PROJECT REPORT

Relationship between Auditory abilities and Iron DeficiencyAnemia in Adolescent girls

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Abstract

Iron deficiency anemia (IDA) is the most common nutritional disorder seen all over the world, more so in developing countries. IDA is reported to be a risk factor for developing hearing loss. However, the hearing and auditory processing related difficulties experienced by individuals with IDA are yet to be well established, especially in India, where the prevalence of IDA is 60 to 70 percent in adolescent girls. The present study was hence planned to evaluate the central auditory processing abilities in Indian adolescent girls with IDA. The participants consisted of 75 adolescent girls with IDA, 50 adolescent girls without IDA, and 50 adolescent boys without IDA. Participants underwent a battery of central auditory processing evaluations to evaluate all the major auditory processes along with the peripheral hearing assessment. In the present study, auditory closure abilities were assessed using speech perception in noise tests and quick speech perception in noise tests in Kannada; binaural integration was evaluated using a dichotic CV test. Temporal processing was assessed using a gap detection test (GDT), and the auditory working memory was assessed using auditory digit sequencing and auditory digit span. Results showed that the hearing thresholds at extremely low and high frequencies (250 Hz and 8000 Hz), though within clinically normal limits, were poorer in girls with IDA in comparison to the control groups. Also, girls with IDA performed poorly in GDT and backward span tests, as revealed through the Kruskal-Wallis test and Mann Whitney U test. It was also observed that the percentage of girls with IDA having peripheral and central auditory abilities weaker than the control non-IDA girls ranged from 0% to 60%, with more deficits seen in central auditory abilities. These subtle auditory deficiencies, as observed in the current study, may be attributed to the compromised blood supply to the central auditory nervous system.

Chapter 1

Introduction

Iron deficiency anemia (IDA) is the most common nutritional disorder seen all over the world, more so in the developing countries, particularly affecting young children of 6–24 months of age, adolescents, women of reproductive age group, and pregnant/ lactating women (Lokeshwar, Mehta, Mehta, Shelke & Babar, 2011). India has the world's highest prevalence of IDA among women, with 60 to 70 percent of the adolescent girls being anemic. Adolescence is considered as a nutritionally critical period of life. World Health Organization (WHO) lists iron deficiency (ID) as one of the"Top Ten Risk Factors contributing to Death." (Dubey, 2006).In the year 2002, IDA was among the most important causative factors for the global burden of disease (WHO, 2002).

1.1 IDA definition

Anemia is a condition in which the number of red blood cells (RBCs) and subsequently, their capacity to carry oxygen is inadequate to meet the body's physiologic needs. These specific physiologic needs are different and depend upon a person's age, gender, an altitude of residence, smoking behavior, and different phases of pregnancy. The most common cause of anemia globally is ID, with additional causes being deficiencies folate, vitamin B12, and vitamin A. The conditions including acute and chronic inflammation, parasitic infections, and inherited or acquired disorders that affect hemoglobin synthesis and red blood cell production can all cause anemia (WHO, 2011).

The diagnostic criterion for anemia is low hemoglobin levels according to the normative based on age and gender. The WHO (2011) classification of anemia is as follows,

- **Children 5-11 years of age:** Mild = 11.0-11.4g/dl; Moderate = 8.0-10.9g/dl; Severe= below 8.0g/dl.
- **Children 12-14 years of age:** Mild = 11.0-11.9g/dl; Moderate = 8.0-10.9g/dl; Severe= below 8.0g/dl.
- **Females >15 years:** Mild = 11.0-11.9g/dl; Moderate = 8.0-10.9g/dl; Severe = below 8.0g/dl.
- **Males >15 years:** Mild = 11.0-12.9g/dl; Moderate = 8.0-10.9g/dl; Severe = below 8.0g/dl.

IDA includes decrement in both hemoglobin levels and serum ferritin levels. The relative extent of iron stores based on serum ferritin concentration given by WHO (2001) is as follows,

- **Depleted iron stores for children less than 5 years of age:** Male = <12µg/L; Female = <12µg/L.
- **Depleted iron stores for individuals more than 5 years of age:** Male = <15µg/L; Female = <15µg/L.
- **Depleted iron stores in the presence of any infection for children less than 5 years of age:** Male = <30µg/L; Female = <30µg/L.
- **Severe risk of iron overload for adults:** Adult male = >200µg/L; Adult female = >150µg/L.

1.2 Incidence and Prevalence of IDA

A multi-centric study by the Indian Council of Medical Research (ICMR) showed that over 90% of adolescent girls throughout the country had some kind of anemia (Toteja & Singh, 2002). These findings were corroborated by district level household survey (DLHS-RCH) in 2002-2003, showing that only 5% of adolescent girls did not have any kind of anemia, and a large proportion was suffering from severe anemia.

There are many studies done in different parts of the world regarding the prevalence of IDA in various populations. The prevalence of IDA in the United States is estimated to be 2%–3% for toddlers up to age three years and increasing to 5% for adolescent girls with significant variation by sex, socioeconomic status, body mass index, and race (Brotanek, Gosz, Weitzman &Flores, 2007, 2008; Looker, Dallman, Carroll, Gunter, &Johnson, 1997; Pfeiffer et al., 2013).

WHO (2001) reported the prevalence and epidemiology of ID in terms of age and gender in industrialized and non-industrialized countries. The report showed higher prevalence in the industrialized countries in all women of age range 15 to 59 years (10.3%), the elderly population of >60 years(12.0%), children from birth to 4 years (20.1%) with the highest prevalence for pregnant women (22.7%). The least prevalence was observed for children in the age range 5 to 14 years (5.9%) and in men (4.3%). In the non-industrialized countries, the prevalence of IDA was higher in all age groups and gender groups in comparison to industrialized countries. The prevalence was highest in pregnant women (52%) followed by children of the age group 5 to 14 years (48.1%), the elderly group of >60 years (45.2%), all women in the age group of 15 to 59 years (42.3%), children in the age group of birth to 4 years (39%) and men (30%). The report accounts for the higher prevalence of ID and anemia in adolescent girls due to menarche; adolescent females usually don't consume sufficient iron to counterbalance menstrual losses. Hence at this age, females generally experience a peak in the prevalence of ID.

In the same study, the estimated prevalence of anemia in different WHO regions were listed. South-east Asian region had the highest prevalence of anemia in comparison to all other regions, and women in the age group of 15 to 59 years showed the highest prevalence of anemia followed by children in the age group of 5 to 14 years. This prevalence study report also indicates a higher prevalence in adolescent and adult age groups among women.

Thane, Bates, and Prentice (2002) assessed the risk factors for low iron intake on a national sample of British people in the age range 4 to 18 years. Low Hb concentration was observed in around 9% of the children age 4 to 6 years, pubertal boys of 11 to 14 years, and older girls of 15 to 18 years. Also, non-caucasian or vegetarian adolescent girls had poorer iron status than Caucasian girls or meat-eaters.

In a study done in one district in Kenya, the prevalence of anemia was 21.1% in adolescent girls (Leenstra et al., 2004). Out of the total anemic patients, 30.4% were anemic because of iron deficiency. In the younger girls, Schistosomiasis and malaria were the leading causes for the IDA, and for older girls, the main reason for IDA was heavy menstrual blood loss. In the same study, a negative correlation was seen between Hb level and time since menarche, which shows that in menstruating girls, ID may progressively increase over time. These findings indicate that in several older girls, the dietary intake of iron is not sufficient to cope with the demands of sexual maturity.

