Relationship between High Frequency Audiometry, Distortion Product Otoacoustic Emissions and Speech Perception in Noise in Children with(C)APD and Children with Normal Auditory Processing

KRUPA BAI B

18AUD018

This Dissertation is submitted as a part of fulfilment

For the Degree of Master of Science in Audiology

University of Mysore, Mysore

All India Institute of Speech and Hearing

Manasagangothri Mysore – 570006

July, 2020

CERTIFICATE

This is to certify that this dissertation entitled '**Relationship between high frequency audiometry, distortion product otoacoustic emissions and speech in noise perception in children with(C)APD and children with normal auditory processing'** is bonafide work submitted in part fulfilment for the degree of Master of Science (Audiology) of the student registration No. 18AUD018. This has been carried out under supervision and guidance of the faculty of this institute and has not been submitted earlier to any other University for the award or any other Diploma or Degree.

Mysuru
July, 2020

Dr. M. Pushpavathi
Director
All India Institute of Speech and Hearing
Manasagangothri, Mysuru – 570006

CERTIFICATE

This is to certify that this dissertation entitled '**Relationship between high frequency audiometry, distortion product otoacoustic emissions and speech in noise perception in children with (C)APD and children with normal auditory processing'** is bonafide work submitted in part fulfilment for the degree of Master of Science (Audiology) of the student registration No. 18AUD018. This has been carried out under my supervision and guidance and has not been submitted earlier to any other University for the award or any other Diploma or Degree.

July, 2020

Mysuru

Dr. Chandni Jain

Guide

Reader in Audiology

Department of Audiology

All India Institute of Speech and Hearing

Manasagangothri, Mysuru – 570006

DECLARATION

This is to certify that this dissertation entitled '**Relationship between high frequency audiometry, distortion product otoacoustic emissions and speech in noise perception in children with(C)APD and children with normal auditory processing'** is result of my own study under the guidance of Dr. Chandni Jain, Reader in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysuru and has not been submitted earlier to any other University for the award or any other Diploma or Degree.

Registration No. 18AUD018

July, 2020

Mysuru

Acknowledgement

Lamentations 3:23 Great is your Faithfulness

All praise, honour and glory to my Lord Jesus Christ for his richest grace and mercy for accomplishment of this research work.

I dedicate my research work to my mom and dad and I am extremely grateful to my parents for their love, prayers, caring and sacrifices for educating me, encouraging me and preparing me for my future.

Iam very much thankful to my beloved (Kutti) for his love, understanding, encouraging through prayers and word of God and continuing support to complete this research work.

Also I express my thanks to my brother (chintu) for his support and valuable prayers.

Heartful thanks to Pastor Elijah for support, prayers and encouraging me always with the word of God.

I would like to express my deep and sincere gratitude to my guide Dr. Chandni Jain for giving me the opportunity to do research and providing valuable guidance throughout this research .I am extremely grateful for what you have offered me I would also like to thank for your continuous support till the end I am extending my heartful thanks for your acceptance, patience throughout .

I thank Dr. M. Pushpavathi, Director, All India Institute of Speech and Hearing, Mysuru for allowing me and provide all facilities to carry out this dissertation work. I thank our HOD Dr. Prawin Kumar for being approachable and helpful throughout.

A heartfelt gratitude to Dr. Asha Yathiraj for helpful suggestions in my dissertation and for always inspiring to learn.

I thank Sharath Kumar sir, Shreyank sir, Anoop sir for all the timely help. I thank Ravi sir and Ravishankar sir for all the technical help in this work.

My special thanks goes to my friend shivaranjini for prayers, support and encouraging me always with the word of God.

Also my sincere thanks to my dearest friends (CPC girls) for their prayers and help at appropriate times.

I also thank pastor Vijay kumar for his prayers and support. God spoke to me through his messages when I was discouraged when I was down.

I thank Megha and shreyas for being my dissertation partner and working together throughout.

Heartful thanks to Binu, Sarah for always being with me comforting me and supporting me.

I thank Gloryland children for their prayers and support.

I thank each and everyone who supported me and prayed for me continuously to complete this research work.

TABLE OF CONTENTS

LIST OF TABLES

Abstract

Speech perception difficulties in individuals with central auditory processing disorders (C)APD could be because of the dysfunction in central auditory nervous system or it could be a dysfunction at the level of cochlea. Children with (C)APD have several behavioural deficits including hearing speech in the presence of noise. High frequencies are important for consonantal discrimination and speech recognition and people with high frequency hearing losses would have difficulties in perceiving speech in noisy environment Thus, it is necessary to evaluate the extended high frequency thresholds in (C)APD individuals to be able to differentiate the involvement of peripheral ear or central auditory system in speech perception difficulties. The aim of the present study was to investigate the relationship between high frequency audiometry, high frequency DPOAEs and speech in noise perception in children with CAPD and children with normal auditory processing. A total of 25 children in age range of 7-14 years participated in the study. They were divided into two groups, control group of 20 typically developing children and clinical group of five children diagnosed as CAPD with auditory closure deficit. Results revealed that there was no significant correlation between high frequency thresholds, high frequency distortion product otoacoustic emissions and speech perception in noise abilities in typically developing children.

Key words; central auditory processing disorder, high frequency audiometry, high frequency DPOAEs, speech perception in noise.

