# WIDEBAND TYMPANOMETRY IN CHILDREN WITH SEVERE TO PROFOUND HEARING LOSS WITH AND WITHOUT COCHLEAR IMPLANT: A COMPARISON STUDY

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# CERTIFICATE

This is to certify that this dissertation entitled **"Wideband Tympanometry in Children with Severe to Profound Hearing Loss with and without Cochlear Implant: A Comparison Study"** is a bonafide work submitted in part fulfillment for the Degree of Master of Science in Audiology of the student with Registration Number **P01II21S0070**. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Place: Mysuru

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# CERTIFICATE

This is to certify that this dissertation entitled **"Wideband Tympanometry in Children with Severe to Profound Hearing Loss with and without Cochlear Implant: A Comparison Study"** has been prepared under my supervision and guidance. It is also certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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# DECLARATION

This is to certify that this dissertation entitled **"Wideband Tympanometry in Children with Severe to Profound Hearing Loss with and without Cochlear Implant: A Comparison Study"** is the result of my own study under the guidance of Dr. Niraj Kumar Singh, Associate Professor, Department of Audiology, All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Place: Mysuru **Registration No. P01II21S0070**

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## ABSTRACT

This study aimed to investigate the differences in wideband tympanometry (WBT) among normal-hearing children and children with sensorineural hearing loss (SNHL), with or without cochlear implantation. It also aimed to compare the effects of different electrode types on WBT. The study included normal hearing group, non-implanted SNHL group and unilateral cochlear implantation group, each with twenty participants. Each participant underwent WBT in the frequency range of 226-8000 Hz using Interacoustics Titan Suite IMP440/WBT440 equipment, and the findings were compared within and between the groups. The implant ears (CI ears) of children with cochlear implantation exhibited lower absorbance in the low-frequency region, than the other two groups and their non-implant ears. Further, the CI ears showed higher absorbance than their non-implant ears and ears of SNHL group in the mid-to-high frequency region. However, there was no significant difference between the two electrode types. These findings have clinical implications as they highlight distinctions in WBT results following cochlear implantation compared to sensorineural hearing loss without cochlear implants. This study opens avenues for further research into the potential contribution of middle ear changes to understand the findings of other tests requiring an air-conduction route for the inner ear stimulation.

# Chapter I

## Introduction

The invention of Wideband tympanometry (WBT) was a ground-breaking effort which produced an efficient method for assessing middle ear function. WBT can be equated to simultaneous multiple tympanograms for several probe tone frequencies; and therefore, it not only yields information obtained from a traditional single frequency tympanogram but also enables the extraction of absorbance graph (amount of energy absorbed across frequencies by the middle ear system), resonance frequency, and wideband averaged tympanogram (Feeney et al., 2009; Keefe & Simmons, 2003; Shahnaz, Longridge, et al., 2009; Terzi et al., 2015; Keefe & Simmons, 2003; Voss & Allen, 1994). WBT employs a broadband click which has a broad frequency composition and therefore allows for absorbance measures in the frequency range of 226 Hz to 8000 Hz. It takes about the same amount of time to execute as a typical tympanogram.

WBT provides a window of opportunity to evaluate and differentially diagnose the middle ear pathologies that are often associated with frequency specific characteristics alteration. In infants and children, it is particularly important to be able to determine middle ear function using wideband acoustic stimuli in ambient ear canal settings (Park et al., 2015; Shahnaz et al., 2008). The use of WBT to diagnose and monitor newborn's hearing as well as adults with otosclerosis, ossicular chain disruptions, tympanic membrane perforations, superior semicircular canal dehiscence syndrome, and middle ear effusions has increased (Feeney et al., 2003; Shahnaz, Bork, et al., 2009; Feeney et al., 2003; Shahnaz, Bork, et al., 2009; Nakajima et al., 2013). Moreover, pre-and post-operative monitoring with WBT is done utilizing non-pressurized wideband absorbance (Park, 2017). Otosclerosis can be detected and monitored using WBT absorbance and resonance data (Feeney et al., 2003; Shahnaz et al., 2009). Low absorbance at < 1 kHz is a typical finding associated with an otosclerotic ear.

Additionally, modifications in resonance frequency over time might reveal the development of a disease. The resonance frequency rises over time as otosclerosis worsens due to middle ear stiffening (Feeney et al., 2003; Shahnaz et al., 2009). Wideband reflectance has a noticeable notch due to ossicular discontinuities between 400 and 800 Hz, which aids in differentially diagnosing it from other middle ear disorders (Nakajima et al., 2013). Using the absorbance measurement, WBT can distinguish between an ear that is air-filled and an ear that has complete otitis media with effusion (Beers et al., 2010; Feeney et al., 2003). WBT can identify perforations and distinguish them from the presence of grommets (Park, 2017). The success of the grommet can also be monitored using pre- and post-insertion WBT measures. In perforated ears, there is higher absorbance at low frequencies, with the smallest perforations showing the highest impact (Feeney et al., 2003).

WBT not only has differential diagnosis applicability for middle ear disorders but has also been found valuable in conditions involving the inner ear, such as Meniere’s disease (Miehe et al., 2022; Tanno et al., 2022) and semicircular canal dehiscence (Nakajima et al., 2013). According to Nakajima et al. (2013), the presence of a cliff at 1kHz in the absorbance curve (notch at 1kHz in the power reflectance curve) has a 100% sensitivity and 95% specificity for detecting semicircular canal dehiscence. Further, the traditional tympanometry uses pressure variation, which makes its use difficult soon after a surgery; however, WBT can be done without applied pressure, which makes it a viable tool to assess the middle ear function immediately after an ear surgery (Feeney et al., 2003; Nakajima et al., 2013). While the findings of WBT in other conditions of sensorineural hearing loss remain relatively unknown, the findings in cases like Meniere's disease seem to suggest the potential value of WBT in assessing the middle ear status and its interaction with the inner ear in individuals with a sensorineural hearing loss.

Sensorineural hearing loss (SNHL) due to several causes could involve structural alterations to the cochlear partition (Bommakanti et al., 2019; Linthicum et al., 2013; Santos & Nadol, 2017), such as abnormal tectorial membranes in association with hair cell degeneration (Ishai et al., 2019), stria vascularis fibrosis (Zhang et al., 2020), or perilymph fibrosis (Linthicum et al., 2013). Some of these abnormal structural changes show modifications to the stiffness and impedances of the cochlear partition, which was evidenced by a decrease in the vibrations of stapes footplate at high frequencies and a lowering of the resonance frequency of the partition (Dewey et al., 2018; Dong & Olson, 2009; Kim & Koo, 2015).

For those with sensorineural hearing loss, cochlear implant (CI) has emerged as the leading rehabilitation solution (Yoon, 2011). A cochlear implant (CI) is a surgically implanted electronic device that restores hearing in patients with severe to profound hearing loss who derive little or no benefit from conventional amplification devices. There are internal and external components to the device. A transmitter, speech processor, and microphone are included in the external components. The internal component of the surgically implanted device has an electrode array that is inserted into the cochlea. Cochlear implant electrode arrays can contain electrodes varying in number from 12 to 24, depending upon the manufacturers (Dhanasingh & Jolly, 2017). It is plausible that the insertion of these electrode arrays into the cochlea creates changes in the stiffness characteristics, or that the surgical procedure for CI has an iatrogenic influence on the middle ear structures, which may lead to changes in the middle ear characteristics. However, the explorations for evidence to gather information about the consequences of cochlear implantation on the middle and inner ear mechanics are still in their nascency.

**1.1 Need of the Study**

Following the surgical procedure for implantation, extreme repercussions, such as ossicular displacement, have been reported in a few studies (Coco et al., 2007; Donnelly et al., 2009). While these conditions would be expected to definitely affect WBT outcomes, they are rarely encountered and do not completely justify the need for WBT investigation among cochlear implantees. Nonetheless, even among those with no such obvious post-implantation structural abnormalities, Donnelly et al. (2009) demonstrated that the vibration patterns of the stapes footplate were altered probably by the presence of an impeding electrode array in the scala tympani, which in turn is connected to the scala vestibuli where oval window containing the stapes footplate is present. This hypothesis was supported by the findings of increased post-implantation air-conduction thresholds despite the unchanged bone-conduction thresholds (Raveh et al., 2015).

The literature on the findings of WBT in CI has been emerging steadily. The ears with CI were found to have different WBT patterns from those of normal-hearing individuals (Attias et al., 2022; Merchant et al., 2015; Saki et al., 2022; Saoji et al., 2020; Zhang et al., 2020; Singh et al., 2022). A common finding across the studies is a decrease in absorbance. While a majority of these studies show reduced absorbance in the low to mid-frequency range, there is a discrepancy in the range of frequencies themselves. For example, the reduced absorbance was observed in the frequency range of 600 to 1100 Hz (Saoji et al., 2020), in the frequencies up to 1200 Hz

(Merchant et al., 2015; Zhang et al., 2020), at 400-800 Hz (Attias et al., 2022); at 1260 to 3175 Hz and 5040 to 8000 Hz (Saki et al., 2022) and in the range of frequencies between 900 Hz and 1800 Hz (Singh et al., 2022). In addition, Attias et al. (2022) reported significantly lower absorbance at 1600 Hz, and additionally reduced absorbance in the frequency range of 4000-5000 Hz. Investigations proposed a relationship between WBT fluctuations and increased inner-ear stiffness. The above findings represent highly variable outcomes of WBT following cochlear implantation. A possible reason for this could be the small sample size in a majority of these studies or even the differences in the electrode arrays between the studies. Additionally, some studies have used non-CI ears as the control ear to compare the changes in the absorbance in the CI ear. However, studies on unilateral mastoidectomy have shown temporary changes in the middle ear characteristics even on the contralateral side where the mastoidectomy was not performed. Since, CI also involves radical mastoidectomy, changes in middle ear characteristics could be expected even on the non-implant side. Therefore, the non-implant ear of a cochlear implantee cannot be considered as control ear to decipher the change of CI ears. Since, ears undergoing cochlear implantation have high degree of sensorineural hearing loss, an SNHL group could be a better control group. Also, none of these studies compared sensorineural hearing loss and cochlear implantees to show that there is a difference between those two as well, and therefore it is the result of CI and not just sensorineural hearing loss or vice versa. It is critical to distinguish WBT patterns associated with the implantation from those associated with the sensorineural hearing loss itself because implanted ears are typically associated with severe to profound SNHL.

## 1.2 Aim

This study aimed to evaluate the findings of WBT in normal-hearing individuals and those with sensorineural hearing loss with or without CI.

## 1.3 Objectives

1. To compare the findings of WBT at peak and ambient pressure among typically hearing children and children with SNHL using hearing aids and cochlear implants.
2. To compare findings of WBT between the implant and non-implant ears of children with a unilateral cochlear implant.
3. To compare the findings on WBT among different electrode arrays used in the implanted ears.

# Chapter II

## Review of Literature

The development of Wideband tympanometry (WBT) marked a significant breakthrough in evaluating middle ear function. WBT not only provides information from a conventional single frequency tympanogram but also offers valuable insights into parameters like absorbance graph, resonance frequency, and wideband averaged tympanogram (Feeney et al., 2009; Keefe & Simmons, 2003; Shahnaz, Longridge, et al., 2009; Terzi et al., 2015; Keefe & Simmons, 2003; Voss & Allen, 1994). WBT employs a broadband click spanning 226 Hz to 8000 Hz, to evaluate the middle ear transfer characteristics, which was not previously possible for other immittance measurements.

WBT facilitates the assessment and differential diagnosis of middle ear pathologies with frequency-specific characteristics alterations, especially crucial for infants and children in ambient pressure setting in the ear canal (Park et al., 2015; Shahnaz et al., 2008). Its applications have expanded to include diagnosing and monitoring various conditions such as otosclerosis, ossicular chain disruptions, tympanic membrane perforations, superior semicircular canal dehiscence syndrome, and middle ear effusions (Feeney et al., 2003; Shahnaz, Bork, et al., 2009; Nakajima et al., 2013). WBT is also utilized for pre- and post-operative monitoring, particularly for otosclerosis detection and evaluation of grommet effectiveness (Park, 2017).