Grondinet al. (2008) studied the prevalence of ID and its effects on the quality of life among female students in Clermont-Ferrand city of France. The serum ferritin level was considered for the diagnosis of ID. The prevalence of ID was 19.3%, and the prevalence of borderline iron status was 11.4%. The quality of life in persons with ID was also affected because of changes in general health. The prevalence of IDA in France was estimated to be about 2.0% in menstruating women and 10.0% in pregnant women (Dhur&Hercberg, 1989; Soustre, Dop, Galan, & Hercberg,1986).

Akramipour, Rezaei,and Rahimi (2008)established the prevalence of IDA among adolescent school girls from a city in Western Iran. The prevalence of anemia (which was estimated using Hb count) was found to be 21.4%, and ID estimated using ferritin level was found to be 2.7%. IDA estimated using Hb count as well as ferritin constituted about 12.2%. Around 57.3% of all anemic girls were iron deficient, according to the study.

In a study done in Turkey byBalcı, Karabulut, Gürses, andÇövüt (2012), the prevalence of anemia in adolescent girls and adolescent boys were 8.3% and 1.6%, respectively. This difference was attributed to pubertal boys having a physiological rise in hemoglobin concentration caused by sexual maturation as well as by a decrease in iron requirements after completion of the growth spurt. In girls, however, the occurrence of menarche and menstrual irregularities terminate the age related increase in hemoglobin concentration. A summary table wherein the prevalence of iron deficiency anemia across different countries is provided in Table 1.1 below.

Table 1.1 Summary table for the prevalence of IDA across different countries

Countries	Studies	Study group	Age range (years)	N	Prevalence (%)
United States	Looker, Dallman, Carroll, Gunter,& Johnson(1997)	Adolescent girls	>1	24894	5%
Britain	Thane, Bates & Prentice (2002)	Children, Adolescent boys, and adolescent girls	4 – 18	1193	9% in children 4 - 6 years; 11 – 14 years adolescent boys; 15 – 18 years adolescent girls
Kenya	Leenstra et al. (2004)	Adolescent girls	12 – 18	648	30.4%
United States	Brotanek, Gosz, Weitzman & Flores(2007, 2008)	Toddlers	1 – 3	7717	2 to 3%
France (Clermont-Ferrand)	Grondin et al (2008)	Adolescent girls and adult women	17 – 38	543	19.3%
Western Iran (Kermanshah)	Akramipour, Rezaei & Rahimi (2008)	Adolescent girls; adult females	14 – 20	384	12.2%
Turkey	Balcı, Karabulut, Gürses, &Çövüt (2012)	Adolescent girls and adolescent boys	12 – 16	1120	8.3% and 1.6%

Various authors have also reported the prevalence of anemia in the Indian population. In India, the prevalence of anemia among adolescent girls was reported to be56%, and this amounts to an average of 64 million girls at any point in time (Aguayo, Paintal, & Singh, 2013). The prevalence of anemia has been reported in different regions of India. The prevalence of anemia in adolescent girls was 52.5% in Belkhera PHC, Madhya Pradesh (Raj & Chopra, 2016), 37% in adolescent boys belonging to Vallab Vidyanagar municipality of the state of Gujarat (Aishwarya, Parita Gajjar, Raykundaliya, Patel, & Neeta, 2015), 41.1% in adolescent girls tested in Belgaum district of Karnataka (Biradar, Biradar, Alatagi, Wantamutte & Malur, 2012), 21.5% in Shimla (Gupta, Parashar, Sharma & Thakur, 2012). The prevalence of IDA was reported to be 56.3% in adolescent girls tested in Lucknow district of Uttar Pradesh (Sachan, Idris & Singh, 2013), 77.33% in adolescent girls in Guntur city of Andhra Pradesh (Koushik, Bollu, Ramarao, Nirojini & Nadendla, 2014), 58.4% among adolescent girls in Chidambaram town of Tamilnadu (Devi, Jaysree, Felix & Ethirajan, 2014) and in Kerala it was reported to be 19.13% among female college students in Kottayam city of Kerala state (Manjula, Parameshwari, Pothen & Sobha, 2014) and 96.5% among women in the tribal area of Wayanad in Kerala (Shrinivasa, Philip, Krishnapali, Suraj, &Sreelakshmi, 2014). The prevalence of anemia was reported to be 21% in adolescent girls in Kerala (Siva, Sobha & Manjula, 2016). It was also noted that the prevalence of anemia was higher among individuals having higher socioeconomic status. The higher prevalence of anemia was attributed to the poor dietary pattern with more snacks and junk foods, which lack micro-nutrients among the higher socioeconomic group.

In another Indian study done in a rural village of Gujarat, India, the prevalence of nutritional anemia was 59.8%. The study also aimed at estimating the factors contributing to the prevalence of anemia. The factors that were significantly associated with anemia included low socioeconomic status, low iron intake, vegetarian diet, history of worm invasion, and history of extreme menstrual bleeding. However, in the study, they didn't find any significant association of age, education, Body Mass Index (BMI), and status of menarche with nutritional anemia (Kaur, Deshmukh & Garg, 2006).

Another Indian study by Vasanthi, Fawashe, Susie, Sujatha, and Raman (1993) assessed the iron nutritional status of adolescent girls from rural areas and urban slums in India. The overall anemia, irrespective of the residence in girls, was observed to be 25%. Higher prevalence was observed in rural girls below the age of 12 years (37.5%), and after that, the prevalence till the menarche age was similar in urban and rural areas. With increasing age, urban girls who had attained menarche showed an increase in the prevalence of anemia even though the overall iron deficiency was much higher in rural girls irrespective of menarcheal status. Table 1.2 summarizes the prevalence of IDA in the different regions within India.

Table 1.2 Summary table for the prevalence of IDA across different regions within India

Regions	**Studies**	**Study group**	**Age range (years)**	**N**	**Prevalence (%)**
Hyderabad (Urban and rural slums)	Vasanthi, Fawashe, Susie, Sujatha & Raman (1993)	Adolescent girls	11 – 16	551	25%
Gujurat (Wardha)	Kaur, Deshmukh & Garg(2006)	Adolescent girls	13 – 19	630	59.8%
Shimla	Gupta, Parashar, Sharma & Thakur, (2012)	Adolescent girls	10 – 19	1596	21.5%
Lucknow	Sachan, Idris & Singh (2013)	Adolescent girls	10 – 19	847	56.3%
Andra Pradesh (Guntur)	Koushik, Bollu, Ramarao, Nirojini&Nadendla (2014)	Adolescent girls	10 – 19	150	77.33%
Tamil Nadu (Chidambaram)	Devi, Jaysree, Felix &Ethirajan, 2014	Adolescent girls	10 – 15	500	58.5%
Kerala (Kottayam)	Manjula, Parameshwari, Pothen&Sobha (2014)	Adolescent girls; adult females	17 - 20	183	19.13%
Kerala (Wayanad)	Shrinivasa, Philip, Krishnapali, Suraj, &Sreelakshmi, (2014)	Adolescent girls; adult females	15 – 45 years	347	96.5%
Gujarat (VallabVidhyanagar municipality)	Aishwarya, ParitaGajjar, Raykundaliya, Patel, & Neeta (2015)	Adolescent boys	13 – 19 years	500	37%
Kerala (Central)	Siva, Sobha& Manjula (2016)	Adolescent girls	10 – 19 years	257	21%
Madhya Pradesh (Belkhera PHC)	Raj & Chopra (2016)	Adolescent girls	10 – 19 years	200	52.5%

Thus, many international studies and Indian studies reported the prevalence of IDA. Still, its effect on the body mechanisms like the hearing or hearing structures has not been studied. Hence, further research is needed to explore the consequences of anemia and its treatment.