Chapter 1

Introduction

“Central auditory processing disorder (C)APD is difficulty in the perceptual processing of auditory information at the level of central auditory nervous system” (ASHA 2005). “These difficulties include poor performance in one or more of the following: lateralization, localization, auditory pattern recognition, auditory discrimination, temporal aspects of audition including - temporal ordering, temporal masking, temporal discrimination as well as auditory performance with degraded acoustic signal” (ASHA, 2005). All studies reveal that the most common feature that is seen in these individuals is the speech perception difficulties in adverse listening conditions (Barmeou et al, 2001; Bellis, 2003; Chermak, 2002; Chermak, Hall, & Musiek, 1999; Keith, 1999; Musiek & Geurkink, 1980; Vanniasegaram et al., 2004).

Difficulties in speech perception which are seen in individuals with (C)APD could be because of the dysfunction in central auditory nervous system or it could be a dysfunction at the level of cochlea. Hence the prefix ‘central’ is removed from (C)APD and it is preferred to use the term APD or (C)APD. This is a symbolic recognition that the possible role of peripheral ear is not ruled out in APD (Moore, 2016). The diagnosis of (C)APD is only confirmed when the individual has speech perception difficulties which are seen even with normal peripheral hearing and deficits in one or several central auditory processing skill areas (Munguia, 2014).

The normal peripheral hearing has been reported in individuals with (C)APD only in conventional frequency range. These frequency ranges from 250 Hz to 8000 Hz (Abel et al, 1990; Marotta et al,2002; Neyenhuis et al, 2004). However, studies have also shown that extended high frequencies are an important aspect in speech perception in the presence of noise (Yeend, Beach, & Sharma, 2018). Studies also state that high frequencies are important for speech recognition and consonant discrimination. Individuals with hearing loss in these frequencies will have problems in distinguishing the signal from the noise (Skinner &Miller, 1983). In a study, the relationship between high frequency thresholds and auditory processing was studied in school going children in Brazil. They reported that there exists a link between auditory processing and high frequency thresholds (Ramos & Pereira 2005).

1.1 Need for the Study

The basic audiological assessment of (C)APD includes conventional audiometry. Puretone thresholds from the frequency range of 250 Hz to 8000 Hz are evaluated. As discussed above, high frequencies are essential for consonantal discrimination and speech perception and individuals with high frequency hearing losses would have difficulties in perceiving speech in noisy environment (Abel et al. 1990). Children with (C)APD have several behavioural deficits which includes hearing speech in the presence of noise. Thus, it is necessary to evaluate the extended high frequency thresholds in (C)APD individuals to be able to differentiate the involvement of peripheral ear or central auditory system in speech perception difficulties. In the present study, two tests- extended high frequency Audiometry (EHFA) and high frequency distortion product otoacoustic emissions (DPAOEs) was evaluated in children with (C)APD and the results were then correlated with the speech perception in noise(SPIN). Thus, the study includes both behavioural and objective measure to assess high frequency sensitivity in children with (C)APD.

1.2 Aim of the Study

The present study aimed to investigate the relationship between EHFA, DPOAEs and SPIN in children with (C)APD and in children with normal auditory processing.

1.3 Objectives of the Study

1. To compare extended high frequency thresholds in children with (C)APD and in children with normal auditory processing.
2. To compare high frequency DPOAEs in children with (C)APD and in children with normal auditory processing.
3. To compare SPIN in children with (C)APD and in children with normal auditory processing.
4. To investigate the correlation between extended high frequency thresholds and DPOAEs with SPIN in children with normal auditory processing.

1.4 Hypothesis

Null hypothesis was assumed in the present study.

1. There would be no significant difference in high frequency thresholds in children with (C)APD and children with normal auditory processing.
2. There would be no significant difference in high frequency DPOAE in children with (C)APD and children with normal auditory processing.
3. There would be no significant difference in SPIN abilities between children with (C)APD and children with normal auditory processing.

4. There would be no significant correlation between high frequency threshold and DPOAEs with SPIN in children with normal auditory processing.

Chapter 2

Review of literature

"Central auditory processing disorder (C)APD is difficulty in the perceptual processing of auditory information at the level of central auditory nervous system" (ASHA 2005). "These difficulties include poor performance in one or more of the following: lateralization, localization, auditory pattern recognition, auditory discrimination, temporal aspects of audition including - temporal ordering, temporal masking, temporal discrimination as well as auditory performance with degraded acoustic signal" (ASHA, 2005).

Perception of speech in difficult listening situation is one of the majorly reported problems in these individual. Bamiou et al., (2001) did a review to study the clinical features that are seen in individuals with auditory processing disorders. The most common symptom that was noted in children with auditory processing disorders was the difficulty of understanding speech. Similarly, Chermak (2002) characterized that individuals with (C)APD as having problems in comprehending spoken language especially in the presence of competing speech, in noise backgrounds and also in reverberation. (C)APD assessment involves test battery to identify lesion and to define the functional auditory deficits in central auditory nervous system. Routine audiological evaluation should be done prior to the assessment of central auditory processes. Behavioral central tests that are used in the evaluation of central auditory processing abilities include:

1. Dichotic tests

2. Binaural interaction tests

3. Temporal processing tests

4. Monoaural low redundancy speech tests

2.1 Speech perception in noise in (C)APD

Speech perception in noise can be assessed through various measures. The speech stimuli can be degraded through variety of strategies such as time compressing the speech signals, filtering selected frequencies and entrenching speech background noise and in verbal competition. The common tests are speech-in-noise test, the synthetic sentence identification with ipsilateral competing message (SSI-ICM) (Jerger & Jerger, 1974), low pass filtered speech test (Rintelmann, 1985), and paediatric speech intelligibility test (Jerger, Jerger & Abrams, 1983), and the compressed speech with reverberation test (Borstein & Museik, 1992).