Notably, WBT extends its diagnostic utility beyond middle ear disorders, proving valuable in assessing inner ear conditions like Meniere's disease and semicircular canal dehiscence (Miehe et al., 2022; Tanno et al., 2022; Nakajima et al., 2013). Its non-invasive nature makes it suitable for immediate post-surgery middle ear function evaluation, unlike traditional tympanometry (Feeney et al., 2003; Nakajima et al., 2013).

While the potential of WBT in sensorineural hearing loss remains relatively unexplored, its application in conditions like Meniere's disease suggests its value in assessing the middle ear's interaction with the inner ear in individuals with sensorineural hearing loss. Sensorineural hearing loss may result from various causes, including structural alterations to the cochlear partition such as abnormal tectorial membranes, stria vascularis fibrosis, or perilymph fibrosis, which affect cochlear stiffness and impedance (Bommakanti et al., 2019; Linthicum et al., 2013; Santos & Nadol, 2017; Ishai et al., 2019; Zhang et al., 2020).

Cochlear implantation has emerged as a primary rehabilitation option for severe to profound sensorineural hearing loss (Yoon, 2011). The advent of cochlear implant technology has revolutionized the field of auditory rehabilitation, offering hope and transformative opportunities to individuals with profound hearing loss. Cochlear implants are electronic devices designed to provide access to sound and facilitate auditory communication for those who derive limited or no benefit from conventional hearing aids.

Cochlear implants are surgically implanted devices that harness the principles of neuroplasticity to bypass damaged or non-functioning hair cells in the inner ear and directly stimulate the auditory nerve fibers. This enables individuals with severe to profound sensorineural hearing loss to perceive sound and speech more effectively than traditional amplification devices, such as hearing aids (Yoon, 2011). Unlike hearing aids, which merely amplify sounds, cochlear implants transform acoustic information into electrical signals that directly stimulate the auditory nerve, allowing for improved speech comprehension (Wilson & Dorman, 2008).

Cochlear implants represent a remarkable and transformative leap forward in the world of auditory rehabilitation. Their advantages are nothing short of extraordinary, bringing profound benefits to individuals facing the challenging reality of severe to profound hearing loss. The most significant advantage of cochlear implants is their potential to restore or significantly improve hearing in individuals with profound hearing loss (Clark, 2015). This restoration can enhance speech understanding and overall quality of life, particularly for those who have never experienced hearing or have lost their hearing later in life. Cochlear implant recipients often experience improved speech perception, which is especially crucial for communication, language development, and social integration (Blamey et al., 2013). Cochlear implants provide access to a broader range of sounds and frequencies compared to traditional hearing aids, allowing recipients to appreciate music, environmental sounds, and nuances in speech (Jiam et al., 2022). Cochlear implants are highly adaptable and can be tailored to meet individual hearing needs through programming adjustments, making them suitable for various age groups and degrees of hearing loss (Dorman et al., 2016).

While the advantages are many, certain shortcomings of cochlear implant persist. Cochlear implantation involves a surgical procedure that carries inherent risks, such as infection, device malfunction, or damage to adjacent structures thereby altering the physiology of auditory system as well (Gaylor et al., 2013). Another noteworthy concern is the occurrence of facial nerve paralysis following implantation surgery, which has been reported in the literature (Vincent et al., 2016). Beyond these concerns, other complications have been documented in the literature. These encompass a range of issues, such as infections at the surgical site (Vincent et al., 2016), device malfunctions (Battmer et al., 2009), and device extrusion or migration

(Todt et al., 2018). Additionally, electrode misplacement or insertion trauma (Gstoettner et al., 1997) has been reported, emphasizing the importance of precise electrode positioning during surgery. This complication, although relatively rare, underscores the importance of meticulous surgical technique to minimize the risk to the facial nerve during electrode insertion. Also, successful cochlear implantation involves a lengthy and intensive process of auditory rehabilitation, including speech therapy and device adjustments, which may require significant time and commitment from the recipient and their caregivers (Pisoni et al., 2008). Furthermore, studies have also explored the potential impact of cochlear implantation on the vestibular system, a system in close proximity of the surgery site for cochlear implantation. Most of the literature in this regard involves the use of vestibular-evoked myogenic potentials (VEMP). Research by Merchant et al. (2020) delves into this area, suggesting that cochlear implantation can lead to alterations in VEMP responses. This finding highlights the significance of monitoring vestibular function in patients undergoing cochlear implant surgery, as changes in VEMPs may have implications for balance and spatial orientation. However, most studies showing affected or absent VEMP responses after cochlear implantation have used air-conduction VEMPs. Since, the CI surgery involves the middle ear exploration, it is plausible that middle ear changes cause alteration to the energy reaching the saccule via this route when using AC-VEMP. Therefore, this chapter reviews the changes in middle ear characteristics after CI to fathom the extent of middle ear changes as a result of CI.

During the surgery for inserting the cochlear implant, the middle ear is widely exposed. This surgical procedure has the tendency to change the middle ear characteristics after surgery, as previously reported in various studies (Saoji et al., 2020; Orhan et al., 2020; Merchant et al., 2020; Scheperle & Hajicek, 2021; Racca et al., 2022; Attias et al., 2022; Saki et al., 2022). However, different studies incorporated different groups as their control. Few studies incorporated no control group as they compared the pre-implant WBT to the post-implant WBT in the same group of individuals. (Saoji et al., 2020; Saki et al., 2022). Other studies included individuals with normal hearing as control group (Merchant et al., 2020; Scheperle and Hajicek, 2021; Attias et al., 2022). Yet others used the non-implant ears of unilateral cochlear implantees as control (Orhan et al., 2022). While they have all reported changes in WBA, there is variability in the frequency region of differences among the studies.

**2.1 Comparison of WBA between the CI group and NH group**

In few studies the absorbance was compared between the children with CI and normal hearing children. These studies reported varied findings (Merchant et al., 2020; Scheperle & Hajicek, 2021; Attias et al., 2022).

In study by Merchant et al. (2020), 27 ears with cochlear implants (mean age = 14.74, age range = 7 to 31 years) were compared against 10 age-matched ears normal hearing (mean age = 17.8, age range = 7 to 31 years) on chirp-evoked wideband acoustic immittance measures at ambient pressure. The authors reported reduced absorbance in the CI ears in the frequency range of 500-1200 Hz and increased absorbance around 2000 Hz than the ears with normal hearing. In this study, the average time elapsed after CI placement was 11.7 years (with a range from 1 to 23 years and a standard deviation of 4.76). It would be beneficial to gather data both before the implantation and immediately after the implantation, as comparing these two sets of data within the same individuals can offer insights into how these responses change over time. The participants of CI group in the study had diverse etiologies of hearing loss, and this diversity could lead to varying effects depending on the location for abnormality or anatomical structures involved. Additionally, participants were implanted with different types of implants, and this variation could introduce confounding results because the dimensions and characteristics of the implants differ among them.

A study by Scheperle and Hajicek (2021) included 11 CI recipients (mean age = 55 years, age range=13-78 years). Their WBT results were compared against a normative dataset from 28 adults without CIs and with normal middle ear function (mean age = 40 years, age range = 21 to 67 years). The results revealed reduced absorbance for the frequency range of 250-891 Hz and 4238-4490 Hz in CI ears compared to the normative dataset, signifying increased middle ear stiffness in a restricted band of low and high frequencies. The generalization of the results of this study could be limited by the use of small sample size in the implant group. Another potential limitation is that while the inclusion criteria ensured that participants had no middle ear pathology by a less than 10 dB air-bone gap or 'A' type tympanogram, it did not ascertain whether the control group had normal hearing or not.

Another study by Attias et al. (2022) aimed to investigate the impact of cochlear implantation and SNHL on WBT patterns, potentially shedding light on changes in middle- and inner-ear mechanics associated with cochlear implantation. The participants included 24 individuals with normal hearing and 17 with cochlear implants (15 unilaterally implanted and 2 bilaterally implanted). All participants exhibited normal otoscopy and inner-ear anatomy. Pure-tone audiometry, standard tympanometry, and click-evoked WBT were administered, with WBT recorded at ambient and peak pressures. The analysis compared normal-hearing ears with impaired non-implanted ears to understand the effect of SNHL on WBT. Additionally, the impact of cochlear implantation was assessed by comparing the

WBT of implanted and non-implanted ears within the same participants. The results indicated that implanted ears exhibited decreased absorbance at low frequencies (400-800 Hz) and increased absorbance around 1600 Hz, likely attributed to increased stiffness due to implantation surgery and the presence of the implant in the inner ear. Conversely, the specific decrease in absorbance around 4000-5000 Hz in both implanted and non-implanted ears compared to normal ears was attributed to aging or the influence of severe-to-profound SNHL on cochlear input impedance. The study underscores the need for further research to discern the combined effects of hearing loss severity and age on wideband acoustic immittance in the ear. Several aspects of this study could be potentially producing bottlenecks to the generalization of its results. First, there is a disparity in the ages of the participants. Most of those with normal hearing were young, whereas among the participants with sensorineural hearing loss (SNHL), whether with or without cochlear implants, there was a wide age range spanning from young adults (6 ears) to middle-aged adults (14 ears) and older adults (14 ears). Age can influence the function and size of the external and middle ear, and in older adults, it has been associated with specific findings related to wideband tympanometry. Furthermore, the electrodes used in the participants varied in design and mass, which could potentially introduce variability into the results. Additionally, the time elapsed since implantation ranged over a period of 16 years, and the post-implantation processes, such as fibrosis or ossification, may progress differently over time, potentially impacting the study outcomes.

**2.2 Comparison of WBA between the CI group and SNHL group**

There are no studies of direct comparison between cochlear implant group and sensorineural hearing loss group. However, there are few studies comparing the findings of pre-implant WBT to post-implant WBT. Since, implantation is done mostly in cases with sensorineural hearing loss, it may not be completely out of place to equate the pre-implant middle ear status to middle ear status in an independent SNHL group. While the SNHL group might seem like a better choice as a control group compared to the NH group to understand effect of CI surgery alone, there could be a potential problem. The SNHL group may have some issues because individuals in this group can have varying degrees of hearing loss and different reasons for their hearing problems. Since the SNHL group and the NH group consist of entirely different individuals compared to the experimental CI group, there may be individual differences that are challenging to account. Nonetheless, a detailed literature search in this regard produced no relevant publication.

### 2.3 Comparison of absorbance between implant and non-implant ears of the CI group

When investigating the effects of CI surgery on the absorbance of middle ear, rather than having a different group of individuals as the control group some studies had non-implant ears of the same cochlear implanted individuals as control group (Orhan et al., 2020; Attias et al., 2022). This was done in order to minimize the individual differences when two different groups of individuals are compared.

This prospective comparative clinical study by Orhan et al. (2020) aimed to assess the impact of cochlear implantation on middle ear status using wideband tympanometry measurements. The study included 48 participants under 18 years of age with congenital bilateral profound sensorineural hearing loss who underwent unilateral CI. WBT measurements of the implanted ears were compared to those of non-implanted ears within the same patient group. The results revealed significant reductions in the average absorbance across all measured frequencies and a more pronounced increase in the average resonance frequency in the implanted ears compared to the non-implanted ears. These findings suggest that CI is associated with decreased absorbance and increased resonance frequencies, potentially indicating heightened stiffness in the middle and inner ear system. Contrary to these findings, Attias et al. (2022), reported reduced absorbance for CI ears reported for frequencies 400 Hz, 500 Hz, 630 Hz and 800 Hz, and increased absorbance for the CI ears at 1600 Hz when compared the non-implant ears. Therefore, the two available studies comparing the absorbance in implant ears and non-implant ears of unilateral cochlear implantees show differences in findings, at least in the mid-frequency regions.

To address individual variability, it's beneficial to compare the implanted ears to non-implant ears within the same person. However, it's worth noting that some studies have shown that surgical procedures like mastoidectomy or other middle ear surgeries can affect the non-operated ear due to vibrations from bone drilling (Latheef et al., 2018). These effects could be equitable on the contralateral side due to equal energy transfer from one side mastoid to the other side mastoid caused by virtually no interaural attenuation between them (Studebaker 1967; Silman, 1991). This might have an effect on the bone in the contralateral ear. Therefore, it's important to consider and measure the impact of bone drilling on the non-implanted side.