1.3 IDA and auditory abilities

ID causes the organs in the body to receive less of iron and reduce the normal functioning. In IDA, there is depletion of iron stores to a greater extent, and thus the blood supply to the ear structures may be compromised. Studies have been done in the past to examine the effect of anemia on auditory abilities.

Roncagliolo, Garrido, Walter, Peirano, and Lozoff (1998) studied the evidence of altered central nervous system development in infants with IDA at six months of age. Myelination of nerve fibers and maturation of synaptic relays lead to an exponential reduction in the central conduction time (CCT) from birth to 24 months. CCT in ABR was assessed using the peak I to peak V inter-peak latency, and this measure was considered as the index of CNS development. The study included 55 infants (29 infants with IDA and 26 healthy infants), and ABR was recorded on them. CCT was longer for the IDA group, and differences were more pronounced at 12 months and 18 months, even with iron therapy. Results showed that the difference was evident for latency measures and not on amplitude measures. Also, more effects were noted on later ABR components (i.e., peak III & peak V). Similar results were reported in an Indian study by Shankar, Tandon, Bandhu, Madan,and Gombe (2000), where a linear correlation between the severity of anemia and the degree of neurophysiological deficits was observed, indicating subclinical involvement of auditory pathway in the brainstem of iron-deficient children.

Iron is essential for normal myelination, and the pathway transmission might be affected in early ID (Algarin, Peirano, Garrido, Pizarro &Lozoff, 2003). Algarin et al. (2003) studied the effects of IDA during infancy and its long-lasting consequences on auditory and visual system functioning. A comparison was made among IDA infants with their non-IDA counterparts through auditory brainstem response (ABR). IDA infants had slower transmission through the auditory brainstem, which was linked to the lesser iron stores. The same set of infants were tested at four years of age, and the absolute latency and inter-peak latencies were found to be longer with the amplitude of the ABR peaks being unaffected. Hence, it was concluded in the study that the effects IDA on the transmissions could be long-lasting, as evident from ABR latency measures.

Chung, Chen, Lin, and Hung (2014) studied the relationship of IDA with sudden sensorineural hearing loss (SNHL) among adults in a large case-control study in Taiwan. It was hypothesized that the inner ear blood supply, which is highly susceptible to ischemic damage, was further compromised by IDA, leading to sudden SNHL. The role of iron in both the vasculature and nervous system raises the possibility of its relationship with common types of pediatric hearing loss. Schieffer, Chuang, Connor, Pawelczyk, and Sekhar (2016) assessed a link between anemia and hearing loss in a retrospective study on 305,339 adults between the ages of 21 and 90 years. Results showed that anemic individuals were twice as likely to develop SNHL and mixed hearing loss than those without anemia. In a study by Park, Yoo, Woo, Kim, and Cho (2017), the prevalence of hearing loss and associated factors in subjects with normal otoscopy was studied, and they reported that anemia was one of the associated factors for hearing loss

In another study, Schieffer, Connor, Pawelczyk, and Sekhar (2017), assessed a correlation between IDA and sudden SNHL in the children (4-21 years) using a retrospective cohort study. Results showed that the prevalence of all hearing loss was 3.0% in the IDA cohort and 1.7% in those without IDA. Children and adolescents with IDA are at increased risk of developing SNHL. They concluded that children with IDA demonstrate an increased likelihood of SNHL.

IDA significantly impairs mental and psychomotor development leading to developmental delay and behavioral disturbances. IDA impairs intellectual development and learning ability by adversely affecting concentration, attention span, language, cognitive and motor skill and development, and educational attainment (Dubey, 2006). IDA can delay the pattern of responses in a discrimination task of highly familiar stimulus from an unfamiliar stimulus. This may be because of alterations in the efficiency of the Central Nervous System (CNS) functions in children with IDA (Burden et al., 2007). IDA leads to headache, impaired auditory and visual evoked potential. Children treated for IDA during infancy, when re-evaluated at 11–14 years of age, demonstrated functional impairment in school. They were more likely to have repeated a grade, to have reduced arithmetic achievement and written expression, differences in motor function, spatial memory, and selected recall (Satyanarayan, Pradhan, Ramanath & Rao, 1990; Lozoff, Jimenez & Wolf, 1991; Sachdev, Ger & Nestel, 2004).

In a study by Lozoff and Georgieff (2006), cognitive motor, social, emotional, and neurophysiologic development was assessed on infants with IDA. The IDA infants were found to score lower in all these domains, and also with iron therapy, there was no improved developmental outcome. However, with supplementation, adverse effects can be prevented or reversed in earlier development or before iron deficiency becomes severe or chronic. Beard (2003) also supported this fact and stated that because of the changes in the chemistry of neurotransmitters, organization, and morphology of the neuronal networks of myelination, it has irreversible effects on IDA. The study also indicated that dopamine receptors and transporters are altered, as are the behaviors related to this neurotransmitter.

1.4 Need of the Study

There are many studies done on the prevalence of IDA in the Indian population. However, there is minimal research done on the association of IDA and hearing loss. Although the prevalence of IDA is reported to be high in Indian states, especially in adolescent girls, the possible peripheral and central auditory difficulties in adolescent girls with IDA are not well understood. Studies that have been done in the past have shown an association between anemia and peripheral hearing loss. The effect of IDA on central auditory processing is not studied till date. The outcome of the current study would likely shift the focus of health care professionals and administrators to this health issue, which is very common in the public though not considered critically. Hence, this study aims to establish a relationship, if any, in the peripheral hearing and central auditory processing abilities in adolescent girls having IDA.

1.5 Aim of the Study

The study aimed to find the relationship between IDA and peripheral and central auditory abilities in adolescent girls

1.6 Objectives of the Study

1. To assess and compare the auditory abilities (peripheral and central) of adolescent girls with IDA with adolescent girls and boys without IDA.
2. To assess the relationship between auditory abilities and IDA in adolescent girls.

3. To estimate the percentage of adolescent girls with IDA having hearing abilities and central auditory processing abilities poorer than control groups

Chapter 2

Methods

The aim of the present study was to assess the relationship between iron deficiency anemia (IDA) and peripheral and central auditory abilities in adolescent girls.

2.1 Research Design

The research design utilized for this study was quasi-experimental. In this cross-sectional study, the quasi-independent variable was the presence or absence of IDA, and the dependent variables were the audiological test results.

2.1 Participants

A total of 175 adolescents in the age range of 10-19 years were selected for the study (WHO defines 'Adolescents' as individuals in the 10-19 years age group). The participants were divided into three groups. Group I included seventy five adolescent girls diagnosed with IDA. Group II and group III included fifty adolescent girls without IDA and fifty typically developing adolescent boys without IDA. Purposive convenient sampling was used for the inclusion of participants for the study. Ethical guidelines recommended by AIISH bio-behavioral research involving human subjects were followed (Venkatesan, 2009). The inclusion and exclusion criteria for the selection of participants are given below.