SPIN is found to be the greatest challenge in individuals with CAPD. Lagace (2010) illustrated psychometric functions of SPIN test based on the hypothetical groups of individuals with (C)APD, intending to find the underlying cause of speech perception in noise problems in(C) APD. They concluded that SPIN-like tests could be instrumental in finding the features of deficits that these individuals have in perceiving speech in noise for (C)APD group.

Keith (1999) reported that basic difficulty in individual with (C)APD is that any speech signal presented in the conditions that are less than optimal is difficult to understand. Similarly, Chermak (2002) characterized individuals with (C)APD as having trouble perceiving spoken language in the presence of competing signal or in noisy backgrounds and in reverberating conditions. In the review article done by Bamiou et al. (2001) which studied the clinical symptoms and causes of auditory processing disorders regarding causes and clinical presentations of auditory processing disorders, found that comprehending speech is the most commonly seen symptom in these individuals.

Vanniasegaram (2004) compared the performance of normal-hearing school-going children had (C)APD to that of normal-hearing control children. The auditory test battery consists of a dichotic test of competing sentences, a Tallal Discrimination Task, Simultaneous and Backward masking and a Consonant Clusters Minimal Pairs (CCMP) in noise test, in which subjects had to identify the minimal pairs as same or different presented in three different manner. One minimal pair with the initial consonant differing between pairs in term of place, manner or voicing, two minimal pair in which one word was obtained from the other by omitting a particular consonant from and consonant cluster at initial position and four minimal sets or pairs that included words differing in a particular consonant of a s-cluster at initial position. This test items were presented binaurally at 60dBSPL with speech spectrum noise presented simultaneously in background taking -2.3 dB as signal-to-noise ratio. From these four tests CCMP had highest ecological validity for suspected group, reflecting the common symptom of the children in APD suspected group of difficulty understanding speech in noisy background.

Thus, the above studies suggest that perception of speech in difficult listening situation is one of the majorly found problem in (C)APD individuals.

2.2 Extended high frequency in children with (C)APD

Individuals with (C)APD generally have peripheral hearing that is normal. However, most studies done to evaluate hearing loss and auditory processing disordersare done in the frequencies from 250 to 8000 Hz (Abel et al, 1990; Marotta et al, 2002; Neyenhuis et al, 2004). The diagnosis of (C)APD is confirmed when individuals have speech perception difficulties even though they have normal peripheral hearing and deficits in one or several central auditory processing skill areas (Munguia, 2014).

However, high frequencies also play an important role in speech perception. As mentioned above, high frequencies are an integral part of consonant discrimination, and speech recognition. It is also noted that people with high frequency hearing loss have difficulty in understanding speech in the presence of noise (figure ground) (Skinner and Miller, 1983).

Thus, speech perception difficulties in individuals with (C)APD could be because of the dysfunction in central auditory nervous system or it could be a dysfunction at the level of cochlea which could be identified with the help of high frequency audiometry. Hence the prefix ‘central’ is removed from (C)APD and it is preferred to use the term APD or (C)APD. This is a symbolic recognition that the possible role of peripheral ear is not ruled out in APD (Moore, 2016).

2.3 Otoacoustic emissions (OAEs) in children with (C)APD

Otoacoustic emission is done in children with (C)APD as a part of routine audiological evaluation to assess outer hair cell functioning. In these individual OAEs are usually present which indicates normal outer hair cell functioning. Recently research is focussed on the medio olivocochlear (MOC) functioning in (C)APD using contralateral suppression of OAEs. Several reports have suggested abnormal MOC function are seen in children with (C)APD when tested with transient evoked OAE (TEOAE) and distortion product OAE (DPOAE) suppression (Muchnik et al., 2004; Oppee et al., 2014;Sanches & Carvallo, 2006). However, there are also contradicting studies which indicate normal MOC functioning in individuals with (C)APD (Burguetti & Carvallo, 2008; Butler et al., 2011).

These mixed results in MOC functioning can be attributed to the heterogeneous nature of (C)APD, and differences in the protocols used to assess OAE suppression by these researchers. Other factors such as the various methodological differences such as the use of different stimulus paradigms such as linear versus non-linear in TEOAEs studies, the use of different parameters to define suppression such as absolute versus signal-to-noise ratio (SNR), bandwidth of the CBBN, methods for reporting EOAE amplitudes, normalisation of the EOAE suppression, use of different response frequencies, and the effects of the middle ear muscle reflex (MEMR).(Jin, S. H. (2013, June).

Thus, from the above literature it is evident that the research related to OAEs in (C)APD in children is mainly related to the study of MOC functioning. However, as stated earlier, high frequencies also are an important aspect in speech perception in noise and thus it would be interesting to see high frequency OAEs in individuals with (C)APD.

Chapter 3

Methods

The present study aimed to investigate the relationship between extended high frequency audiometry (EHFA), distortion product otoacoustic emission (DPOAEs) and speech in noise perception (SPIN) in children with Central Auditory Processing Disorder (C)APD and those in children with normal auditory processing.

