (1.6)	6 (9.4)
Moderate	2 (3.1)	12 (18.7)	8 (12.5)	1 (1.6)	2 (3.1)	1 (1.6)	26 (40.6)
Severe	3 (4.7)	8 (12.5)	14 (21.9)	0 (0)	3 (4.7)	4 (6.2)	32 (50)
Deep	5 (7.8)	23 (35.9)	24 (37.5)	1 (1.6)	5 (7.8)	6 (9.4)	64 (100)

Table 3. Association between contrast sensitivity abnormalities and types of hearing loss in different spatial frequencies

Spatial frequency	Type of hearing loss	Abnormal Number (%)	Normal Number (%)	Results
3 cycles per degree	Congenital	28 (84.8)	25 (92.6)	*P*=0.44
	Acquired	5 (15.2)	2 (7.4)	
6 cycles per degree	Congenital	25 (89.3)	32 (88.9)	*P*=0.99
	Acquired	3 (10.7)	4 (11.1)	
12 cycles per degree	Congenital	27 (84.4)	30 (93.7)	*P*=0.42
	Acquired	5 (15.6)	2 (6.3)	
18 cycles per degree	Congenital	37 (88.1)	20 (90.9)	*P*=0.99

different spatial frequencies for the first time to check the CS in deaf people. As some diseases affect specific spatial frequencies, checking different frequencies helps evaluate sensitivity defects more accurately and completely.

This study showed that there was no significant relationship between the CS defects and the type of hearing defect or its severity. Another study on 223 deaf children also showed that CS abnormality had no significant relationship with the severity of hearing defect.[19] In fact, in both studies, CS abnormalities in deaf people were more than what observed in the normal hearing population but had no relationship with the severity or type of hearing loss.

The high prevalence of CS abnormalities in deaf people could be the result of specific syndromes, which also involve the visual system. For example, Usher syndrome which is associated with peripheral retinal degenerations, affects CS in low spatial frequencies and it can show early defects of retinal function before pathological signs manifest.[3]

Previous studies reported the prevalence of ocular abnormalities (except CS) as 8-61%.[15-18] One of the reasons that our study in Tehran and Khandekar's in Oman presented a higher prevalence of CS abnormalities than other studies investigating the prevalence of ocular abnormalities other than CS in deaf populations was that CS test is very sensitive and any type of defect, even in initial phases, in the visual system such as foveal, retinal, or in the neural pathways to the cortex, can affect the CS results. On the other hand, as different diseases affect different spatial frequencies naturally while we evaluate the field in four different frequencies, any type of defect in the visual system (even a mild one) can potentially be picked up by the CS test.

It is obvious that deaf people are exposed to a great risk for ocular problems. The high frequency of CS defects in the current study shows the importance of the assessment of CS in deaf people. Considering the fact that CS defects seriously affect the child's learning communication skills, the CS vector vision CVS-1000 test should be an essential part of routine eye examinations in deaf individuals even with a history of good eye examinations.

On the other hand, the high frequency of CS defects in higher spatial than other spatial frequencies points to a higher frequency of defects in the central visual system rather than in the periphery in deaf people.

In conclusion, while deaf persons are more dependent on a healthy visual system in comparison to those with normal hearing, they are at a higher risk of having CS abnormalities.

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Conflicts of Interest

There are no conflicts of interest.

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