2.1.1 Inclusion criteria.

The inclusion criteria for the participants of the group I were as follows:

- All the participants were diagnosed to have IDA. IDA was identified by low hemoglobin according to the age and gender of the participant with at least one event consistent with low MCV, low MCH, increased RDW, and peripheral smear suggestive of microcytic hypochromic anemia.
    - ✓ **Children 5-11 years of age:** mild = 11.0-11.4g/dl; moderate = 8.0-10.9g/dl; severe= below 8.0g/dl.
    - ✓ **Children 12-14 years of age:** mild = 11.0-11.9g/dl; moderate = 8.0-10.9g/dl; severe= below 8.0g/dl.
    - ✓ **Females >15 years:** mild = 11.0-11.9g/dl; moderate = 8.0-10.9g/dl; severe = below 8.0g/dl.
    - ✓ **Males** > **15 years:** 11.0-12.9g/dl; moderate = 8.0-10.9g/dl; severe = below 8.0g/dl.
- None of the participants reported ill health during the testing.
- All the participants were native speakers of Kannada language from the city of Mysuru and Suttur.
- The participants didn't have any history or current condition of middle ear pathology.
- The participants with history of any retrocochlear pathology, cognitive impairment, or neurological complaints were excluded from the study.

The inclusion criteria for group II and group III included the following,

- All the participants had normal hemoglobin according to the age and gender of the participant, indicating that none of them had anemia.
- All the participants had bilateral normal hearing sensitivity, i.e., a pure tone average of less than 15 dBHL for air conduction thresholds for octave frequencies from 250 Hz to 8000 Hz and bone conduction thresholds from 250 Hz to 4000 Hz (Clarke, 1981).
- All the participants had a speech recognition threshold of +\-12 dB relative to their pure tone thresholds and normal middle ear functioning.
- An informal interview was carried out to obtain additional information about the developmental history of the participant. Participants with a history of delayed development, sensory issues, behavioral or neurological problems were excluded from the study.

Written informed consent was taken from the participants/guardians of all the participants. The informal interview was carried out before starting the actual test.

2.2 Material

1. For speech recognition testing (SRT), spondee word lists in Kannada developed by Rajashekar (1976) was used.

2. A phonemically balanced (PB) word list in Kannada (Yathiraj & Vijayalakshmi, 2005) was used for speech identification scores (SIS). There are four lists with 25 bisyllabic words in each list.

3. Phonemically balanced word lists for adults in Kannada (Manjula, Antony, Kumar, & Geetha, 2015) were used at 0 dB SNR for speech in noise (SPIN) assessment. Two lists out of the 21 lists were utilized, with each list consisting of 25 words.
4. Quick speech perception in noise test in Kannada developed by Avinash, Meti, and Kumar (2010) was used to calculate SNR 50. There are seven lists with each list containing seven sentences presented in the presence of eight talker babble.
5. The dichotic CV test developed by Yathiraj (1999) in the Department of Audiology, AIISH, was utilized for assessing binaural integration. The list with 0 ms lag was used for the testing.

2.3 Equipment

1. A calibrated diagnostic dual-channel audiometer (Interacoustics AD 629)with HDA 200 circumaural headphones and B-71 bone vibrator was used for air conduction and bone conduction testing.
2. Interacoustics AT235 middle ear analyzer was used to check the middle ear status.
3. A laptop installed with MATLAB software version 7.10 (Mathworks Inc., 2014) and Maximum Likelihood Procedure (MLP) for carrying out Gap Detection Test (GDT) was used. The same laptop was installed with Smriti-Shravan software version 1.10 (Kumar & Sandeep, 2013) for carrying out working memory tasks.
4. A right-left splitter-adaptor was used to present dichotic CV stimuli to both the ears.

2.4 Procedure

An informal case history was taken from all the participants before enrolling them for the study. Information about hearing loss, tinnitus, and any other otological complaints was recorded. Participants from all the groups were assessed for peripheral and central auditory skills.

2.4.1. Assessment of peripheral auditory skills. The peripheral auditory abilities were tested using pure tone audiometry, speech audiometry, and immittance evaluation.

Pure-tone audiometry. A calibrated double channel diagnostic audiometer was used to carry out thetesting. The audiometric hearing thresholds were measured for the octave frequencies from 250 Hz to 8000 Hz for air-conduction, and from 250 to 4000 Hz for bone-conduction using the modified Hughson-Westlake procedure (Carhart & Jerger, 1959). Initially, at supra-threshold levels, 5 dB step size was used was and atthe near threshold, 2 dB step size was used to estimatethreshold. The pure-tone average (PTA) was calculated as the average thresholds of four octave frequencies, i.e., 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz.

Speech audiometry. SRT and SIS were assessed in speech audiometry. The SRT was done using spondee words in Kannada developed by Rajashekhar (1976). The SRT was established by using a starting presentation level of 20 dB SL (ref: PTA) (Tillman & Olsen, 1973). The instruction given to the participant was to repeat the spondees as he/she could. The lowest intensity level at which the participant correctly repeated at least 50% of the spondees was consideredas the SRT. The SIS was obtained at 40 dB SL (ref: SRT) using the PB word list in Kannada (Yathiraj& Vijayalakshmi, 2005). The participant was instructed to repeat the words that he/she heard. The words were presented at a constant level through a monitored live voice. The total number of words correctly repeated by the participant was noted downand converted into a percentage.Each correct response was given a score of 4%. SRT and SIS wereassessed for the right and left ear of the participants separately.

Immittance evaluation. The tympanogram and acoustic reflexes were measured to rule out middle ear pathology. During the measurement, participants were instructed to sit comfortably, not to swallow and move the head, jaw, and also not to talk. A 226Hz probe tone was used to measure admittance, and the type of tympanogram was noted down. The ipsilateral and contralateral acoustic reflex was also measuredfor 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz stimuli.

2.4.2 Assessment of central auditory processing skills. The participants were evaluated for all the major auditory processes to assess central auditory processing viz. auditory closure, binaural integration, temporal processing, and working memory.

Test to assess auditory closure. SPIN in Kannada and quick speech perception in noise test in Kannada(Avinash, Meti& Kumar,2010) wasused to assess auditory closure abilities. In the SPIN task, words were presented in the presence of speech noise. Phonemically balanced word lists developed by Manjula et al. (2015) were used. In the present study, two lists (lists 1 & 2) out of the 21 noise lists were taken, and the words were mixed with speech noise at 0 dB SNRusing MATLAB software.The participants were instructed to repeat the words by ignoring the noise. The total number of words correctly repeated by the participant was noted down and converted into a percentage.

Quick speech perception in noise test in Kannada (Avinash, Meti & Kumar, 2010) was also used to assess auditory closure. There are 7 lists with each list containing 7 sentences of increasing levels of difficulty, i.e., the SNR starts from +20 dB for the first sentence and reduces in 5 dB steps with SNR being -10 dB for the last sentence. For the present study, list 1 and 2 was used. The sentences were given along with eight talker babble, and the participants were instructed to ignore the babble and repeat the sentence heard. The participant was encouraged to repeat how many ever words he/she hears. The total number of words correctly repeated was noted down, and SNR 50 was calculated using the Spearman-Karber equation (Finney, 1952) as follows,

$$\textbf{SNR-50} = \mathbf{i} + \tfrac{1}{2}\,\mathbf{(d)} - \mathbf{(d)}\,\mathbf{(\#correct)} / \mathbf{w}$$

Where,

i = the initial presentation level

d = the attenuation step size

w = number of keywords per decrement

#correct = total number of correct keywords

Test to assess binaural integration. The dichotic CV test (Yathiraj, 1999) was used to assess the binaural integration. Stimuli consistedof six syllables /pa/, /ta/,/ka/,/ba/,/da/ and/ga/ which werepresented five times randomly to make it a total of 30 presentations. The syllables are presented simultaneously to both ears. There area total of five lists with 0 ms, 30ms, and 90 ms lag either in the right or left ear track. Only 0 ms lag list was utilized for the present experiment. The stimuli were presented through a calibrated laptop connected to HDA 200 headphones. The headphones were connected to a laptop through a splitter-adaptor. This setup was used for presenting two different syllables to the two ears simultaneously. The participants were instructed to listen to the two syllables presented simultaneously and write down the syllables heard from both the ears. The scoring involved assessing for single correct scores and double correct scores.