3.1. Research Design

A between subject design to compare EHFA, DPOAEs and SPIN between clinical group and control group was used. Further a within-subject design to determine relationship between EHFA, DPOAEs and SPIN in control group was used in this study.

3.2. Participants

Total of 25 participants within the age range of 7 to 14 years participated in the present study. Participants were then grouped into two groups – the control group and the clinical group. Clinical group included five children with the mean age of 11.8 years who were clinically diagnosed as (C)APD with auditory closure deficit. In the control group-20 children who had normal auditory processing skills with a mean age of 10.4 years were taken. Control group participants passed 'Screening Checklist for Auditory Processing' (SCAP) developed by Yathiraj and Mascarenhas (2002, 2004). The participants in the study fulfilled the below-mentioned criteria:

3.2.1 Participant inclusion criteria

- Hearing thresholds within normal limits that is air conduction thresholds in the frequency range of 250 to 8000 Hz, and bone conduction thresholds in the frequency range of 250 to 4000Hz were within or equal to 15dBHL and the air-bone gap was lesser than 10dBHLat all the frequencies bilaterally.
- Normal functioning of middle ear as indicated by'A' type tympanogram and ipsilateral and contralateral acoustic reflexes present for both ears.
- All the participants were native Kannada speakers.
- Speech identification scores in quiet greater than 80% assessed using Phonetically Balanced word list in Kannada.

3.2.2 Participant exclusion criteria

Any participants who had a history of otological, speech and language problem, developmental delay and associated deficits were excluded from the study. This exclusion was done based on a detailed case history.

3.3 Test environment

Sound treated room with ambient noise levels within permissible noise limits (ANSI S3.1: 1991) were used to conduct all the tests.

3.4 Instrumentation

The instruments used in the study were as follows: -

- Calibrated diagnostic audiometer, two channel Inventis piano with Sennheiser HDA 200 circumaural headphones with MX 141 adapter and B-71 bone vibrator was used in routine audiological evaluation.
- Calibrated Immittance meter, GSI Tympstar (version 2) was used to do tympanometry. This same equipment was used to assess middle ear reflexes.
- Screening Checklist for Auditory Processing (SCAP) was administered for inclusion of the participants in the control group.
- A personal laptop was used to present speech identification in noise in Kannada (SPIN) (Vaidyanath & Yathiraj, 2012). This test includes 4 list of bisyllabic word taken from 'phonetically balanced word identification test in Kannada' and 8-speaker speech babble served as noise stimuli was played through CD routed through audiometer connected via auxiliary input.
- A calibrated DP-2000 Starkey was used to record DPOAEs.

3.5 Procedure

An Informed consent was obtained from all the parents/guardians of participants before the study.

3.5.1 Routine audiological evaluation

Pure tone audiometry and immittance evaluation was conducted for all the participants. Modified Hughson and Westlake procedure (Carhart & Jerger,1959) was used to evaluate air conduction thresholds and bone conduction thresholds at each octave from 250 Hz to 8000 Hz and 250 to 4000 Hz respectively. Pure tone air conduction thresholds at 500 Hz, 1000 Hz, 2000 Hz and4000 Hz was obtained. Speech identification in quite (Yathiraj, A., & Vijayalakshmi, C. S. (2005). was assessed at 40dBSL with reference to SRT. Immittance evaluation was carried out to check middle ear functioning on all the participants having threshold within 15dBHL.

3.5.2 CAPD Screening

SCAP was administered to select participants in control group. SCAP given by Yathiraj & Mascarenhas (2002, 2004) is a screening questionnaire, consisting of 12 questions. Each question is scored on a 2 point rating scale as ‘Yes’ or ‘No’. For each answer marked as yes a score of ‘one’ was given and each answer marked as no a score of ‘zero’ was given. Based on this questionnaire children who scored below 50% were taken as participants for control group. Children diagnosed with (C)APD with auditory closure deficit were included as clinical group.

3.5.3 Extended High Frequency Audiometry

The hearing thresholds of all the participants was estimated using modified Hughson and Westlake procedure (Carhart & Jerger,1959) with the two channel Inventis Piano audiometer. The thresholds were estimated for 9000 Hz, 10000 Hz, 11200 Hz, 12500 Hz, 14000 Hz and 16000 Hz frequencies.

3.5.4 DPOAE testing

Participants were asked to sit comfortably and instructed to relax and minimize extraneous movements during the test. An appropriate probe tip was inserted gently into the ear canal. The DPOAE stimulus was two pure tone signals in the frequency ratio of 1.2. The testing was done for test frequencies ranging from 500 Hz to 16000 Hz with a frequency resolution of two points per octave. Two level chosen wereL_1 = 65 dB SPL and L_2 = 55 dB SPL. Further, DP amplitude and signal to noise ratio (SNR) was noted down for each participant to consider the presence and absence of DPOAEs.

3.5.5 Assessment of Speech Perception in Noise

The SPIN test was done using the CD version of the speech stimuli loaded into the personal laptop at 0 dB SNR (Vaidyanath & Yathiraj, 2012). The output from the laptop was routed through the audiometer at 40dB SL of the pure tone average. 25 words were presented to each ears and verbal response was taken from each participant. The score of one for every correct response and score of zero for every incorrect response was given.

3.6 Statistical Analyses

Data from both the groups were compiled, tabulated and then statistically analyzed using Statistical Package for social Sciences (SPSS V.20). Descriptive statistics was used to obtain the mean and standard deviation for each of the tests for both the groups. Shapiro Wilks tests of normality was used for assessing normality of data and Spearman's Rank correlation was done for within group comparison for assessing correlation.