**2.4 Comparison of WBA between the pre- and post-CI implanted individuals**

Previous studies have shown changes in the absorbance characteristics of middle ear after cochlear implantation (Saoji et al, 2020; Saki et al, 2022; Racca et al, 2022). In study by Saoji et al. (2020), the objective was to investigate changes in middle ear absorbance measured through wide-band tympanometry (WBT) following cochlear implantation (CI). The study involved five individuals with sensorineural hearing loss who later underwent unilateral cochlear implantation. These participants were in the age range of 7-84 years. Wideband absorbance measurements were done bilaterally during the pre- and post-operative clinical visits. The post-operative visits took place after 45 to 60 days following the cochlear implant surgery. Cochlear implantation was carried out using the facial recess approach, employing devices from Advanced Bionics and Cochlear Corporation. In every case, a successful full insertion was accomplished without any complications. They measured absorbance at a fixed tympanometric pressure. The analysis of the study was done at fifteen 1/3-octave frequency bands spanning 226– 8000 Hz. Results revealed a broad spectral pattern of WBT absorbance measurements across a frequency range of 226 to 8000 Hz. Notably, postoperative WBT patterns exhibited significantly reduced low-frequency absorbance in the implanted ears, specifically in the frequency region from 0.6 to 1.1 kHz, with the maximum effect observed at 1 kHz. This reduction suggests a potential decrease in low-frequency acoustic absorbance as a consequence of cochlear implantation, indicating its impact on the high impedance status of the middle and inner ears. Although the CI ears showed a change after implantation, the non-CI ears of the same individual showed no significant change in the absorbance pattern after the surgery. The wide age disparity among the participants of the study might have had an effect on the results; similar age group participants could have been used to eliminate the maturational or developmental and aging effects on the findings of WBT outcomes.

In a prospective study by Saki et al. (2022) involving 35 unilaterally implanted children under 24 months of age with normal temporal bone anatomy, the objective was to investigate the impact of cochlear implantation (CI) on sound conduction mechanisms in the pediatric population. The study employed (WBT) to assess middle ear mechanics recorded at 16 discrete frequencies of 1/ 3$^{rd}$ octaves from 226 to 8000 Hz frequency range. Preoperative and three-month postoperative assessments of WBT were conducted in both the implanted and non-implanted ears. The results revealed a significant reduction in absorbance in the mid-frequency (1260 to 3175 Hz) and high-frequency regions (5040 to 8000 Hz) in the implanted ears following CI. Although the CI ears showed a change after implantation, the non-CI ears of the same individual showed no significant change in the absorbance pattern after the surgery.

In a study by Racca et al. (2022), the authors compared pre-CI and post CI ears similar to Saoji et al. (2020) and Saki et al. (2022). However, instead of single time point, when the WBT was performed on multiple time points to also see the effect of duration after CI surgery. WBT was performed at 6 time-points from CI-activation to 6 months after surgery. At the time of CI activation, the mean age of the participants included in the study was 62.52 ± 13.63 years. They reported significantly reduced absorbance in post-CI in the frequency range of 305-938 Hz and 1078-1336 Hz at 1-month after the surgery. Further, they reported notable reduction in absorbance in the implanted ear at all time points following surgery, although the extent of this reduction in absorbance gradually narrowed with increasing time post-activation. Unlike the above two studies, the CI ears showed a change after implantation, the non-CI ears reported significant difference in absorbance in the non-CI ears in the frequency above 1000 Hz before 1-month of post-implantation., after 1 month no differences in absorbances were found in non-CI ears. Few of the limitations pertaining to this study could be the elderly age group involved in the study. Since the study had incomplete data at different time points after the implantation, it is essential to assess each time point because there are rapid changes occurring in the middle and inner ear following cochlear implantation. Additionally, it's worth considering the potential influence of aging on absorbance, as previous research by Mazlan et al. (2015) has noted its effects, which could have affected the results.

Even if we address the limitations mentioned earlier by comparing different groups, the varying time elapsed after implantation could still have an impact. Therefore, conducting a long-term study that examines the effects of CI surgery at different time points can provide a more comprehensive understanding of the significant changes that occur after the procedure. All the studies discussed focused on addressing the impact of CI surgery specifically in octave frequencies. However, it's important to examine absorbance changes at even more precise frequencies, as there might be specific frequencies where differences are observed while others remain unaffected. Therefore, it would be a limitation to solely compare the groups based on the octave frequencies.

### 2.5 Comparison of absorbance at peak and ambient pressure conditions between the two electrode types

The electrodes of different manufacturers have somewhat different electrode characteristics such as length, width, material, angle and number of electrodes (Ertas et al., 2022). These differences in the electrodes might have effect on the absorbance patterns of the middle ear and on the stiffness characteristics of the cochlea, due to the variability in the fluid volume displacement caused by them. No literature pertaining to the effect of different types of electrodes on the middle ear impedance were found during the literature review.

# Chapter III

# Method

The present study aimed to compare the findings of WBT at peak and ambient pressure conditions in normal-hearing children and those with sensorineural hearing loss with or without CI. Additionally, the present study also aimed to compare findings of WBT between the implant and non-implant ears of children with a unilateral cochlear implant. A final aim of the present study was to compare the WBT findings between the electrode types.

## 3.1 Research design

To accomplish the aims of the study, a 'standard multiple group comparison' research design was used.

## 3.2 Participants

The present study incorporated three groups of children in the age range of 3-13 years who were divided into three groups on the basis of certain pre-defined criteria. The parents/guardians of these children signed the informed written consent prior to their children's enrolment in the study. The consent form is attached in Appendix A. Their participation in the study was on a non-payment basis.

### 3.2.1 Group I (Normal hearing children)

Group I consisted of 20 normal-hearing children (10 males & 10 females, mean age = 7.20 years, SD = 2.25, median age = 8.00 years, IQR = 3.00). The normal auditory function in them was ensured through a detailed structured case history, otoscopic examination, and audiological evaluation consisting of pure tone audiometry, immittance evaluation, otoacoustic emissions, and auditory brainstem responses. The participants in this group had air-conduction pure-tone thresholds of 20 dB HL or less across the octave and mid-octave frequencies between 250 to 8000 Hz, ‘A’ type tympanogram on standard single-frequency (226 Hz) tympanometry, presence of acoustic stapedial reflex at or below 100dB for frequency range of 500–2000 Hz, and presence of transient evoked otoacoustic emissions defined by the signal-to-noise ratio of ≥6 dB with a response reproducibility of ≥75%. Furthermore, their auditory brainstem response traces had presence of discernible peaks with inter-aural latency difference of ≤0.2 ms, inter-peak latency difference of ≤2.0 ms for waves I-III and III-V and ≤4.0 ms for waves I-V, and the amplitude ratio of V/I ≥0.5.

### 3.2.2 Group II (Children with sensorineural hearing loss who had undergone cochlear implantation)

Group II consisted of 20 children (11 males & 9 females, mean age = 5.20 years, SD = 1.11, median age = 5.30 years, IQR = 1.70). with congenital bilateral hearing impairment who have undergone unilateral cochlear implantation. The individuals in this group had no history of chronic otitis media, other middle-ear diseases, or prior ear surgery other than the CI surgery. The participants’ files were explored to verify normal anatomy before the surgery, as evidenced through radiological evaluation. Furthermore, the participants included in this group were devoid of post-surgical complications. The final inclusion criteria was at least a 30 days gap after the cochlear implantation surgery in order to ensure against the presence of post-implantation inflammatory changes at the time of their participation in the study. The mean age of the children in this group was 5.2 years with a standard deviation of 1.11 (age range: 3.1-6.9 years, median age = 5.30 years, IQR = 1.70) and the mean implant age was 5.65 months with a standard deviation of 4.25 (range = 1-16 months, median age = 4.00 years, IQR = 7.00). The demographics including the age, implant age, side of implant, CI manufacturer and electrode type, model of processor, model of implant and surgeon is given in Table 3.2.2.1 and Table 3.2.2.2.

**Table 3.2.2.1.**

*Demographic data for the study participants of CI group*

| CI Participants | Age (in years) | Implant Age (in months) | Side of Implant | CI Manufacturer | Processor Model | Implant Model | Surgeon |
|---|---|---|---|---|---|---|---|
| 1 | 5.1 | 5 | Right | Cochlear | CP802 | CI422 | A |
| 2 | 6.3 | 11 | Right | Med-El | Opus 2 | Sonata Ti100 | B |
| 3 | 3.5 | 4 | Left | Med-El | Opus 2 | Sonata Ti100 | C |
| 4 | 3.9 | 9 | Right | Med-El | Opus 2 | Sonata Ti100 | B |
| 5 | 5.2 | 5 | Right | Cochlear | CP802 | CI422 | D |
| 6 | 5.6 | 12 | Right | Med-El | Opus 2 | Sonata Ti100 | E |
| 7 | 4.9 | 3 | Right | Cochlear | CP802 | CI422 | C |
| 8 | 6.9 | 8 | Right | Med-El | Opus 2 | Sonata Ti100 | F |
| 9 | 4.4 | 2 | Right | Cochlear | CP802 | CI422 | C |
| 10 | 5.5 | 3 | Right | Cochlear | CP802 | CI422 | G |
| 11 | 3.1 | 1 | Right | Cochlear | CP802 | CI422 | F |
| 12 | 6.3 | 3 | Right | Cochlear | CP802 | CI422 | C |
| 13 | 5.1 | 3 | Right | Cochlear | CP802 | CI422 | C |
| 14 | 5.4 | 1 | Right | Cochlear | CP802 | CI422 | G |
| 15 | 6.3 | 11 | Left | Cochlear | CP802 | CI422 | D |
| 16 | 5.9 | 2 | Right | Cochlear | CP802 | CI422 | D |
| 17 | 6.5 | 8 | Right | Med-El | Opus 2 | Sonata Ti100 | F |
| 18 | 3.1 | 16 | Right | Cochlear | CP802 | CI422 | D |
| 19 | 5.1 | 4 | Left | Cochlear | CP802 | CI422 | B |
| 20 | 6 | 2 | Right | Cochlear | CP802 | CI422 | B |

**Table 3.2.2.2.**

*Demographic characteristics of CI group*

| Characteristics | Specifics | No. of patients |
|---|---|---|
| Side of Implant | Right | 17 |
| | Left | 3 |
| CI Manufacturer and electrode type | Cochlear (CI422) | 14 |
| | Medel-El (Sonata Ti100) | 6 |
| Surgeon | A | 1 |
| | B | 4 |
| | C | 5 |
| | D | 4 |
| | E | 1 |
| | F | 3 |
| | G | 2 |

### 3.2.3 Group III (Children with sensorineural hearing loss who use hearing aids in both ears)

Group III consisted of 20 children (10 males & 10 females, mean age = 7.85 years, SD = 3.22, median age = 7.25 years, IQR = 5.85), with sensorineural hearing loss of severe to profound degree, fitted with binaural hearing aids. The diagnosis of the specified degree of hearing loss of sensorineural variety was ensured through a detailed structured case history, otoscopic examination, and audiological evaluation consisting of pure tone audiometry, immittance evaluation, otoacoustic emissions, and auditory brainstem response. In addition, the above-mentioned test battery ensured that the children do not have any middle ear pathology. The other inclusion criteria in this group were the same as in Group II, except that they did not undergo cochlear implantation. Also, the information on inner ear anomalies is not known for several of them, since they have not undergone cochlear implant candidacy assessment.

### 3.3 Test Environment

The wideband tympanometry was performed in a sound-treated room with ambient noise levels within the permissible limits (ANSI S3.1 1991). The test rooms were air-conditioned and had appropriate illumination.

### 3.4 Procedure

The WBT measurements were performed using an Interacoustics Titan Suite IMP440/WBT440 version 3.3.1 equipment (Interacoustics A/S, Middelfart, Denmark) with an advanced research module. Participants were seated comfortably and instructed to remain still and quiet for the entire test duration. After completing the otoscopy, an airtight seal was obtained in the ear canal with a suitable ear tip. WBA was obtained using the click stimulus of 100 dB peSPL delivered at a rate of 21.5 Hz. The ear canal pressure was swept from +200 to -400 daPa at a rate of 200 daPa/s. The responses to 40 clicks were averaged to obtain the final WBT graph. The energy absorbance and other WBT parameter values at tympanometric peak pressure and ambient pressure conditions across frequencies were noted. The WBT measurement produced 122 frequency data points (1/24th octave bands) and all the 122 frequencies were analysed in the present study. The system was calibrated every day using the calibration software given by the manufacturer, which is comparable to the source parameter calibration in four metal waveguide calibration units of 0.2, 0.5, 2, and 5 cc volumes. The cavity radius for cavities used in the study was 0.2 cm. The method suggested by Norgaard et al. (2017) was used to reduce evanescent wave effects, and the use of small diameter cavities connected directly to the transducer without a plastic tip assured reliable transducer placement in the calibration cavities (direct coupling). By verifying that all participants had low absorbance at the lowest end of the frequency (10% or 0.1 absorbances), the probe fit and insertion depth was determined.