Test to assess temporal processing. GDT was used to assess the temporal processing ability. The participant's ability to detect a temporal gap in the center of 500 ms broadband noise was measured (Harris, Eckert, Ahlstrom, & Dubno, 2010). The noise with 0.5 ms cosine ramps at the beginning and the end of the gap was used for the estimation of the GDT. In a three-block alternate forced-choice task, the standard stimulus was always a 500 ms broadband noise with no gap, whereas the variable stimulus contained the gap. GDT was done using MLP employed in MATLAB software. The participants were instructed to tell which among the three stimuli had the gap. GDT was measured for each ear separately.

Tests to assess Working Memory. The auditory working memory of the individuals was assessed using auditory digit sequencing and auditory digit span through Smriti-Shravan software version 1.10 (Kumar & Sandeep, 2013). In auditory digit span, forward and backward digit span tasks were done, and in auditory digit sequencing, ascending and descending digit tasks were done. In this software, stimuli consisted of digits from one to nine. The numbers were presented in random order with an increasing level of difficulty with the minimum number of digits being two and an interstimulus interval of 250 ms.

In the forward digit span test, the participants were presented with clusters of numbers, and they were asked to repeat the numbers in the same order. In the backward span test, they were asked to repeat the digits in the reverse order. In ascending digit sequencing tasks, participants were presented with cluster of numbers, and they were asked to arrange them in ascending order. In descending task, they were asked to arrange the numbers in descending order and then repeat them.All the tests were done using one up one down procedure i.e., with every correct response, the number of digits presented increased by one digit, and with every incorrect response, the number of digits presented decreased by one digit. The participants were given examples before the actual testing. Auditory working memory capacity was calculated as the total number of digits that the participants can recall in sequencing and digit span.

2.5 Statistical Analyses

The data of the present study were subjected to statistical analyses using the Statistical Package for the Social Sciences (Version 20). Descriptive statistics were done to assess the mean and standard deviation (SD) of all the parameters on the three groups of participants. The data obtained were subjected to Shapiro-Wilk's test for normality. The results revealed a non-normal distribution of data ($p<0.05$), and therefore non-parametric tests were administered. A Kruskal Wallis test was done to compare the scores obtained on various tests among the three groups of participants. Further, Spearman's correlation analysis was carried out to examine the relationship between auditory abilities and IDA in adolescent girls.

Chapter 3

Results

The present study focused on the relationship between Iron deficiency anemia (IDA) and central auditory processing abilities in adolescent girls. The data was collected on three groups of participants. Group I included adolescent girls having IDA and Group II and group III included adolescent girls and boys without IDA, respectively. Table 3.1 shows the number of participants and the mean age of the participants in each group. The Table 3.1 also gives the details of mild, moderate and severe anemic participants in Group 1.

Table 3.1. ***The number of participants and the mean age of the participants in each group.***

Groups		Number of participants	Mean Age (Years)
I	Mild anemia	28	13.47
	Moderate anemia	34	13.52
	Severe anemia	13	13.12
	Total	75	13.44
II		50	13.04
III		50	13.29

3.1 Comparison of auditory abilities across groups

Comparison of peripheral hearing abilities across groups

The peripheral hearing was assessed using pure tone audiometry,including air conduction (AC) pure tone thresholds for right and left ears at each octave from 250 Hz to 8000 Hz, bone conduction (BC) thresholds from 250 Hz to 4000 Hz. Speech recognition thresholds (SRT) and speech identification scores (SIS) for right and left ears were also assessed. The mean, standard deviation (SD), median, and range for AC and BC at different frequencies and SRT and SIS for right and left ears are given for all the three groups in Table 3.2. It can be noted that the mean thresholds are higher for group 1 compared to group 2 and 3 for all the frequencies.

Table 3.2 Mean, SD, median and range for peripheral hearing parameters of all the three groups

Tests	Frequencies	Groups	Mean	SD	Median	Range
AC R (dB)	250 Hz	Group 1	11.44	2.844	10	4 to 20
		Group 2	10.20	2.5563	10	0 to 15
		Group 3	9.80	.251	10	4 to 20
	500 Hz	Group 1	10.15	2.902	10	-3 to 15
		Group 2	9.56	2.111	10	-2 to 15
		Group 3	9.32	3.054	10	5 to 15
	1000 Hz	Group 1	9.83	2.782	10	0 to 30
		Group 2	8.98	2.6462	10	0 to 15
		Group 3	9.98	.114	10	2 to 15
	2000 Hz	Group 1	9.33	2.107	10	0 to 40
		Group 2	8.62	3.070	10	-2 to 15
		Group 3	8.92	2.776	10	0 to 15
	4000 Hz	Group 1	8.59	3.499	10	0 to 20
		Group 2	7.96	3.790	10	-2 to 20
		Group 3	8.40	4.101	10	0 to 20
	8000 Hz	Group 1	7.19	6.364	5	0 to 55
		Group 2	4.82	4.758	5	-8 to 15
		Group 3	3.20	4.686	5	-6 to 15
AC L (dB)	250 Hz	Group 1	11.60	3.111	10	5 to 25
		Group 2	10.18	2.405	10	0 to 15
		Group 3	9.42	2.807	10	4 to 15
	500 Hz	Group 1	10.28	3.266	10	0 to 19
		Group 2	9.58	2.540	10	-6 to 10
		Group 3	8.94	2.910	10	-6 to 19
	1000 Hz	Group 1	10.08	3.199	10	0 to 30
		Group 2	9.74	2.648	10	0 to 15
		Group 3	9.92	2.538	10	2 to 15
	2000 Hz	Group 1	9.44	3.032	10	4 to 50
		Group 2	9.40	2.619	10	-2 to 14
		Group 3	8.68	3.047	10	0 to 18
	4000 Hz	Group 1	8.80	4.178	10	0 to 55
		Group 2	8.26	2.609	10	-8 to 20