Chapter 4

Results

The current study aimed to study the relationship between high frequency audiometry (HFA), distortion product otoacoustic emissions (DPOAEs) and speech perception in noise (SPIN) in children with central auditory processing disorders (C)APD and children with normal auditory processing. A total of 5 children with (C)APD and 20 children with normal auditory processing skills participated in the study in the age range of 7 to 14 years. The results of the study are discussed below:

4.1 High frequency thresholds in children with (C)APD and children with normal auditory processing.

Table 4.1 shows the individual scores of all the five participants in high frequency audiometry and Table 4.2 shows the mean and standard deviation (SD) of the high frequency audiometric thresholds for the control group and clinical group. From the Table 4.2, it can be noted that the mean high frequency threshold was better in the clinical group compared to the control group for both ears. However, statistical analysis was not done to compare the high frequency thresholds between the two groups as the number of participants in the (C)APD group was less.

Table 4.1

Individual scores (dB) of high frequency audiometry in clinical group

Participant no.	Age/ Gender	Ear	Frequency (Hz)					
			9000	10000	11200	12500	14000	16000
S1	10/F	Right ear	10	10	10	15	10	15
		Left ear	10	10	10	15	15	20
S2	12/M	Right ear	10	10	10	15	10	15
		Left ear	10	10	10	15	15	20
S3	9/M	Right ear	10	10	10	15	15	15
		Left ear	10	10	10	15	10	15
S4	11/F	Right ear	10	10	15	15	15	20
		Left ear	10	10	15	15	15	20
S5	12/M	Right ear	10	10	15	10	15	20
		Left ear	15	10	15	15	15	20

Table 4.2

Mean and SD of the high frequency audiometric thresholds among control group and clinical group.

Frequency (Hz)		Control group		Clinical group	
		Mean (dB)	SD	Mean (dB)	SD
Right ear	9000	10	.000	11	2.23
	10000	20	.000	10	0
	11200	20	2.512	12	2.73
	12500	20	2.22	15	0
	14000	20	3.59	14	2.23
	16000	20	2.35	19	2.23
Left ear	9000	10	.000	10	0
	10000	10.2	1.11	10	0
	11200	13.5	2.35	12	2.73
	12500	12.75	2.55	14	2.23
	14000	13.5	2.35	13	2.73
	16000	17	2.44	17	2.23

4.2 High frequency DPOAEs in children with (C)APD and children with normal auditory processing.

Table 4.3 shows the individual scores of DPOAE amplitude and SNR for the clinical group. Table 4.4 shows the mean and SD of the DP amplitude and SNR of the control and the clinical group. From the Table 4.4, it can be seen that the control group had better mean DP amplitude and SNR than the clinical group for both the ears. The statistical analysis was not done to compare the high frequency DPOAEs between the two groups as number of participants in the clinical group were less

Table 4.3

Individual scores of DPOAE amplitude and SNR for the clinical group.

Clinical group (N=5)	Ear	Parameters	Frequency (Hz)											
			328	469	609	938	1266	1875	2578	3844	5109	6422	7688	10266
S1	Right ear	DP amplitude	2.9	8.6	6.5	-15.9	17	19.6	22	12.4	7.5	17.7	7.3	19.8
		SNR	18.9	11.2	11.7	13.2	27.1	29.4	27.6	21.4	12.3	9.5	10.7	6.3
	Left ear	DP amplitude	-12.2	-4.1	-2.7	8.5	8.8	7.7	4.5	1	-6.3	-5.3	2	-22.8
		SNR	-0.1	14.4	16.7	24.6	27.2	29.5	26.1	14.6	9.3	9.6	7.1	-1.5
S2	Right ear	DP amplitude	21.8	2.6	5.2	14.3	10.2	9.8	5.5	9	4.8	8.2	3.5	-26
		SNR	12.3	24.9	24.3	28.6	18.7	27.6	35.6	33.3	10.	3.6	9.2	14
	Left ear	DP amplitude	9.2	13.4	18.7	15.7	14.5	9.7	12.5	17.2	5.5	-8.9	-2	7.6
		SNR	14.6	21.5	27.3	31.4	26.2	28.7	30.3	31.6	19.9	12.2	11.6	20.9
S3	Right ear	DP amplitude	13.4	18.7	15.7	14.5	9.7	12.5	17.	5.5	8.9	5.8	9.6	3.5
		SNR	0.1	14.4	16.7	24.6	27.2	29.5	26.1	14.6	9.3	9.6	7.1	-1.5
	Left ear	DP amplitude	-10.2	-3.1	-2.6	6.5	38.5	6.7	5.6	2.4	-4.3	-6.5	2	9.2
		SNR	-18.9	11.2	11.7	30.2	27.1	29.4	27.6	21.4	12.3	9.5	10.7	-6.3
S4	Right ear	DP amplitude	12.2	4.1	2.7	8.5	8.8	7.7	4.5	1	6.3	5.3	9.6	3.5
		SNR	14.6	21.5	27.3	31.4	26.2	28.7	30.3	31.6	19.9	12.2	11.6	20.9
	Left ear	DP amplitude	-13.2	-5.4	-2.9	14.5	9.8	9.7	5.4	2	-7.3	-6.9	2	-21.6
		SNR	12.3	24.9	24.3	28.6	18.7	27.6	35.6	33.3	10.9	3.6	1.7	14
S5	Right ear	DP amplitude	5.6	4.7	9.7	8.7	9.2	14.6	32	2	9.3	4.8	6.5	4.2
		SNR	16	13.2	17.5	14.9	27.9	24.9	34.9	24.8	17.8	7.9	14.9	19.5
	Left ear	DP amplitude	-13.2	11.4	-2.8	9.5	6.7	7.7	5.8	3.5	-7.5	-7.3	2	11.9
		SNR	12.5	13.3	12.8	20.4	16.7	18.9	36	21.4	15.7	16.9	15.9	19