**3.5 Statistical Analyses:**

All statistical analyses were accomplished using SPSS software version 20 or Smith's Statistical Package (SSP, a free public domain software). The Shapiro-Wilk's test of normality was used to decide on the use of parametric or non-parametric procedures to compare wideband tympanometry findings across subjects. The results of Shapiro Wilk's test showed non-normality in both the ears of all the three groups for a majority of the frequencies ($p < 0.05$) and hence further statistical analyses were carried out using non-parametric tests.

For the comparison of the WBT measures among the groups, a Kruskal-Wallis *H* test was carried out. In case of a significant difference on the Kruskal-Wallis *H* test ($p < 0.05$), Mann-Whitney *U* test was used for pair-wise comparison between the groups. For a statistically significant difference, the α-correction (*p*-value divided by the number of pair-wise comparisons) was applied due to which a *p*-value of < 0.016 was considered for a statistically significant difference. This was done to eliminate the chances of type 1 error due to multiple comparisons. Further, the Mann-Whitney *U* test was also used for comparison between the two electrode types. For the comparison within the group, the Wilcoxon signed rank test was used.

For analysis and comparison of the individual data, the criteria based on IQR and median of the normal hearing group was used. Whenever the absorbance values in the CI group or the SNHL group fell outside the range of IQR and median of the NH group, (formula mentioned in Equation 1 and Equation 2) , the absorbance value was deemed abnormal (Bouton & Cole, 2014; Tukey, 1977).

$$Lower\ Bound = Q1 - 0.75 * IQR \qquad - Equation\ 1$$

$$Upper\ Bound = Q3 + 0.75 * IQR \qquad - Equation\ 2,$$

where, Q1 is first quartile of the normal hearing group; Q3 is third quartile of the normal hearing group; IQR is interquartile range of the normal hearing group.

The proportion of such abnormal results were compared between the groups using the Equality of test for proportion using the SSP software. For the within group comparison of such proportions, a McNemar test was administered.

# Chapter IV

## Results

The present study aimed to compare the findings of WBT at peak and ambient pressure conditions in normal-hearing children and those with sensorineural hearing loss with or without CI. Additionally, the present study also aimed to compare the findings of WBT between the implant and non-implant ears of children with a unilateral cochlear implant. A final aim of the present study was to compare the WBT findings between the electrode types. To fulfill these aims, WBT was performed on 60 children, of which 20 had normal hearing (henceforth called NH group) and 40 had congenital hearing impairment of sensorineural type. Among the 40 with a sensorineural hearing loss, 20 had undergone unilateral CI (henceforth called the CI group), whereas the remaining 20 were bilateral hearing aid users (henceforth called the SNHL group). Since the CI group had implantation done in 17 right ears and 3 left ears; the comparison of the implant ears was done with 17 right ears and 3 left ears in the other two groups. A similar approach was used for the comparison of non-implant ears. The absorbance values were recorded at peak pressure and ambient pressure conditions across 122 frequencies ranging from 226 Hz to 8000 Hz. The comparisons of these measures were done separately for peak and ambient pressure conditions. Further, the resonance frequency values were also obtained from both ears of all participants for within and between groups comparisons.

Shapiro-Wilk's test of normality showed a non-normal distribution ($p < 0.05$) of data at a majority of the test frequencies. Hence, further statistical analyses necessitated the use of non-parametric tests.

### 4.1 Comparison of absorbance at peak and ambient pressure conditions among the groups.

The absorbance at peak and ambient pressure conditions across 122 frequencies were subjected to descriptive statistics in order to obtain the mean, median, standard deviation (SD), and interquartile range (IQR). The outcomes of the descriptive statistics are shown in Table 4.1.1, Table 4.1.2, and Table 4.1.3 for peak pressure condition, and Table 4.1.4, Table 4.1.5, and Table 4.1.6 for ambient pressure condition.

**Table 4.1.1.**

*Mean, standard deviation, median and interquartile range of absorbance at peak pressure in the frequency range of 226 Hz to 8000 Hz in both ears of the CI group*

| Frequency (in Hz) | CI ears of CI group | | | | Non-CI ears of CI group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 226.00 | 0.10 | 0.04 | 0.09 | 0.07 | 0.13 | 0.06 | 0.13 | 0.08 |
| 250.00 | 0.11 | 0.04 | 0.09 | 0.07 | 0.14 | 0.06 | 0.14 | 0.08 |
| 257.33 | 0.11 | 0.04 | 0.10 | 0.08 | 0.14 | 0.06 | 0.14 | 0.08 |
| 264.87 | 0.11 | 0.05 | 0.10 | 0.08 | 0.14 | 0.06 | 0.14 | 0.09 |
| 272.63 | 0.12 | 0.05 | 0.10 | 0.08 | 0.15 | 0.06 | 0.14 | 0.09 |
| 280.62 | 0.12 | 0.05 | 0.10 | 0.08 | 0.15 | 0.06 | 0.15 | 0.09 |
| 288.84 | 0.13 | 0.05 | 0.11 | 0.08 | 0.16 | 0.06 | 0.15 | 0.10 |
| 297.30 | 0.13 | 0.05 | 0.11 | 0.09 | 0.16 | 0.06 | 0.16 | 0.10 |
| 306.12 | 0.13 | 0.06 | 0.11 | 0.09 | 0.17 | 0.07 | 0.17 | 0.11 |
| 314.98 | 0.14 | 0.06 | 0.12 | 0.09 | 0.17 | 0.07 | 0.17 | 0.11 |
| 324.21 | 0.14 | 0.06 | 0.12 | 0.09 | 0.18 | 0.07 | 0.18 | 0.11 |
| 333.71 | 0.15 | 0.06 | 0.13 | 0.10 | 0.19 | 0.07 | 0.18 | 0.12 |
| 343.49 | 0.15 | 0.06 | 0.13 | 0.10 | 0.19 | 0.08 | 0.19 | 0.13 |
| 353.55 | 0.16 | 0.06 | 0.14 | 0.10 | 0.20 | 0.08 | 0.20 | 0.14 |
| 363.91 | 0.16 | 0.07 | 0.14 | 0.10 | 0.21 | 0.08 | 0.21 | 0.14 |
| 374.58 | 0.17 | 0.07 | 0.15 | 0.09 | 0.22 | 0.09 | 0.22 | 0.15 |
| 385.55 | 0.17 | 0.07 | 0.16 | 0.08 | 0.22 | 0.09 | 0.23 | 0.16 |
| 396.95 | 0.18 | 0.07 | 0.16 | 0.09 | 0.23 | 0.09 | 0.24 | 0.16 |

Table continued on next page

Table 4.1.1 continued from previous page

| Frequency (in Hz) | CI ears of CI group | | | | Non-CI ears of CI group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 408.48 | 0.18 | 0.07 | 0.16 | 0.11 | 0.24 | 0.09 | 0.25 | 0.17 |
| 420.45 | 0.19 | 0.07 | 0.17 | 0.12 | 0.25 | 0.10 | 0.26 | 0.18 |
| 432.77 | 0.19 | 0.08 | 0.17 | 0.12 | 0.26 | 0.10 | 0.26 | 0.18 |
| 445.45 | 0.20 | 0.08 | 0.18 | 0.12 | 0.27 | 0.10 | 0.27 | 0.19 |
| 458.50 | 0.20 | 0.08 | 0.19 | 0.13 | 0.27 | 0.10 | 0.27 | 0.19 |
| 471.94 | 0.22 | 0.08 | 0.21 | 0.12 | 0.29 | 0.10 | 0.29 | 0.20 |
| 485.77 | 0.22 | 0.08 | 0.21 | 0.11 | 0.30 | 0.11 | 0.29 | 0.19 |
| 500.00 | 0.23 | 0.08 | 0.22 | 0.11 | 0.31 | 0.11 | 0.30 | 0.19 |
| 514.65 | 0.24 | 0.08 | 0.24 | 0.10 | 0.32 | 0.11 | 0.31 | 0.19 |
| 529.73 | 0.24 | 0.08 | 0.24 | 0.10 | 0.33 | 0.11 | 0.31 | 0.19 |
| 545.25 | 0.25 | 0.09 | 0.25 | 0.10 | 0.34 | 0.12 | 0.33 | 0.19 |
| 561.23 | 0.26 | 0.09 | 0.25 | 0.11 | 0.36 | 0.12 | 0.34 | 0.18 |
| 577.68 | 0.27 | 0.09 | 0.26 | 0.11 | 0.37 | 0.12 | 0.35 | 0.18 |
| 594.60 | 0.28 | 0.09 | 0.25 | 0.11 | 0.39 | 0.12 | 0.36 | 0.17 |
| 612.03 | 0.28 | 0.09 | 0.26 | 0.12 | 0.39 | 0.12 | 0.37 | 0.17 |
| 629.96 | 0.29 | 0.09 | 0.27 | 0.12 | 0.40 | 0.12 | 0.38 | 0.17 |
| 648.42 | 0.30 | 0.10 | 0.27 | 0.13 | 0.41 | 0.12 | 0.40 | 0.17 |
| 667.42 | 0.31 | 0.10 | 0.28 | 0.14 | 0.42 | 0.12 | 0.41 | 0.16 |
| 686.98 | 0.32 | 0.10 | 0.29 | 0.15 | 0.43 | 0.13 | 0.41 | 0.15 |
| 707.11 | 0.32 | 0.11 | 0.29 | 0.16 | 0.45 | 0.13 | 0.42 | 0.15 |
| 727.83 | 0.33 | 0.11 | 0.29 | 0.17 | 0.46 | 0.13 | 0.42 | 0.16 |
| 749.15 | 0.34 | 0.12 | 0.30 | 0.18 | 0.47 | 0.13 | 0.43 | 0.15 |

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Table 4.1.1 continued from previous page

| Frequency (in Hz) | CI ears of CI group | | | | Non-CI ears of CI group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 771.11 | 0.35 | 0.12 | 0.32 | 0.18 | 0.48 | 0.13 | 0.45 | 0.15 |
| 793.70 | 0.36 | 0.12 | 0.33 | 0.19 | 0.49 | 0.13 | 0.46 | 0.17 |
| 816.96 | 0.37 | 0.13 | 0.34 | 0.20 | 0.51 | 0.13 | 0.48 | 0.18 |
| 840.90 | 0.38 | 0.13 | 0.35 | 0.21 | 0.52 | 0.14 | 0.50 | 0.20 |
| 865.54 | 0.39 | 0.13 | 0.35 | 0.21 | 0.53 | 0.14 | 0.52 | 0.21 |
| 890.90 | 0.40 | 0.14 | 0.36 | 0.20 | 0.55 | 0.13 | 0.53 | 0.21 |
| 917.00 | 0.41 | 0.14 | 0.37 | 0.21 | 0.56 | 0.13 | 0.53 | 0.21 |
| 943.87 | 0.42 | 0.14 | 0.39 | 0.21 | 0.57 | 0.13 | 0.54 | 0.21 |
| 971.53 | 0.44 | 0.15 | 0.41 | 0.21 | 0.59 | 0.13 | 0.54 | 0.23 |
| 1000.00 | 0.45 | 0.15 | 0.43 | 0.22 | 0.60 | 0.14 | 0.55 | 0.24 |
| 1029.30 | 0.47 | 0.15 | 0.44 | 0.23 | 0.61 | 0.14 | 0.56 | 0.25 |
| 1059.46 | 0.48 | 0.16 | 0.46 | 0.25 | 0.62 | 0.14 | 0.58 | 0.25 |
| 1090.51 | 0.49 | 0.16 | 0.47 | 0.27 | 0.63 | 0.14 | 0.60 | 0.25 |
| 1122.46 | 0.51 | 0.17 | 0.49 | 0.27 | 0.65 | 0.14 | 0.62 | 0.27 |
| 1155.35 | 0.53 | 0.17 | 0.52 | 0.28 | 0.66 | 0.13 | 0.62 | 0.23 |
| 1189.21 | 0.54 | 0.17 | 0.55 | 0.29 | 0.67 | 0.13 | 0.64 | 0.21 |
| 1224.05 | 0.56 | 0.17 | 0.58 | 0.30 | 0.67 | 0.13 | 0.66 | 0.21 |
| 1259.92 | 0.57 | 0.17 | 0.61 | 0.29 | 0.67 | 0.14 | 0.69 | 0.23 |
| 1296.84 | 0.59 | 0.17 | 0.64 | 0.27 | 0.67 | 0.15 | 0.70 | 0.23 |
| 1334.84 | 0.60 | 0.17 | 0.65 | 0.26 | 0.68 | 0.16 | 0.70 | 0.24 |
| 1373.95 | 0.61 | 0.17 | 0.66 | 0.25 | 0.68 | 0.16 | 0.70 | 0.26 |
| 1414.21 | 0.62 | 0.16 | 0.67 | 0.23 | 0.69 | 0.16 | 0.69 | 0.27 |