		Group 3	8.30	4.107	10	4 to 14
	8000 Hz	Group 1	5.32	5.903	5	0 to 60
		Group 2	3.46	4.376	5	-8 to 20
		Group 3	3.16	5.246	5	0 to 15
BC (dB)	250 Hz	Group 1	9.48	1.727	10	0 to 15
		Group 2	9.00	2.474	10	0 to 10
		Group 3	8.28	3.665	10	0 to 15
	500 Hz	Group 1	9.12	2.405	10	-5 to 15
		Group 2	9.00	2.474	10	-6 to 10
		Group 3	8.28	3.665	10	0 to 15
	1000 Hz	Group 1	8.93	2.418	10	0 to 15
		Group 2	8.40	3.264	10	0 to 10
		Group 3	9.10	2.410	10	0 to 15
	2000 Hz	Group 1	8.25	2.553	10	0 to 20
		Group 2	8.10	3.334	10	-5 to 10
		Group 3	7.80	3.665	10	0 to 15
	4000 Hz	Group 1	7.00	3.487	5	0 to 30
		Group 2	6.60	3.264	5	-10 to 15
		Group 3	6.80	4.712	5	0 to 10
SRT R (dB)		Group 1	11.04	2.528	10	7 to 20
		Group 2	10.18	1.395	10	5 to 15
		Group 3	10.22	1.682	10	6 to 16
SRT L (dB)		Group 1	11.27	2.479	10	10 to 20
		Group 2	10.28	1.552	10	5 to 15
		Group 3	10.22	1.682	10	6 to 16
SIS R (%)		Group 1	98.77	1.857	100	96 to 100
		Group 2	99.04	1.726	100	96 to 100
		Group 3	98.48	1.961	100	96 to 100
SIS L (%)		Group 1	98.13	2.401	100	92 to 100
		Group 2	98.08	2.174	100	92 to 100
		Group 3	97.68	2.436	100	92 to 100

Further, the Kruskal-Wallis test was done to assess the significant difference in thresholds across groups. Table 3.3 depicts the results of the Kruskal-Wallis test for AC, BC, and speech thresholds. Pair-wise comparison across groups wasmade using the Mann Whitney U test. Results showed that group 1 performed significantly poorer than groups 2 and 3 for the AC thresholds at 250 Hz and 8000 Hz of right ear, BC thresholds at 250 Hz, and SRT of the left ear.

Table 3.3. Kruskal Wallis test results to compare threshold across groups

Tests	Frequencies	χ2(2)	P
AC R (dB)	250 Hz	9.001	**.011**
	500 Hz	2.49	.287
	1000 Hz	4.719	.094
	2000 Hz	1.833	.400
	4000 Hz	1.096	.578
	8000 Hz	14.046	**.001**
AC L (dB)	250 Hz	16.333	**.000**
	500 Hz	6.357	**.042**
	1000 Hz	.486	.784
	2000 Hz	.897	.639
	4000 Hz	.395	.821
	8000 Hz	4.833	.089
BC (dB)	250 Hz	6.482	**.039**
	500 Hz	1.547	.461
	1000 Hz	1.628	.443
	2000 Hz	.050	.975
	4000 Hz	.814	.666
SRT R (dB)		5.663	.059
SRT L (dB)		9.890	**.007**
SIS R (%)		2.286	.319
SIS L (%)		1.299	.522

Comparison of central auditory processing abilities across groups

The central auditory processing abilities were assessed on all the participants. The auditory closure abilities were evaluated using speech perception in noise test (SPIN and SNR-50). Temporal processing was evaluated bygap detection thresholds (GDT), and binaural integration was assessed using a dichotic digit test. Working memory was assessed through forward, backward, ascending, and descending span tests. The mean and SD of all the tests across groups 1, 2, and 3 are given in Figure 3.1 and Table 3.4. It can be noted from Table 3.4 that the mean thresholds were poorer for group 1 compared to group 2 and 3 for all the tests.

Table 3.4 Mean, SD, median and range for central auditory processingtest across all the three groups

Tests	Frequencies	Groups	Mean	SD	Median	Range
SPIN (%)	SPIN R	Group 1	90.24	5.23	88	84 to 100
		Group 2	92.48	4.47	92	84 to 100
		Group 3	91.12	4.66	92	80 to 100
	SPIN L	Group 1	88.75	5.08	88	80 to 100
		Group 2	88.24	4.94	88	80 to 100
		Group 3	88.08	10.83	88	20 to 100
QuickSIN (dB)	SNR 50 R	Group 1	-2.42	1.12	-2.5	-5.5 to 0.5
		Group 2	-2.93	1.58	-2.5	-7.5 to 0.5
		Group 3	-2.83	1.36	-2.5	-7.3to -0.7
	SNR 50 L	Group 1	-2.91	1.79	-3.1	-7.3 to 2.3
		Group 2	-3.65	2.23	-3.1	-10.3 to 2.9
		Group 3	-3.41	1.92	-3.7	-7.3 to 0.5
DCV (No. of syllables repeated)	SCS R	Group 1	20.04	5.30	20	8 to 29
		Group 2	21.38	4.67	20	11 to 29
		Group 3	19.64	4.31	23	8to 28
	SCS L	Group 1	16.92	5.47	16	5 to 28
		Group 2	18.38	4.61	17	8 to 27
		Group 3	16.96	4.49	18.5	8 to 25
	DCS	Group 1	13.37	6.29	12	2 to 26
		Group 2	15.32	4.98	14	5 to 25
		Group 3	13.78	4.85	15	4 to 23
GDT R (ms)		Group 1	4.14	3.01	2.95	1.62 to 16.47
		Group 2	2.65	.87	2.65	1.42 to 7.46
		Group 3	2.72	.61	2.52	1.7 to 4.29
GDT L (ms)		Group 1	3.90	2.53	3.12	1.48 to 16.47
		Group 2	2.52	.64	2.8	1.62 to 4.91
		Group 3	2.75	.70	2.45	1.55 to 5.23
Working memory (digit spans)	Forward	Group 1	4.55	.75	5	3 to 7
		Group 2	4.88	.84	5	4 to 8
		Group 3	4.94	1.02	5	3 to 8
	Backward	Group 1	3.48	.554	3	3 to 5
		Group 2	3.78	.616	3	3 to 6
		Group 3	3.66	.772	4	3 to 5
	Ascending	Group 1	4.45	.843	4	3 to 7
		Group 2	4.84	1.22	5	3 to 10
		Group 3	4.78	1.37	5	3 to 10
	Descending	Group 1	4.37	.85	4	3 to 7
		Group 2	4.76	.98	5	3 to 8
		Group 3	4.62	1.14	5	3 to 7