Table 4.4

Mean and SD of the DP amplitude and SNR of the control and the clinical group

Frequency (Hz)		Control group				Clinical group			
		DP amplitude(dB)		SNR		DP amplitude(dB)		SNR	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Left ear	328	1.88	7.12	9.765	7.14	-7.92	9.53	4.00	14.08
	469	6.39	6.57	15.65	7.20	2.38	9.01	17.00	6.12
	609	9.81	10.24	19.28	9.98	1.54	9.76	18.60	6.65
	938	13.40	10.07	27.14	8.56	10.90	4.14	27.00	4.52
	1266	10.85	9.60	25.55	7.16	15.60	13.07	23.20	4.81
	1875	6.245	9.73	24.66	6.95	8.42	1.39	27.00	4.52
	2578	5.43	10.16	30.14	3.06	6.56	3.12	31.20	4.60
	3844	11.51	10.38	28.65	7.37	5.18	6.66	24.20	7.79
	5109	7.69	10.79	20.49	7.95	-3.28	5.63	13.60	4.39
	6422	-1.87	11.97	10.12	7.89	-6.94	1.44	10.60	4.66
	7688	8.835	10.84	14.64	8.76	1.20	1.78	9.60	5.32
	10266	-4.11	13.36	10.94	10.01	-3.20	17.68	9.20	12.39
Right ear	328	.384	8.188	6.820	10.16	-6.00	12.85	4.80	14.75
	469	6.95	5.082	15.86	4.79	.80	11.05	17.00	6.12
	609	11.29	8.72	21.56	6.93	4.40	9.07	19.60	5.94
	938	15.95	9.37	30.31	7.23	5.80	12.49	26.0	6.55
	1266	11.84	8.18	21.88	6.34	4.20	11.86	25.40	3.64
	1875	9.05	7.97	26.09	6.58	-1.00	15.23	28.20	1.92
	2578	7.48	8.085	29.26	3.59	-5.40	20.63	31.0	4.35
	3844	12.59	7.96	27.24	5.35	1.20	8.04	25.21	7.56
	5109	7.30	9.95	18.59	7.38	-5.40	5.94	14.0	4.74
	6422	.06	7.22	13.11	4.22	-6.00	8.57	8.80	3.03
	7688	11.6	9.182	16.06	8.07	4.60	6.98	9.40	5.03
	10266	-2.75	13.67	12.05	8.43	-6.80	14.94	9.40	12.60

4.3 Speech perception in noise in children with (C)APD and children with normal auditory processing.

Table 4.5 depicts the individual scores of SPIN for all the five participants in the clinical group. Table 4.6 shows the mean and SD of SPIN scores of the control and the clinical group. From Table 4.6, it can be noted that the mean SPIN scores was better in the control group compared to the clinical group for both ears. Also, variation as depicted by SD is greater for clinical group as compared to control group for both ears. However, the statistical analysis was not done to compare the SPIN scores between the two groups as the number of participants in the (C)APD group was less.

Table 4.5

Individual score of SPIN in children with CAPD in clinical group

	Ear	**S1**	**S2**	**S3**	**S4**	**S5**
SPIN	Right ear	11	14	12	14	17
	Left ear	12	10	11	15	15

Table 4.6

Mean and (SD) of SPIN scores for clinical and control group

	Ear	**Clinical group (N=5)**		**Control group (N=20)**	
		Mean	**SD**	**Mean**	**SD**
SPIN-K	Right ear	14	2.302	18.533	1.726
	Left ear	13	2.302	18.333	1.914

4.4 Correlation between high frequency thresholds, high frequency DPOAEs and speech perception in noise in typically developing children.

Normality of the data for the control group was assessed using Shapiro- Wilk test to check for correlation between high frequency thresholds, high frequency DPOAEs and speech perception in noise in children with normal auditory processing. The analysis revealed that few of the test parameters for both ears did not fulfil the assumptions of normality ($p<0.05$). Hence the non-parametric test was used for inferential statistics.

Spearman rank correlation test was used to check if there is any correlation between high frequency thresholds, high frequency DPOAEs with speech perception in noise in children with normal auditory processing for both ears. Results showed no significant correlation between high frequency thresholds, high frequency DPOAEs and SPIN in children with normal auditory processing for both ears.

Chapter 5

Discussion

The present study aimed to investigate the relationship between EHFA, DPOAEs and SPINin children with (C)APD and children with normal auditory processing. The results of the study are discussed below:

5.1 High frequency thresholds in children with (C)APD and children with normal auditory processing

The present study assessed high frequency thresholds in individuals with (C)APD and normal auditory processing. The statistics could not be done due to less number of subjects in clinical group. However the mean thresholds were better for clinical group compared to the control group. These results are contrary as it was expected that speech perception in noise in individuals with (C)APD could be attributed to the loss in high frequency sensitivity (Hunter et al. (2020). However, these results cannot be generalized as the number of participnats in the clinical group was only five.