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Table 4.1.1 continued from previous page

| Frequency (in Hz) | CI ears of CI group | | | | Non-CI ears of CI group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 1455.65 | 0.63 | 0.16 | 0.67 | 0.23 | 0.70 | 0.15 | 0.69 | 0.27 |
| 1498.31 | 0.64 | 0.15 | 0.68 | 0.21 | 0.70 | 0.15 | 0.69 | 0.27 |
| 1542.21 | 0.64 | 0.15 | 0.68 | 0.20 | 0.70 | 0.16 | 0.70 | 0.26 |
| 1587.40 | 0.65 | 0.15 | 0.67 | 0.19 | 0.69 | 0.17 | 0.70 | 0.25 |
| 1633.92 | 0.66 | 0.15 | 0.65 | 0.18 | 0.69 | 0.17 | 0.72 | 0.22 |
| 1681.79 | 0.67 | 0.14 | 0.65 | 0.19 | 0.69 | 0.16 | 0.74 | 0.20 |
| 1731.07 | 0.68 | 0.14 | 0.67 | 0.20 | 0.69 | 0.15 | 0.74 | 0.18 |
| 1781.80 | 0.69 | 0.13 | 0.69 | 0.19 | 0.69 | 0.15 | 0.71 | 0.16 |
| 1834.01 | 0.71 | 0.13 | 0.70 | 0.17 | 0.69 | 0.15 | 0.71 | 0.14 |
| 1887.75 | 0.73 | 0.13 | 0.72 | 0.17 | 0.68 | 0.15 | 0.70 | 0.14 |
| 1943.06 | 0.75 | 0.12 | 0.73 | 0.18 | 0.68 | 0.15 | 0.69 | 0.17 |
| 2000.00 | 0.76 | 0.12 | 0.76 | 0.19 | 0.68 | 0.14 | 0.68 | 0.14 |
| 2058.60 | 0.78 | 0.12 | 0.78 | 0.19 | 0.68 | 0.14 | 0.67 | 0.16 |
| 2118.93 | 0.80 | 0.12 | 0.80 | 0.19 | 0.69 | 0.15 | 0.66 | 0.18 |
| 2181.02 | 0.81 | 0.12 | 0.83 | 0.17 | 0.69 | 0.15 | 0.68 | 0.23 |
| 2244.92 | 0.83 | 0.11 | 0.85 | 0.16 | 0.71 | 0.15 | 0.70 | 0.26 |
| 2310.71 | 0.84 | 0.11 | 0.86 | 0.15 | 0.72 | 0.15 | 0.72 | 0.30 |
| 2378.41 | 0.85 | 0.11 | 0.87 | 0.15 | 0.74 | 0.15 | 0.74 | 0.30 |
| 2448.11 | 0.86 | 0.11 | 0.88 | 0.14 | 0.76 | 0.15 | 0.76 | 0.29 |
| 2519.84 | 0.86 | 0.12 | 0.90 | 0.13 | 0.78 | 0.15 | 0.79 | 0.28 |
| 2593.68 | 0.86 | 0.12 | 0.91 | 0.11 | 0.80 | 0.14 | 0.83 | 0.28 |
| 2669.68 | 0.86 | 0.12 | 0.89 | 0.09 | 0.82 | 0.14 | 0.86 | 0.26 |

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Table 4.1.1 continued from previous page

| Frequency (in Hz) | CI ears of CI group | | | | Non-CI ears of CI group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 2747.91 | 0.86 | 0.12 | 0.89 | 0.10 | 0.84 | 0.13 | 0.87 | 0.24 |
| 2828.43 | 0.86 | 0.11 | 0.89 | 0.12 | 0.85 | 0.13 | 0.89 | 0.23 |
| 2911.31 | 0.86 | 0.11 | 0.88 | 0.10 | 0.86 | 0.12 | 0.90 | 0.21 |
| 2996.61 | 0.86 | 0.11 | 0.88 | 0.12 | 0.86 | 0.12 | 0.91 | 0.19 |
| 3084.42 | 0.86 | 0.11 | 0.88 | 0.15 | 0.87 | 0.11 | 0.91 | 0.18 |
| 3174.80 | 0.85 | 0.12 | 0.88 | 0.16 | 0.87 | 0.10 | 0.91 | 0.14 |
| 3267.83 | 0.85 | 0.13 | 0.87 | 0.17 | 0.87 | 0.09 | 0.90 | 0.10 |
| 3363.59 | 0.84 | 0.13 | 0.85 | 0.17 | 0.87 | 0.09 | 0.90 | 0.07 |
| 3462.15 | 0.84 | 0.14 | 0.83 | 0.18 | 0.87 | 0.09 | 0.89 | 0.08 |
| 3563.59 | 0.83 | 0.14 | 0.82 | 0.19 | 0.86 | 0.10 | 0.89 | 0.10 |
| 3668.02 | 0.83 | 0.14 | 0.83 | 0.21 | 0.85 | 0.10 | 0.89 | 0.12 |
| 3775.50 | 0.82 | 0.14 | 0.83 | 0.22 | 0.84 | 0.11 | 0.88 | 0.15 |
| 3886.13 | 0.81 | 0.14 | 0.80 | 0.24 | 0.83 | 0.11 | 0.85 | 0.17 |
| 4000.00 | 0.79 | 0.15 | 0.81 | 0.23 | 0.82 | 0.12 | 0.84 | 0.17 |
| 4117.21 | 0.77 | 0.15 | 0.81 | 0.22 | 0.81 | 0.13 | 0.84 | 0.20 |
| 4237.85 | 0.75 | 0.17 | 0.80 | 0.25 | 0.79 | 0.14 | 0.81 | 0.21 |
| 4362.03 | 0.73 | 0.18 | 0.78 | 0.28 | 0.78 | 0.15 | 0.77 | 0.25 |
| 4489.85 | 0.71 | 0.19 | 0.76 | 0.31 | 0.77 | 0.16 | 0.75 | 0.26 |
| 4621.41 | 0.69 | 0.20 | 0.74 | 0.35 | 0.75 | 0.17 | 0.73 | 0.28 |
| 4756.83 | 0.68 | 0.20 | 0.70 | 0.35 | 0.74 | 0.17 | 0.72 | 0.30 |
| 4896.21 | 0.66 | 0.21 | 0.67 | 0.35 | 0.73 | 0.18 | 0.70 | 0.32 |
| 5039.68 | 0.64 | 0.20 | 0.65 | 0.34 | 0.71 | 0.18 | 0.68 | 0.34 |

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Table 4.1.1 continued from previous page

| Frequency (in Hz) | CI ears of CI group | | | | Non-CI ears of CI group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 5187.36 | 0.62 | 0.20 | 0.62 | 0.31 | 0.69 | 0.19 | 0.66 | 0.34 |
| 5339.36 | 0.59 | 0.19 | 0.58 | 0.30 | 0.66 | 0.19 | 0.62 | 0.34 |
| 5495.81 | 0.56 | 0.19 | 0.54 | 0.30 | 0.63 | 0.19 | 0.57 | 0.36 |
| 5656.85 | 0.52 | 0.19 | 0.50 | 0.29 | 0.59 | 0.19 | 0.52 | 0.35 |
| 5822.61 | 0.49 | 0.18 | 0.46 | 0.28 | 0.55 | 0.18 | 0.48 | 0.35 |
| 5993.23 | 0.46 | 0.18 | 0.42 | 0.29 | 0.52 | 0.18 | 0.44 | 0.35 |
| 6168.84 | 0.43 | 0.18 | 0.39 | 0.28 | 0.48 | 0.17 | 0.41 | 0.34 |
| 6349.60 | 0.40 | 0.17 | 0.35 | 0.26 | 0.45 | 0.17 | 0.39 | 0.33 |
| 6535.66 | 0.38 | 0.17 | 0.33 | 0.23 | 0.42 | 0.16 | 0.37 | 0.30 |
| 6727.17 | 0.36 | 0.16 | 0.32 | 0.20 | 0.39 | 0.16 | 0.36 | 0.27 |
| 6924.29 | 0.34 | 0.15 | 0.33 | 0.19 | 0.37 | 0.16 | 0.35 | 0.27 |
| 7127.19 | 0.32 | 0.14 | 0.31 | 0.18 | 0.35 | 0.16 | 0.35 | 0.27 |
| 7336.03 | 0.31 | 0.14 | 0.30 | 0.19 | 0.34 | 0.16 | 0.35 | 0.26 |
| 7550.99 | 0.30 | 0.14 | 0.29 | 0.20 | 0.33 | 0.17 | 0.32 | 0.26 |
| 7772.26 | 0.30 | 0.14 | 0.29 | 0.21 | 0.32 | 0.17 | 0.31 | 0.27 |
| 8000.00 | 0.30 | 0.14 | 0.29 | 0.21 | 0.32 | 0.18 | 0.31 | 0.27 |

*Note*. ‘SD’- standard deviation, ‘IQR’- interquartile range

Table 4.1.2.

*Mean, standard deviation, median and interquartile range of absorbance at peak pressure in the frequency range of 226 Hz to 8000 Hz in both ears of SNHL group*

| Frequency (in Hz) | CI-matched ears of SNHL group | | | | Non-CI-matched ears of SNHL group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 226.00 | 0.17 | 0.10 | 0.15 | 0.09 | 0.16 | 0.08 | 0.14 | 0.09 |
| 250.00 | 0.18 | 0.10 | 0.16 | 0.10 | 0.17 | 0.08 | 0.15 | 0.10 |
| 257.33 | 0.18 | 0.10 | 0.16 | 0.10 | 0.17 | 0.09 | 0.15 | 0.10 |
| 264.87 | 0.19 | 0.10 | 0.17 | 0.10 | 0.17 | 0.09 | 0.15 | 0.10 |
| 272.63 | 0.19 | 0.10 | 0.17 | 0.10 | 0.18 | 0.09 | 0.16 | 0.10 |
| 280.62 | 0.20 | 0.11 | 0.17 | 0.10 | 0.18 | 0.09 | 0.16 | 0.10 |
| 288.84 | 0.20 | 0.11 | 0.18 | 0.10 | 0.19 | 0.09 | 0.17 | 0.11 |
| 297.30 | 0.21 | 0.11 | 0.19 | 0.11 | 0.20 | 0.10 | 0.18 | 0.11 |
| 306.12 | 0.22 | 0.12 | 0.19 | 0.11 | 0.20 | 0.10 | 0.18 | 0.12 |
| 314.98 | 0.22 | 0.12 | 0.20 | 0.11 | 0.21 | 0.10 | 0.19 | 0.12 |
| 324.21 | 0.23 | 0.12 | 0.21 | 0.11 | 0.21 | 0.10 | 0.20 | 0.13 |
| 333.71 | 0.24 | 0.12 | 0.22 | 0.12 | 0.22 | 0.10 | 0.21 | 0.13 |
| 343.49 | 0.24 | 0.13 | 0.23 | 0.12 | 0.23 | 0.10 | 0.22 | 0.13 |
| 353.55 | 0.25 | 0.13 | 0.24 | 0.13 | 0.24 | 0.10 | 0.24 | 0.14 |
| 363.91 | 0.26 | 0.13 | 0.25 | 0.14 | 0.25 | 0.11 | 0.25 | 0.14 |
| 374.58 | 0.27 | 0.13 | 0.26 | 0.14 | 0.25 | 0.11 | 0.26 | 0.15 |
| 385.55 | 0.28 | 0.13 | 0.27 | 0.15 | 0.26 | 0.11 | 0.27 | 0.15 |
| 396.95 | 0.28 | 0.14 | 0.28 | 0.15 | 0.27 | 0.11 | 0.27 | 0.16 |