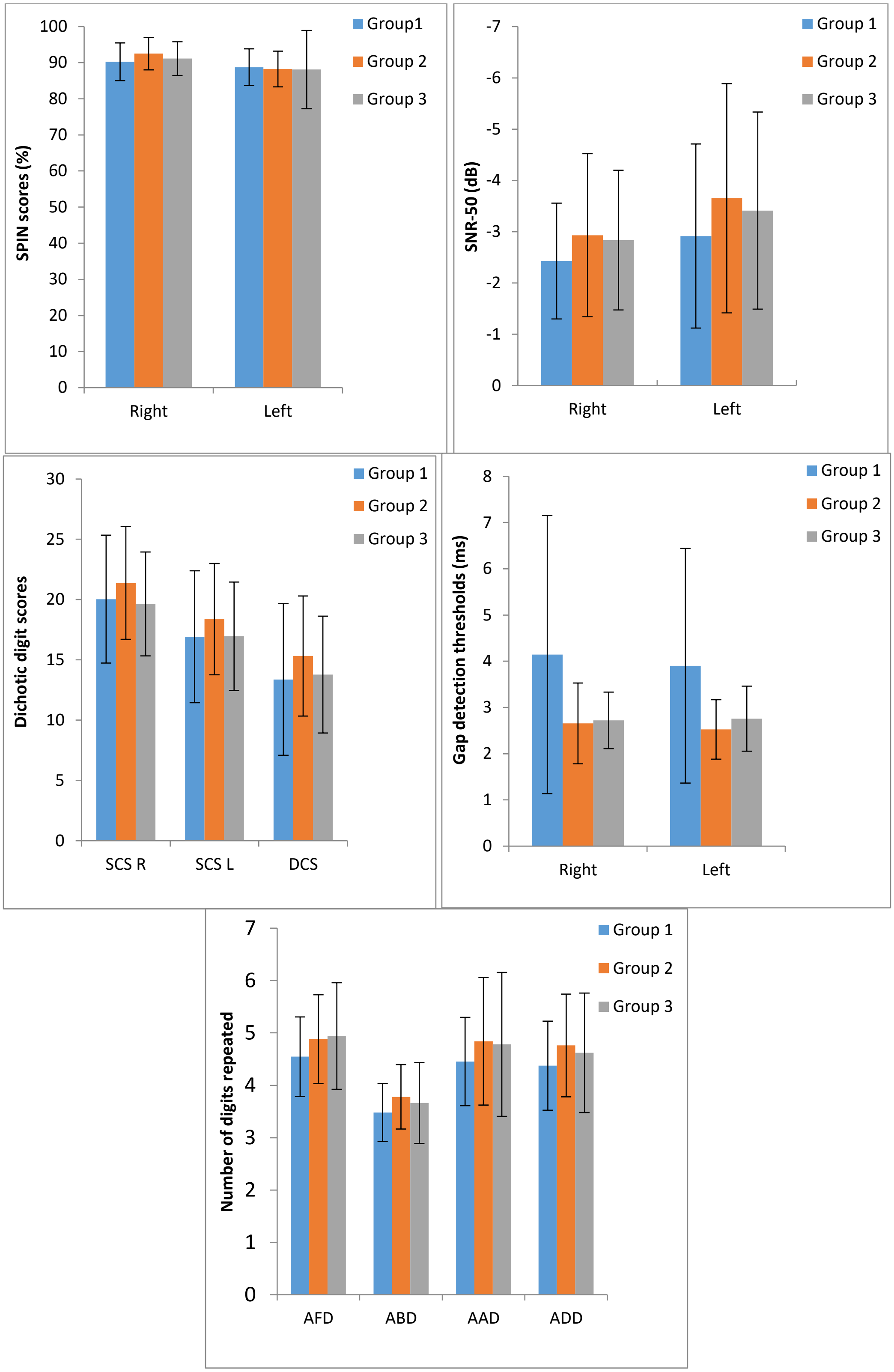

Figure 3.1 Bar graph representing mean and SD for central auditory processingtest across all the three groups

Further, the Kruskal-Wallis test was done to assess the significant difference in scores across groups. Table 3.5 depicts the results of the Kruskal-Wallis test for all the central auditory tests across groups. Pair-wise comparison across groups was done using Mann Whitney U test. The significant main effect of groups was seen for GDT of both ears and backward span tests. Pair-wise comparison using the Mann Whitney U test showed that group 1 performed significantly poorer than group 2 and 3 for these tests.

Table 3.5. Kruskal Wallis test result to compare central auditory processing tests across groups

Tests	**Frequencies**	$\chi 2(2)$	**p**
SPIN (%)	SPIN R	5.880	.053
	SPIN L	1.212	.546
QuickSIN (dB)	SNR 50 R	4.308	.116
	SNR 50 L	3.645	.162
DCV (No. of syllables repeated)	SCS R	4.909	.086
	SCS L	2.907	.234
	DCS	3.898	.142
GDT R (ms)		20.803	**.000**
GDT L (ms)		22.612	**.000**
Working memory (digit spans)	Forward	5.994	.050
	Backward	6.739	**.034**
	Ascending	2.781	.249
	Descending	3.835	.147

3.2 Relationship between IDA and auditory abilities

The relationship between IDA and auditory abilities were established using correlation. The Spearman correlation test was done to assess the relationship between different degrees of anemia and auditory abilities. The results showed no correlation between anemia and any peripheral and central auditory abilities ($p>0.05$) irrespective of the severity of anemia.

3.4 Percentage of adolescent girls with IDA having hearing abilities and central auditory processing abilities poorer than control groups

The percentage of adolescent girls with IDA with hearing abilities and central auditory processing abilities poorer than the control groups was assessed. For this purpose, the mean with +1SD of Group 2 (non-IDA girls) was considered as the cut-off criteria for peripheral tests, and the mean with -1SD of Group 2 (non-IDA girls) was considered as the cut-off criteria for central tests (Jain et al., 2021). Group III was not used in the analysis because of previously reported sex differences in hearing thresholds (Shuster et al., 2019). Any participant who scored less than that was considered to calculate the percentage. The percentage of adolescent girls with different degrees of IDA who performed poorer than Group 2 is given in Table 3.6.

Table 3.6. Percentage of adolescent girls with IDA with different degrees of IDA who performed poorer than Group 2

Tests	IDA degree	Frequencies/Parameters	Cut off	Prevalence (%)
AC R (dB)	Mild	250 Hz	12.75	17.85
	Moderate			26.4
	Severe			30.76
	Mild	500 Hz	11.67	10.71
	Moderate			11.7
	Severe			15.3
	Mild	1000 Hz	11.62	10.71
	Moderate			5.88
	Severe			7.69
	Mild	2000 Hz	11.69	3.5
	Moderate			2.9
	Severe			0
	Mild	4000 Hz	11.75	0
	Moderate			17.6
	Severe			0
	Mild	8000 Hz	9.57	35.7
	Moderate			50
	Severe			23

AC L (dB)	Mild	250 Hz	12.58	35.7
	Moderate			23.5
	Severe			30.7
	Mild	500 Hz	12.12	25
	Moderate			17.6
	Severe			15.3
	Mild	1000 Hz	12.38	21.4
	Moderate			17.64
	Severe			7.6
	Mild	2000 Hz	12.02	7.14
	Moderate			11.7
	Severe			0
	Mild	4000 Hz	10.87	7.14
	Moderate			20.5
	Severe			0
	Mild	8000 Hz	7.84	28.5
	Moderate			47
	Severe			7.6
BC (dB)	Mild	250 Hz	11.47	0
	Moderate			2.9
	Severe			0
	Mild	500 Hz	11.47	0
	Moderate			0
	Severe			0
	Mild	1000 Hz	11.66	0
	Moderate			2.9
	Severe			0
	Mild	2000 Hz	11.43	0
	Moderate			0
	Severe			0
	Mild	4000 Hz	9.86	46.4
	Moderate			42.10
	Severe			30.7
SRT R (dB)	Mild		11.57	14.2
	Moderate			17.6
	Severe			23
SRT L (dB)	Mild		11.83	28.5
	Moderate			17.6
	Severe			23
SIS R (%)	Mild		97.314	14.2
	Moderate			38.2
	Severe			46.15
SIS L (%)	Mild		95.906	3.5
	Moderate			8.8

	Severe			0
SPIN R (%)	Mild		88.01	17.8
	Moderate			20.5
	Severe			23
	Mild		83.3	7.14
SPIN L (%)	Moderate			8.8
	Severe			7.6
QuickSIN (dB)	Mild	SNR 50 R	-1.35	17.8
	Moderate			20.5
	Severe			23
	Mild	SNR 50 L	-1.42	17.8
	Moderate			29.4
	Severe			30.7
DCV (No. of syllables repeated)	Mild	SCS R	16.71	35.7
	Moderate			20.5
	Severe			23
	Mild	SCS L	13.77	25
	Moderate			41
	Severe			23
	Mild	DCS	10.34	45.8
	Moderate			44.11
	Severe			23
GDT (ms)	Mild	Threshold R	3.52	45.8
	Moderate			47
	Severe			53.8
	Mild	Threshold L	3.16	50
	Moderate			50
	Severe			46.15
Working memory (Digit spans)	Mild	Forward	4.04	4.1
	Moderate			5.8
	Severe			7.69
	Mild	Backward	3.16	60.7
	Moderate			50
	Severe			53.8
	Mild	Ascending	3.62	14.2
	Moderate			5.8
	Severe			15.3
	Mild	Descending	3.78	10.71
	Moderate			8.8
	Severe			30.7

As seen in Table 6, the current pilot data suggest that a high percentage of adolescent girls with IDA show poorer peripheral and central auditory abilities than non-IDA girls, with maximum deficits noted for GDT and backward digit span.