5.2 High frequency DPOAEs in children with (C)APD and children with normal auditory processing

In the present study, data revealed that mean of high frequency DPOAE amplitude and SNR was better in control group as compared to the clinical group. These findings are not in consistent with the previous results of high frequency audiometry. However, this is more reliable as it is an objective measure to assess high frequency sensitivity compared to the behavioural high frequency pure tone audiometry. Thus, from this results we can imply that high frequency sensitivity is affected in individuals with (C)APD which could have lead to poorer speech perception in noise abilities in them. As high frequency play an important role in consonant identification in the presence of noise (Hunter et al. (2020).

5.3 Speech perception in noise abilities in children with (C)APD and typically developing children

Speech perception in noise abilities was evaluated using speech identification in noise in Kannada (SPIN) (Vaidyanath & Yathiraj, 2012). As stated above, analysis was not done to compare the ability as number of participnats in clinical group are less. On observation, data reveals better mean SPIN scores in control group as compared to clinical group. Similar results were reported by Lagace (2011), they used four sentence lists given combined with a babble masker at four distinct signal-to-noise ratios, they found that children with (C)APD had lower overall sentence key word recognition scores than the control group. Keith (1999) also reported that basic difficulty in individuals with (C)APD is that any speech signal presented in the conditions that are less than optimal is difficult to understand.

5.4 Correlation between high frequency thresholds, DPOAEs and speech perception in noise in children with normal auditory processing.

In the present study, high frequency thresholds, DPOAEs and SPIN was assessed. The findings revealed that there was no significant correlation between high frequency thresholds, DPOAEs and speech perception in noise in children with normal auditory processing. These results are not consistent with the literature (Jin, 2013). Guest, Munro, and Plack (2018) found a significant correlation between EHF thresholds and SPIN, although it is unclear whether this is due to a direct relation between EHF hearing and SPIN, or whether elevated EHF thresholds are a marker for hidden damage at lower frequencies.

Mukari &Mamat (2008) studied the relationship between MOC functioning and speech perception in noise in older adults . They used contralateral DPOAE suppression to measure MOC functioning. SPIN was evaluated using Hearing in Noise Test (HINT) in different test conditions such as noise-ipsilateral, noise-front and noise-contralateral. The findings of this study showed that the older group had a significant lower high-frequency (3–8 kHz) contralateral DPOAE suppression, and they performed more poorly in the noise-ipsilateral condition when compared to the younger group. However, it was seen that there was no correlation between contralateral DPOAE suppression and speech perception in noise. The authors attributed the poor speech perception in noise in older adults could be attributed to the decline in MOC functioning, among other factors. In the present study, contralateral suppression of OAEs was not done and significant correlation was not found, which was due to the less number of CAPD participants used for the study.

Chapter 6

Summary and Conclusion

Difficulty in listening to speech in the noisy background is one of the significant behavioural deficit of children with central auditory processing disorder (CAPD). The present study aimed to investigate the relationship between extended high frequency thresholds (EHFA), distortion product otoacoustic emissions (DPOAEs)and speech in noise perception (SPIN) in children with (C)APD and children with normal auditory processing. The main objectives of the study were to assess EHFA, DPOAEs and SPIN in children with(C)APD and typically developing children and to correlate between high frequency thresholds, DPOAEs and SPIN in typically developing children. A total of 25 children participated in the study. Control group comprised 20 typically developing children, and the clinical group included 5 children diagnosed as (C)APD with auditory closure deficit. Children in the control group were selected if they pass the Screening Checklist for Auditory Processing. High frequency thresholds, DPOAEs and SPIN were assessed on each participant.

Results showed the following,

- On observation, mean high frequency threshold was better in clinical group compared to the control group for both the ears.
- Mean DPOAEs and mean SPIN scores were better in control group as compared to clinical group for both the ears.
- Results showed no significant correlation between high frequency thresholds, high frequency DPOAEs and speech perception in noise in children with normal auditory processing for both ears.

6.1 Implications of the study

- This study help us to understand better the high frequency thresholds of typically developing children and children with (C)APD
- Apparently DPOAEs and SPIN of children with (C)APD lag behind typically developing children

6.2 Limitation of the study

Participants in clinical group were less as compared to control group. Thus, analysis could not be done to compare the abilities between two groups and to establish correlation between both abilities in clinical group.

6.3 Future direction

- Similar study can be conducted on more number of participants in clinical group.
- Developmental trend for high frequency thresholds, high frequency DPOAEs can be studied.

References

Abel, S. M., Krever, E. M., & Alberti, P. W. (1990). Auditory detection, discrimination and speech processing in ageing, noise-sensitive and hearing-impaired listeners. *Scandinavian audiology*, *19*(1), 43-54.

Bamiou, D. E., Musiek, F. E., &Luxon, L. M. (2001). Aetiology and clinical presentations of auditory processing disorders—a review. *Archives of disease in childhood*, *85*(5), 361-365.

Bellis, T. J. (2011). *Assessment and management of central auditory processing disorders in the educational setting: From science to practice*. Plural Publishing.

Cacace, A. T., & McFarland, D. J. (2005). The importance of modality specificity in diagnosing central auditory processing disorder. *American journal of audiology*.

Carhart, R., &Jerger, J. F. (1959). Preferred method for clinical determination of pure-tone thresholds. *Journal of speech and hearing disorders*, *24*(4), 330-345.