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Table 4.1.2 continued from previous page

| Frequency (in Hz) | CI-matched ears of SNHL group | | | | Non-CI-matched ears of SNHL group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 408.48 | 0.29 | 0.14 | 0.29 | 0.16 | 0.28 | 0.11 | 0.28 | 0.16 |
| 420.45 | 0.30 | 0.14 | 0.30 | 0.16 | 0.29 | 0.11 | 0.28 | 0.17 |
| 432.77 | 0.31 | 0.14 | 0.31 | 0.17 | 0.29 | 0.11 | 0.29 | 0.17 |
| 445.45 | 0.32 | 0.14 | 0.32 | 0.17 | 0.30 | 0.12 | 0.30 | 0.17 |
| 458.50 | 0.32 | 0.14 | 0.33 | 0.18 | 0.31 | 0.12 | 0.31 | 0.17 |
| 471.94 | 0.34 | 0.15 | 0.35 | 0.19 | 0.32 | 0.12 | 0.32 | 0.17 |
| 485.77 | 0.34 | 0.15 | 0.36 | 0.19 | 0.33 | 0.12 | 0.32 | 0.18 |
| 500.00 | 0.35 | 0.15 | 0.36 | 0.19 | 0.34 | 0.12 | 0.33 | 0.18 |
| 514.65 | 0.36 | 0.15 | 0.37 | 0.18 | 0.36 | 0.13 | 0.35 | 0.19 |
| 529.73 | 0.37 | 0.16 | 0.37 | 0.17 | 0.37 | 0.13 | 0.36 | 0.19 |
| 545.25 | 0.38 | 0.16 | 0.38 | 0.17 | 0.38 | 0.13 | 0.36 | 0.20 |
| 561.23 | 0.39 | 0.16 | 0.38 | 0.16 | 0.39 | 0.14 | 0.36 | 0.22 |
| 577.68 | 0.40 | 0.16 | 0.39 | 0.15 | 0.41 | 0.14 | 0.37 | 0.24 |
| 594.60 | 0.40 | 0.16 | 0.39 | 0.14 | 0.42 | 0.15 | 0.37 | 0.26 |
| 612.03 | 0.41 | 0.16 | 0.39 | 0.14 | 0.42 | 0.15 | 0.38 | 0.26 |
| 629.96 | 0.41 | 0.16 | 0.40 | 0.14 | 0.43 | 0.15 | 0.39 | 0.26 |
| 648.42 | 0.42 | 0.16 | 0.41 | 0.14 | 0.45 | 0.16 | 0.40 | 0.27 |
| 667.42 | 0.43 | 0.17 | 0.42 | 0.13 | 0.46 | 0.16 | 0.40 | 0.28 |
| 686.98 | 0.44 | 0.17 | 0.43 | 0.13 | 0.46 | 0.16 | 0.41 | 0.28 |
| 707.11 | 0.45 | 0.17 | 0.44 | 0.13 | 0.47 | 0.16 | 0.42 | 0.27 |
| 727.83 | 0.46 | 0.17 | 0.44 | 0.14 | 0.48 | 0.16 | 0.42 | 0.26 |
| 749.15 | 0.47 | 0.17 | 0.44 | 0.14 | 0.48 | 0.16 | 0.43 | 0.26 |

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Table 4.1.2 continued from previous page

| Frequency (in Hz) | CI-matched ears of SNHL group | | | | Non-CI-matched ears of SNHL group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 771.11 | 0.47 | 0.17 | 0.45 | 0.14 | 0.49 | 0.16 | 0.43 | 0.27 |
| 793.70 | 0.48 | 0.17 | 0.45 | 0.15 | 0.50 | 0.16 | 0.44 | 0.27 |
| 816.96 | 0.49 | 0.17 | 0.45 | 0.15 | 0.51 | 0.16 | 0.45 | 0.27 |
| 840.90 | 0.50 | 0.17 | 0.46 | 0.16 | 0.51 | 0.16 | 0.46 | 0.27 |
| 865.54 | 0.51 | 0.17 | 0.47 | 0.18 | 0.52 | 0.16 | 0.47 | 0.27 |
| 890.90 | 0.52 | 0.17 | 0.48 | 0.19 | 0.53 | 0.16 | 0.48 | 0.27 |
| 917.00 | 0.53 | 0.17 | 0.49 | 0.19 | 0.55 | 0.16 | 0.50 | 0.27 |
| 943.87 | 0.54 | 0.17 | 0.50 | 0.21 | 0.56 | 0.16 | 0.51 | 0.27 |
| 971.53 | 0.55 | 0.16 | 0.51 | 0.22 | 0.57 | 0.16 | 0.53 | 0.27 |
| 1000.00 | 0.56 | 0.16 | 0.53 | 0.22 | 0.58 | 0.16 | 0.55 | 0.27 |
| 1029.30 | 0.56 | 0.15 | 0.54 | 0.21 | 0.59 | 0.16 | 0.56 | 0.26 |
| 1059.46 | 0.57 | 0.15 | 0.56 | 0.18 | 0.60 | 0.15 | 0.58 | 0.26 |
| 1090.51 | 0.57 | 0.14 | 0.56 | 0.16 | 0.61 | 0.15 | 0.59 | 0.25 |
| 1122.46 | 0.58 | 0.14 | 0.57 | 0.16 | 0.61 | 0.14 | 0.60 | 0.22 |
| 1155.35 | 0.58 | 0.14 | 0.57 | 0.17 | 0.62 | 0.14 | 0.61 | 0.20 |
| 1189.21 | 0.58 | 0.14 | 0.59 | 0.18 | 0.62 | 0.13 | 0.62 | 0.19 |
| 1224.05 | 0.59 | 0.13 | 0.59 | 0.18 | 0.63 | 0.13 | 0.65 | 0.17 |
| 1259.92 | 0.59 | 0.13 | 0.58 | 0.18 | 0.63 | 0.12 | 0.65 | 0.14 |
| 1296.84 | 0.59 | 0.13 | 0.57 | 0.21 | 0.63 | 0.12 | 0.65 | 0.13 |
| 1334.84 | 0.59 | 0.13 | 0.56 | 0.22 | 0.63 | 0.12 | 0.65 | 0.13 |
| 1373.95 | 0.59 | 0.13 | 0.56 | 0.21 | 0.63 | 0.12 | 0.64 | 0.12 |
| 1414.21 | 0.59 | 0.13 | 0.55 | 0.20 | 0.62 | 0.11 | 0.64 | 0.12 |

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Table 4.1.2 continued from previous page

| Frequency (in Hz) | CI-matched ears of SNHL group | | | | Non-CI-matched ears of SNHL group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 1455.65 | 0.59 | 0.12 | 0.57 | 0.20 | 0.62 | 0.11 | 0.63 | 0.12 |
| 1498.31 | 0.59 | 0.12 | 0.58 | 0.19 | 0.62 | 0.10 | 0.63 | 0.13 |
| 1542.21 | 0.59 | 0.11 | 0.58 | 0.20 | 0.62 | 0.10 | 0.63 | 0.16 |
| 1587.40 | 0.59 | 0.11 | 0.59 | 0.21 | 0.63 | 0.10 | 0.63 | 0.16 |
| 1633.92 | 0.59 | 0.11 | 0.60 | 0.21 | 0.63 | 0.10 | 0.62 | 0.15 |
| 1681.79 | 0.60 | 0.11 | 0.59 | 0.21 | 0.63 | 0.11 | 0.61 | 0.15 |
| 1731.07 | 0.60 | 0.11 | 0.59 | 0.21 | 0.64 | 0.12 | 0.62 | 0.16 |
| 1781.80 | 0.60 | 0.11 | 0.59 | 0.21 | 0.64 | 0.12 | 0.64 | 0.17 |
| 1834.01 | 0.61 | 0.11 | 0.59 | 0.21 | 0.64 | 0.13 | 0.64 | 0.17 |
| 1887.75 | 0.61 | 0.12 | 0.60 | 0.22 | 0.65 | 0.14 | 0.66 | 0.18 |
| 1943.06 | 0.61 | 0.12 | 0.61 | 0.23 | 0.65 | 0.15 | 0.67 | 0.19 |
| 2000.00 | 0.62 | 0.13 | 0.62 | 0.22 | 0.66 | 0.16 | 0.65 | 0.23 |
| 2058.60 | 0.63 | 0.13 | 0.62 | 0.22 | 0.66 | 0.17 | 0.66 | 0.27 |
| 2118.93 | 0.64 | 0.14 | 0.62 | 0.23 | 0.67 | 0.17 | 0.68 | 0.30 |
| 2181.02 | 0.65 | 0.14 | 0.63 | 0.24 | 0.67 | 0.18 | 0.68 | 0.31 |
| 2244.92 | 0.66 | 0.15 | 0.65 | 0.26 | 0.68 | 0.18 | 0.69 | 0.28 |
| 2310.71 | 0.67 | 0.16 | 0.66 | 0.26 | 0.68 | 0.18 | 0.68 | 0.25 |
| 2378.41 | 0.67 | 0.17 | 0.68 | 0.26 | 0.69 | 0.18 | 0.68 | 0.26 |
| 2448.11 | 0.68 | 0.17 | 0.70 | 0.27 | 0.69 | 0.19 | 0.68 | 0.26 |
| 2519.84 | 0.68 | 0.18 | 0.69 | 0.28 | 0.69 | 0.19 | 0.68 | 0.25 |
| 2593.68 | 0.68 | 0.18 | 0.69 | 0.29 | 0.69 | 0.19 | 0.70 | 0.26 |
| 2669.68 | 0.69 | 0.18 | 0.70 | 0.29 | 0.69 | 0.20 | 0.71 | 0.29 |

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Table 4.1.2 continued from previous page

| Frequency (in Hz) | CI-matched ears of SNHL group | | | | Non-CI-matched ears of SNHL group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 2747.91 | 0.69 | 0.17 | 0.69 | 0.30 | 0.69 | 0.20 | 0.73 | 0.26 |
| 2828.43 | 0.70 | 0.17 | 0.69 | 0.29 | 0.69 | 0.21 | 0.74 | 0.23 |
| 2911.31 | 0.70 | 0.17 | 0.68 | 0.25 | 0.69 | 0.22 | 0.74 | 0.27 |
| 2996.61 | 0.71 | 0.17 | 0.69 | 0.27 | 0.70 | 0.22 | 0.74 | 0.32 |
| 3084.42 | 0.71 | 0.17 | 0.71 | 0.28 | 0.71 | 0.23 | 0.74 | 0.33 |
| 3174.80 | 0.71 | 0.18 | 0.72 | 0.23 | 0.71 | 0.23 | 0.76 | 0.32 |
| 3267.83 | 0.70 | 0.20 | 0.72 | 0.23 | 0.72 | 0.23 | 0.76 | 0.33 |
| 3363.59 | 0.70 | 0.21 | 0.73 | 0.25 | 0.72 | 0.22 | 0.76 | 0.34 |
| 3462.15 | 0.70 | 0.21 | 0.74 | 0.24 | 0.72 | 0.22 | 0.73 | 0.32 |
| 3563.59 | 0.70 | 0.20 | 0.73 | 0.22 | 0.72 | 0.22 | 0.73 | 0.30 |
| 3668.02 | 0.71 | 0.19 | 0.73 | 0.21 | 0.71 | 0.21 | 0.73 | 0.28 |
| 3775.50 | 0.72 | 0.17 | 0.74 | 0.22 | 0.71 | 0.20 | 0.73 | 0.29 |
| 3886.13 | 0.72 | 0.16 | 0.74 | 0.19 | 0.71 | 0.19 | 0.74 | 0.32 |
| 4000.00 | 0.72 | 0.15 | 0.75 | 0.22 | 0.70 | 0.18 | 0.73 | 0.35 |
| 4117.21 | 0.72 | 0.15 | 0.75 | 0.24 | 0.70 | 0.18 | 0.71 | 0.32 |
| 4237.85 | 0.71 | 0.15 | 0.73 | 0.24 | 0.70 | 0.17 | 0.70 | 0.29 |
| 4362.03 | 0.70 | 0.15 | 0.70 | 0.25 | 0.69 | 0.17 | 0.71 | 0.29 |
| 4489.85 | 0.69 | 0.16 | 0.68 | 0.25 | 0.68 | 0.17 | 0.72 | 0.30 |
| 4621.41 | 0.67 | 0.16 | 0.66 | 0.24 | 0.68 | 0.17 | 0.72 | 0.29 |
| 4756.83 | 0.66 | 0.16 | 0.65 | 0.22 | 0.67 | 0.16 | 0.72 | 0.28 |
| 4896.21 | 0.65 | 0.15 | 0.63 | 0.19 | 0.67 | 0.16 | 0.73 | 0.27 |
| 5039.68 | 0.64 | 0.15 | 0.62 | 0.19 | 0.66 | 0.15 | 0.69 | 0.26 |