Chapter 4

Discussion

The present study focussed on the relationship between Iron deficiencyanemia (IDA) and central auditory processing abilities amongadolescent girls. The results of the study are discussed below:

4.1 Comparison of auditory abilities across groups

When the peripheral hearing abilities were compared across the groups, results showed that Group 1 performed significantly poorer than Groups 2 and 3 for the AC 250 Hz and 8000 Hz of right ear, AC 250 and 500 Hz of left ear, BC 250 Hz and SRT of the left ear. After an extensive literature review, the authors could not find studies comparing peripheral and central auditory processing in participants with IDA. However, studies have shown that anemia is one of the associated factors for hearing loss (Park et al., 2017). IDA as a cause of hearing loss has also been reported in other literature studies (Chung et al., 2014; Schieffer, Connor, et al., 2017). A significant association between IDA and SNHL was also reported among both adults and children (Mohammed et al., 2019). In the present study, the difference was evident for low frequencies as compared to high frequencies.

The central auditory processing abilities were assessed on all the participants, and a comparison was made across Groups. Results showed that SPIN-K of right ear, GDT, and backward span tests differed significantly across groups, and Group 1 performed significantly poorer than Groups 2 and 3 for these tests. After a comprehensive literature review, this is the first study wherein auditory processing abilities have been assessed in adolescent girls diagnosed with IDA. Although behavioral testing has not been used in studies, auditory evoked potential

(AEP) and visual evoked potential (VEP) results suggest that IDA had adverse effects on both systems (Algarín et al., 2003). In the IDA group, longer latencies were noted in both AEP and VEP compared to the non-IDA Group, exceeding 1 SD, and showing almost no effect on the potential amplitude. This difference was attributed to the impact of IDA on myelinization. Further, most of the studies have done retrospective analysis to assess the relation ship between anemia and hearing loss (Park et al.,2017; Schieffer, Chuang, et al., 2017). In the present study adolescent girls diagnosed with IDA were included for the study.A significant difference was noted only for SPIN-K of the right ear, GDT, and backward digit span in the present study. Studies have shown that a backward digit span is an excellent measure to assess working memory compared to other digit spans (Maerlender et al., 2004). Thus, it can be hypothesized that working memory is affected in these individuals. Studies have shown a relationship between working memory and auditory abilities (Jain & Kumar, 2016). However, a significant difference in other measures was not seen. This could be attributed to the fewer number of participants considered in the current study. However, as noted in the last objective, the percentage of participants with IDA that showed poorer peripheral hearing and central processing abilities is high. Thus, in view of this there is a need of regular monitroring of hearing abilities in adolescent girls with IDA. If IDA is long standing this might further have impact on hearing abilities.

4.2 Relationship between IDA and auditory abilities

The relationship between different degrees of IDA and different peripheral and central auditory abilities was established using correlations. The results showed that there was no correlation between anemia and the various peripheral and central auditory abilities. These results do not agree with the studies done in the past. Studies have shown that IDA is associated with hearing loss (Chung et al., 2014; Schieffer, Chuang, et al., 2017; Schieffer, Connor, et al., 2017). However, these are retrospective studies wherein a large number of samples were considered for correlations. In the present study, the number of participants in the severe anemic category was less. This could have attributed to no correlation between anemia and different peripheral and central auditory abilities.

4.3 Percentage of adolescent girls with IDA having hearing abilities and central auditory processing abilities poorer than control groups

The percentage of adolescent girls with IDA having hearing abilities and central auditory processing abilities poorer than control groups was assessed. Results showed that the percentage ranged from 0% to 60% across different degrees of anemia. Most peripheral and central auditory abilities were poorer in the IDA group than the control group (non-IDA girls). Further, it was also noted that central auditory abilities are more affected compared to peripheral abilities. However, the deficits, when compared across the different degrees of anemia, were not consistent and though statistically significant, the mean difference was not high among groups for few tests such as working memory measures. This could be because of fewer participants in IDA group and more specifically the severe degree of Group I.

The poorer auditory abilities in adolescent girls with IDA may be attributed to the affected blood supply to the central auditory nervous system, which could have compromised the central auditory processes (Chung et al., 2014). Also, reduced myelination of nerve fibers resulting from iron deficiency could explain why the poorer results are seen in the IDA population (Algarín et al., 2003; Roncagliolo et al., 1998). IDA has also been shown to affect concentration, attention span, cognition, motor development, and educational attainment (Dubey, 2006). These reasons seem like a plausible explanation for the high percentage of auditory deficits in the IDA population, as observed in the current study. Thus, the current preliminary study adds to a long-felt need for extensive research on the effect of IDA on peripheral and central auditory processing abilities.

Chapter 5

Summary and Conclusion

IDA is considered to be one of the major health factors in developing countries, owing to its large prevalence and health complications. Some of the research carried out in the foreign population has shown that hearing related deficiencies are common in individuals with IDA. However, an indigenous effort to demonstrate it is yet to be reported irrespective of its importance. Moreover, earlier researchers have evaluated and reported peripheral hearing difficulties. A probable central auditory processing deficit in them is yet to be explored. The current study was hence planned to evaluate peripheral hearing and all the major central auditory processes in 75 adolescent girls with IDA. Their performance in these tasks was compared with 50 adolescent girls without IDA and 50 adolescent boys without IDA. Routine audiological evaluations were accompanied with special tests to tap the auditory closure abilities, temporal processing abilities, auditory working memory, and binaural integration abilities. The results revealed that the pure tone thresholds were poorer in adolescent girls with IDA at extreme high and low frequencies. It was also observed that the temporal processing abilities and some aspects of auditory working memory, as demonstrated in the backward span test, were also poorer in girls with IDA. It was also observed that the percentage of girls with IDA having peripheral and central auditory abilities poorer than the control non IDA girls ranged from 0% to 60 %, with more deficits seen in central auditory abilities. These deficiencies, as shown in the results, may be attributed to the peripheral hearing deficit and the compromised blood supply to the central auditory nervous system.

Thus, current study findings suggest that the hearing abilities in adolescent girls with IDA is poorer than that of girls and boys without IDA. These deficiencies are not just focused at the peripheral level, but splurge to the central auditory functioning as well. Correspondingly, such a deficit can have an undesirable effect on their academic performance also. This study finding hence suggests the importance of hearing health care intervention in adolescents with IDA. Present study findings also reflect on the necessity of further research in the hearing assessment and management opportunities in them. However, further study with more number of participants across different duration of IDA would strengthen the present results. Also, in future, ferretin level can also be considered for the diagnosis of IDA.

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