Chermak, G. D. (2002). Deciphering auditory processing disorders in children. *Otolaryngologic Clinics of North America*, *35*(4), 733-749.

Chermak, G. D., Hall, J. W., &Musiekl, F. E. (1999). Differential Diagnosis and Management of Central Auditory Processing Disorder and. *Journal of the American Academy of Audiology*, *10*(6), 289-303.

Guest, H., Munro, K., &Plack, C. J. (2018). Relations between speech perception in noise, high-frequency audiometry,and physiological measures of cochlear synaptopathy. *The Journal of the Acoustical Society of America*, *144*(3), 1935-1935.

Hunter, L. L., Monson, B. B., Moore, D. R., Dhar, S., Wright, B. A., Munro, K. J., ... Siegel, J. H. (2020). Extended high frequency hearing and speech perception implications in adults and children. *Hearing research*, 107922.

Jerger, J., &Jerger, S. (1974). Auditory findings in brain stem disorders. *Archives of Otolaryngology*, *99*(5), 342-350.

Jerger, S., Jerger, J., & Abrams, S. (1983). Speech audiometry in the young child. *Ear and Hearing*, *4*(1), 56-66.

Keith, R. W. (1999). Clinical issues in central auditory processing disorders. *Language,Speech, and Hearing Services in Schools*, *30*(4), 339-344.

Lagacé, J., Jutras, B., &Gagné, J. P. (2010). Auditory processing disorder and speech perception problems in noise: Finding the underlying origin. *American Journal of Audiology*.

Lagacé, J., Jutras, B., Giguère, C., &Gagné, J. P. (2011). Speech perception in noise: Exploring the effect of linguistic context in children with and without auditory processing disorder. *International journal of audiology*, *50*(6), 385-395.

Musiek, F. E., & Geurkink, N. A. (1980). Auditory perceptual problems in children:Considerations for theotolaryngologist and audiologist. *The Laryngoscope*, *90*(6), 962-971.

Munguia, R. (2014). Auditory Processing Disorders: Earlier Diagnosis Possible? *Communication Disorders Deaf Studies & Hearing Aids*, *2*(1), e110.

Mukari, S. Z. M. S., &Mamat, W. H. W. (2008). Medial olivocochlear functioning and speech perception in noise in older adults. *Audiology and Neurotology*, *13*(5), 328-334.

Moore, D. R. (2016). What's new in auditory processing. *ENT Audiol News*, *25*(2), 2-3.

Mattsson, T. S., Lind, O., Follestad, T., Grøndahl, K., Wilson, W., &Nordgård, S. (2019). Contralateral suppression of otoacoustic emissions in a clinical sample of children with auditory processing disorder. *International Journal of Audiology*, *58*(5), 301-310.

Nishi, K., &Wróblewski, M. (2019). Use of Sentence Context and Speech Perception in Noise for Children Who Were Suspected for Auditory Processing Disorder. *Audiology and Speech Research*, *15*(1), 54-62.

Neijenhuis, K., Tschur, H., &Snik, A. (2004). The effect of mild hearing impairment on auditory processing tests. *Journal of the American Academy of Audiology*, *15*(1), 6-16.

Ramos, C. S., & Pereira, L. D. (2005). Auditory processing and high frequency audiometry in students of São Paulo. *Pro-fono: revista de atualizacaocientifica*, *17*(2), 153-164.

Rintelmann, W. (1985). Monaural speech tests in the detection of central auditory disorders. *Assessment of central auditory dysfunction: Foundations and clinical correlates*, 173-200.

Salvi , R, Henderson , D, Boettcher, F , & Powers, N (1992). *Functional changes in centralauditory pathways resulting from cochlear diseases.* Central auditory processing. A transdisciplinary View . St. Louis , MO: Mosby year book ,Inc , 47-60 .

Skinner, M.W, &Miller , J.D.(1983). Amplification bandwidth and intelligibility of speech in quite and noise for listeners with sensorineural hearing loss. *Audiology*, *22*(3), 253.

Sanches, S. G. G., &Carvallo, R. M. (2006). Contralateral suppression of transient evoked otoacoustic emissions in children with auditory processing disorder. *Audiology and Neurotology*, *11*(6), 366-372.

Task Force on Central Auditory Processing Consensus Development. (1996). Central auditory processing: Current status of research and implications for clinical practice. *American Journal of Audiology*, *5*(2), 41-52.

Vaidyanath, R., & Yathiraj, A.(2012). *Speech -in-Noise test in Kannada.* Material Developed at Department of Audiology, All India Institute of Speech and Hearing, Mysuru.

Vanniasegaram, I., Cohen, M., & Rosen, S. (2004). Evaluation of selected auditory tests in school-age children suspected of auditory processing disorders. *Ear and Hearing*, *25*(6), 586-597.

Yeend, I., Beach, E. F., & Sharma, M. (2019). Working memory and extended high-frequency hearing in adults: Diagnostic predictors of speech-in-noise perception. *Earand hearing*, *40*(3), 458-467.

Yathiraj, A., & Vijayalakshmi, C. S. (2005). *Phonemically balanced word identification test in Kannada.* Department of Audiology, All India Institute of speech and hearing Mysore.

Yathiraj, A., & Mascarenhas, K. (2002). *The Screening Checklist for Auditory Processing (SCAP*). Developed at Department of Audiology, All India Institute of Speech and Hearing, Mysuru.