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Table 4.1.2 continued from previous page

| Frequency (in Hz) | CI-matched ears of SNHL group | | | | Non-CI-matched ears of SNHL group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 5187.36 | 0.62 | 0.14 | 0.62 | 0.18 | 0.65 | 0.15 | 0.64 | 0.25 |
| 5339.36 | 0.59 | 0.14 | 0.60 | 0.17 | 0.62 | 0.15 | 0.62 | 0.26 |
| 5495.81 | 0.56 | 0.13 | 0.57 | 0.15 | 0.59 | 0.14 | 0.61 | 0.23 |
| 5656.85 | 0.53 | 0.14 | 0.52 | 0.17 | 0.55 | 0.14 | 0.60 | 0.21 |
| 5822.61 | 0.49 | 0.14 | 0.47 | 0.18 | 0.52 | 0.14 | 0.56 | 0.22 |
| 5993.23 | 0.46 | 0.15 | 0.43 | 0.20 | 0.48 | 0.14 | 0.51 | 0.22 |
| 6168.84 | 0.43 | 0.15 | 0.40 | 0.22 | 0.45 | 0.14 | 0.48 | 0.20 |
| 6349.60 | 0.41 | 0.15 | 0.38 | 0.24 | 0.42 | 0.14 | 0.44 | 0.21 |
| 6535.66 | 0.39 | 0.16 | 0.37 | 0.24 | 0.39 | 0.14 | 0.40 | 0.21 |
| 6727.17 | 0.37 | 0.16 | 0.35 | 0.25 | 0.37 | 0.15 | 0.38 | 0.22 |
| 6924.29 | 0.35 | 0.16 | 0.34 | 0.25 | 0.35 | 0.15 | 0.36 | 0.23 |
| 7127.19 | 0.34 | 0.17 | 0.31 | 0.26 | 0.33 | 0.15 | 0.34 | 0.23 |
| 7336.03 | 0.34 | 0.18 | 0.28 | 0.28 | 0.32 | 0.15 | 0.31 | 0.23 |
| 7550.99 | 0.34 | 0.19 | 0.26 | 0.30 | 0.31 | 0.15 | 0.31 | 0.24 |
| 7772.26 | 0.34 | 0.20 | 0.25 | 0.31 | 0.31 | 0.15 | 0.31 | 0.25 |
| 8000.00 | 0.34 | 0.20 | 0.27 | 0.30 | 0.31 | 0.16 | 0.31 | 0.25 |

*Note.* ‘SD’- standard deviation, ‘IQR’- interquartile range

Table 4.1.3.

*Mean, standard deviation, median and interquartile range of absorbance at peak pressure in the frequency range of 226 Hz to 8000 Hz in both ears of the NH group*

| Frequency (in Hz) | CI-matched ears of NH group | | | | Non-CI-matched ears of NH group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 226.00 | 0.15 | 0.05 | 0.15 | 0.06 | 0.14 | 0.05 | 0.13 | 0.05 |
| 250.00 | 0.16 | 0.05 | 0.15 | 0.06 | 0.14 | 0.05 | 0.13 | 0.06 |
| 257.33 | 0.16 | 0.05 | 0.16 | 0.06 | 0.15 | 0.05 | 0.13 | 0.06 |
| 264.87 | 0.16 | 0.05 | 0.16 | 0.06 | 0.15 | 0.05 | 0.14 | 0.07 |
| 272.63 | 0.17 | 0.05 | 0.16 | 0.07 | 0.15 | 0.05 | 0.15 | 0.07 |
| 280.62 | 0.17 | 0.05 | 0.17 | 0.07 | 0.16 | 0.05 | 0.15 | 0.08 |
| 288.84 | 0.18 | 0.06 | 0.18 | 0.07 | 0.16 | 0.05 | 0.16 | 0.08 |
| 297.30 | 0.19 | 0.06 | 0.18 | 0.08 | 0.17 | 0.06 | 0.17 | 0.08 |
| 306.12 | 0.19 | 0.06 | 0.19 | 0.08 | 0.17 | 0.06 | 0.17 | 0.08 |
| 314.98 | 0.20 | 0.07 | 0.19 | 0.08 | 0.18 | 0.06 | 0.18 | 0.09 |
| 324.21 | 0.20 | 0.07 | 0.20 | 0.08 | 0.18 | 0.06 | 0.18 | 0.09 |
| 333.71 | 0.21 | 0.07 | 0.21 | 0.09 | 0.19 | 0.06 | 0.19 | 0.09 |
| 343.49 | 0.22 | 0.07 | 0.22 | 0.09 | 0.20 | 0.06 | 0.19 | 0.09 |
| 353.55 | 0.23 | 0.08 | 0.22 | 0.10 | 0.20 | 0.07 | 0.20 | 0.09 |
| 363.91 | 0.23 | 0.08 | 0.23 | 0.10 | 0.21 | 0.07 | 0.21 | 0.10 |
| 374.58 | 0.24 | 0.08 | 0.23 | 0.11 | 0.22 | 0.07 | 0.21 | 0.10 |
| 385.55 | 0.25 | 0.09 | 0.24 | 0.12 | 0.23 | 0.08 | 0.22 | 0.10 |
| 396.95 | 0.26 | 0.09 | 0.25 | 0.13 | 0.23 | 0.08 | 0.23 | 0.11 |

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Table 4.1.3 continued from previous page

| Frequency (in Hz) | CI-matched ears of NH group | | | | Non-CI-matched ears of NH group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 408.48 | 0.27 | 0.09 | 0.26 | 0.14 | 0.24 | 0.08 | 0.24 | 0.11 |
| 420.45 | 0.27 | 0.10 | 0.27 | 0.14 | 0.25 | 0.09 | 0.24 | 0.11 |
| 432.77 | 0.28 | 0.10 | 0.28 | 0.14 | 0.26 | 0.09 | 0.25 | 0.12 |
| 445.45 | 0.29 | 0.10 | 0.29 | 0.14 | 0.27 | 0.09 | 0.26 | 0.12 |
| 458.50 | 0.30 | 0.10 | 0.29 | 0.15 | 0.28 | 0.10 | 0.27 | 0.12 |
| 471.94 | 0.32 | 0.11 | 0.31 | 0.16 | 0.30 | 0.10 | 0.28 | 0.13 |
| 485.77 | 0.33 | 0.11 | 0.32 | 0.16 | 0.30 | 0.11 | 0.29 | 0.13 |
| 500.00 | 0.34 | 0.11 | 0.33 | 0.17 | 0.31 | 0.11 | 0.30 | 0.14 |
| 514.65 | 0.35 | 0.12 | 0.35 | 0.18 | 0.33 | 0.12 | 0.32 | 0.15 |
| 529.73 | 0.36 | 0.12 | 0.36 | 0.18 | 0.34 | 0.12 | 0.33 | 0.15 |
| 545.25 | 0.37 | 0.12 | 0.36 | 0.18 | 0.35 | 0.12 | 0.34 | 0.15 |
| 561.23 | 0.39 | 0.12 | 0.38 | 0.17 | 0.37 | 0.13 | 0.35 | 0.16 |
| 577.68 | 0.41 | 0.13 | 0.40 | 0.17 | 0.38 | 0.13 | 0.36 | 0.17 |
| 594.60 | 0.42 | 0.13 | 0.41 | 0.18 | 0.40 | 0.13 | 0.38 | 0.17 |
| 612.03 | 0.43 | 0.13 | 0.41 | 0.18 | 0.41 | 0.13 | 0.39 | 0.18 |
| 629.96 | 0.44 | 0.13 | 0.42 | 0.18 | 0.42 | 0.14 | 0.40 | 0.18 |
| 648.42 | 0.46 | 0.13 | 0.43 | 0.18 | 0.43 | 0.14 | 0.43 | 0.19 |
| 667.42 | 0.47 | 0.14 | 0.45 | 0.17 | 0.45 | 0.14 | 0.43 | 0.21 |
| 686.98 | 0.49 | 0.14 | 0.46 | 0.15 | 0.46 | 0.14 | 0.44 | 0.22 |
| 707.11 | 0.50 | 0.14 | 0.47 | 0.15 | 0.47 | 0.14 | 0.45 | 0.22 |
| 727.83 | 0.52 | 0.15 | 0.49 | 0.16 | 0.49 | 0.14 | 0.47 | 0.24 |
| 749.15 | 0.54 | 0.15 | 0.50 | 0.17 | 0.50 | 0.14 | 0.48 | 0.25 |

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Table 4.1.3 continued from previous page

| Frequency (in Hz) | CI-matched ears of NH group | | | | Non-CI-matched ears of NH group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 771.11 | 0.55 | 0.15 | 0.51 | 0.18 | 0.52 | 0.14 | 0.49 | 0.27 |
| 793.70 | 0.57 | 0.15 | 0.53 | 0.19 | 0.53 | 0.14 | 0.50 | 0.28 |
| 816.96 | 0.58 | 0.15 | 0.54 | 0.20 | 0.55 | 0.14 | 0.51 | 0.27 |
| 840.90 | 0.60 | 0.15 | 0.56 | 0.20 | 0.56 | 0.14 | 0.52 | 0.25 |
| 865.54 | 0.61 | 0.15 | 0.57 | 0.20 | 0.57 | 0.14 | 0.54 | 0.22 |
| 890.90 | 0.62 | 0.14 | 0.58 | 0.20 | 0.58 | 0.14 | 0.56 | 0.21 |
| 917.00 | 0.64 | 0.14 | 0.60 | 0.20 | 0.60 | 0.14 | 0.58 | 0.21 |
| 943.87 | 0.65 | 0.13 | 0.62 | 0.21 | 0.61 | 0.14 | 0.59 | 0.21 |
| 971.53 | 0.66 | 0.12 | 0.64 | 0.21 | 0.63 | 0.13 | 0.58 | 0.21 |
| 1000.00 | 0.68 | 0.12 | 0.65 | 0.21 | 0.64 | 0.13 | 0.60 | 0.21 |
| 1029.30 | 0.69 | 0.11 | 0.65 | 0.19 | 0.65 | 0.13 | 0.62 | 0.22 |
| 1059.46 | 0.69 | 0.11 | 0.66 | 0.19 | 0.66 | 0.13 | 0.64 | 0.23 |
| 1090.51 | 0.70 | 0.11 | 0.68 | 0.18 | 0.66 | 0.13 | 0.66 | 0.24 |
| 1122.46 | 0.71 | 0.11 | 0.69 | 0.17 | 0.67 | 0.13 | 0.67 | 0.22 |
| 1155.35 | 0.71 | 0.11 | 0.68 | 0.17 | 0.67 | 0.13 | 0.69 | 0.19 |
| 1189.21 | 0.71 | 0.11 | 0.69 | 0.18 | 0.68 | 0.13 | 0.71 | 0.16 |
| 1224.05 | 0.71 | 0.11 | 0.69 | 0.19 | 0.68 | 0.13 | 0.71 | 0.15 |
| 1259.92 | 0.71 | 0.12 | 0.69 | 0.20 | 0.68 | 0.13 | 0.71 | 0.15 |
| 1296.84 | 0.71 | 0.12 | 0.71 | 0.19 | 0.68 | 0.13 | 0.71 | 0.17 |
| 1334.84 | 0.71 | 0.12 | 0.72 | 0.19 | 0.67 | 0.13 | 0.70 | 0.18 |
| 1373.95 | 0.70 | 0.12 | 0.72 | 0.19 | 0.67 | 0.13 | 0.70 | 0.18 |
| 1414.21 | 0.70 | 0.12 | 0.73 | 0.20 | 0.67 | 0.13 | 0.69 | 0.17 |

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Table 4.1.3 continued from previous page

| Frequency (in Hz) | CI-matched ears of NH group | | | | Non-CI-matched ears of NH group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 1455.65 | 0.70 | 0.12 | 0.73 | 0.20 | 0.67 | 0.13 | 0.69 | 0.15 |
| 1498.31 | 0.70 | 0.12 | 0.72 | 0.19 | 0.67 | 0.13 | 0.69 | 0.15 |
| 1542.21 | 0.70 | 0.12 | 0.70 | 0.19 | 0.67 | 0.13 | 0.69 | 0.14 |
| 1587.40 | 0.70 | 0.11 | 0.68 | 0.18 | 0.67 | 0.13 | 0.69 | 0.13 |
| 1633.92 | 0.70 | 0.11 | 0.68 | 0.17 | 0.67 | 0.13 | 0.69 | 0.14 |
| 1681.79 | 0.70 | 0.10 | 0.69 | 0.17 | 0.67 | 0.13 | 0.69 | 0.15 |
| 1731.07 | 0.70 | 0.10 | 0.71 | 0.16 | 0.68 | 0.14 | 0.69 | 0.15 |
| 1781.80 | 0.71 | 0.10 | 0.71 | 0.16 | 0.68 | 0.14 | 0.69 | 0.17 |
| 1834.01 | 0.71 | 0.10 | 0.72 | 0.14 | 0.69 | 0.15 | 0.69 | 0.21 |
| 1887.75 | 0.72 | 0.10 | 0.72 | 0.14 | 0.69 | 0.15 | 0.69 | 0.25 |
| 1943.06 | 0.73 | 0.11 | 0.71 | 0.15 | 0.69 | 0.16 | 0.70 | 0.27 |
| 2000.00 | 0.73 | 0.11 | 0.72 | 0.16 | 0.70 | 0.16 | 0.72 | 0.26 |
| 2058.60 | 0.74 | 0.11 | 0.75 | 0.16 | 0.70 | 0.16 | 0.72 | 0.25 |
| 2118.93 | 0.76 | 0.11 | 0.77 | 0.17 | 0.71 | 0.16 | 0.72 | 0.25 |
| 2181.02 | 0.77 | 0.11 | 0.77 | 0.20 | 0.71 | 0.16 | 0.72 | 0.25 |
| 2244.92 | 0.79 | 0.11 | 0.80 | 0.20 | 0.72 | 0.17 | 0.74 | 0.25 |
| 2310.71 | 0.80 | 0.11 | 0.83 | 0.21 | 0.73 | 0.17 | 0.77 | 0.24 |
| 2378.41 | 0.82 | 0.11 | 0.84 | 0.20 | 0.73 | 0.17 | 0.79 | 0.22 |
| 2448.11 | 0.83 | 0.11 | 0.86 | 0.19 | 0.74 | 0.17 | 0.81 | 0.22 |
| 2519.84 | 0.84 | 0.11 | 0.88 | 0.18 | 0.75 | 0.18 | 0.83 | 0.22 |
| 2593.68 | 0.85 | 0.11 | 0.89 | 0.18 | 0.76 | 0.18 | 0.83 | 0.20 |
| 2669.68 | 0.85 | 0.11 | 0.89 | 0.21 | 0.76 | 0.18 | 0.84 | 0.18 |

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Table 4.1.3 continued from previous page

| Frequency (in Hz) | CI-matched ears of NH group | | | | Non-CI-matched ears of NH group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 2747.91 | 0.86 | 0.11 | 0.89 | 0.20 | 0.77 | 0.18 | 0.82 | 0.16 |
| 2828.43 | 0.86 | 0.11 | 0.88 | 0.20 | 0.77 | 0.18 | 0.82 | 0.19 |
| 2911.31 | 0.86 | 0.10 | 0.87 | 0.19 | 0.78 | 0.18 | 0.82 | 0.20 |
| 2996.61 | 0.86 | 0.10 | 0.88 | 0.17 | 0.78 | 0.18 | 0.82 | 0.20 |
| 3084.42 | 0.87 | 0.10 | 0.88 | 0.17 | 0.78 | 0.18 | 0.82 | 0.20 |
| 3174.80 | 0.87 | 0.11 | 0.89 | 0.16 | 0.78 | 0.18 | 0.80 | 0.22 |
| 3267.83 | 0.86 | 0.11 | 0.89 | 0.18 | 0.78 | 0.18 | 0.79 | 0.23 |
| 3363.59 | 0.86 | 0.12 | 0.89 | 0.17 | 0.78 | 0.18 | 0.80 | 0.23 |
| 3462.15 | 0.85 | 0.12 | 0.87 | 0.18 | 0.77 | 0.19 | 0.80 | 0.26 |
| 3563.59 | 0.84 | 0.13 | 0.85 | 0.20 | 0.77 | 0.19 | 0.81 | 0.29 |
| 3668.02 | 0.83 | 0.13 | 0.84 | 0.20 | 0.77 | 0.19 | 0.82 | 0.26 |
| 3775.50 | 0.82 | 0.14 | 0.85 | 0.22 | 0.77 | 0.18 | 0.83 | 0.22 |
| 3886.13 | 0.82 | 0.14 | 0.84 | 0.22 | 0.77 | 0.18 | 0.81 | 0.24 |
| 4000.00 | 0.81 | 0.15 | 0.83 | 0.21 | 0.77 | 0.17 | 0.79 | 0.21 |
| 4117.21 | 0.80 | 0.15 | 0.80 | 0.20 | 0.76 | 0.17 | 0.79 | 0.20 |
| 4237.85 | 0.78 | 0.16 | 0.80 | 0.20 | 0.75 | 0.17 | 0.81 | 0.22 |
| 4362.03 | 0.77 | 0.16 | 0.79 | 0.19 | 0.74 | 0.18 | 0.79 | 0.24 |
| 4489.85 | 0.75 | 0.16 | 0.77 | 0.17 | 0.72 | 0.18 | 0.78 | 0.25 |
| 4621.41 | 0.73 | 0.15 | 0.76 | 0.15 | 0.71 | 0.18 | 0.77 | 0.26 |
| 4756.83 | 0.71 | 0.15 | 0.74 | 0.14 | 0.69 | 0.18 | 0.74 | 0.26 |
| 4896.21 | 0.70 | 0.15 | 0.72 | 0.13 | 0.67 | 0.18 | 0.72 | 0.25 |
| 5039.68 | 0.68 | 0.15 | 0.69 | 0.14 | 0.65 | 0.17 | 0.69 | 0.24 |

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Table 4.1.3 continued from previous page

| Frequency (in Hz) | CI-matched ears of NH group | | | | Non-CI-matched ears of NH group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 5187.36 | 0.66 | 0.14 | 0.66 | 0.16 | 0.63 | 0.17 | 0.66 | 0.24 |
| 5339.36 | 0.62 | 0.14 | 0.62 | 0.17 | 0.60 | 0.16 | 0.62 | 0.23 |
| 5495.81 | 0.58 | 0.14 | 0.57 | 0.18 | 0.56 | 0.15 | 0.58 | 0.23 |
| 5656.85 | 0.54 | 0.13 | 0.52 | 0.19 | 0.53 | 0.14 | 0.53 | 0.24 |
| 5822.61 | 0.50 | 0.13 | 0.47 | 0.18 | 0.49 | 0.13 | 0.49 | 0.24 |
| 5993.23 | 0.46 | 0.13 | 0.43 | 0.19 | 0.46 | 0.12 | 0.46 | 0.21 |
| 6168.84 | 0.42 | 0.13 | 0.40 | 0.20 | 0.43 | 0.12 | 0.43 | 0.21 |
| 6349.60 | 0.40 | 0.14 | 0.36 | 0.20 | 0.40 | 0.12 | 0.41 | 0.20 |
| 6535.66 | 0.37 | 0.15 | 0.33 | 0.20 | 0.38 | 0.12 | 0.38 | 0.23 |
| 6727.17 | 0.36 | 0.16 | 0.30 | 0.19 | 0.36 | 0.12 | 0.37 | 0.22 |
| 6924.29 | 0.34 | 0.17 | 0.28 | 0.20 | 0.35 | 0.13 | 0.34 | 0.22 |
| 7127.19 | 0.34 | 0.18 | 0.28 | 0.21 | 0.34 | 0.14 | 0.32 | 0.23 |
| 7336.03 | 0.33 | 0.19 | 0.29 | 0.21 | 0.33 | 0.15 | 0.31 | 0.25 |
| 7550.99 | 0.33 | 0.19 | 0.28 | 0.23 | 0.32 | 0.15 | 0.30 | 0.25 |
| 7772.26 | 0.32 | 0.19 | 0.28 | 0.24 | 0.32 | 0.16 | 0.29 | 0.24 |
| 8000.00 | 0.32 | 0.19 | 0.28 | 0.25 | 0.32 | 0.16 | 0.29 | 0.24 |

*Note*. ‘SD’- standard deviation, ‘IQR’- interquartile range

**Table 4.1.4.**

*Mean, standard deviation, median and interquartile range of absorbance at ambient pressure in the frequency range of 226 Hz to 8000 Hz in both ears of the CI group*

| Frequency (in Hz) | CI ears of CI group | | | | Non-CI ears of CI group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 226.00 | 0.10 | 0.04 | 0.09 | 0.07 | 0.12 | 0.06 | 0.11 | 0.10 |
| 250.00 | 0.10 | 0.04 | 0.09 | 0.07 | 0.13 | 0.07 | 0.12 | 0.11 |
| 257.33 | 0.10 | 0.04 | 0.09 | 0.08 | 0.13 | 0.07 | 0.12 | 0.12 |
| 264.87 | 0.10 | 0.04 | 0.09 | 0.08 | 0.13 | 0.07 | 0.12 | 0.12 |
| 272.63 | 0.11 | 0.05 | 0.10 | 0.08 | 0.13 | 0.07 | 0.12 | 0.13 |
| 280.62 | 0.11 | 0.05 | 0.10 | 0.08 | 0.14 | 0.07 | 0.12 | 0.14 |
| 288.84 | 0.11 | 0.05 | 0.10 | 0.09 | 0.14 | 0.07 | 0.13 | 0.14 |
| 297.30 | 0.12 | 0.05 | 0.11 | 0.09 | 0.15 | 0.08 | 0.13 | 0.15 |
| 306.12 | 0.12 | 0.05 | 0.11 | 0.09 | 0.15 | 0.08 | 0.13 | 0.15 |
| 314.98 | 0.13 | 0.06 | 0.11 | 0.09 | 0.16 | 0.08 | 0.13 | 0.15 |
| 324.21 | 0.13 | 0.06 | 0.12 | 0.09 | 0.16 | 0.08 | 0.14 | 0.16 |
| 333.71 | 0.13 | 0.06 | 0.12 | 0.10 | 0.17 | 0.09 | 0.14 | 0.16 |
| 343.49 | 0.14 | 0.06 | 0.12 | 0.10 | 0.18 | 0.09 | 0.14 | 0.17 |
| 353.55 | 0.14 | 0.07 | 0.13 | 0.10 | 0.18 | 0.09 | 0.15 | 0.17 |
| 363.91 | 0.15 | 0.07 | 0.13 | 0.10 | 0.19 | 0.10 | 0.15 | 0.18 |
| 374.58 | 0.15 | 0.07 | 0.14 | 0.10 | 0.19 | 0.10 | 0.15 | 0.19 |
| 385.55 | 0.16 | 0.07 | 0.15 | 0.11 | 0.20 | 0.10 | 0.15 | 0.19 |
| 396.95 | 0.16 | 0.07 | 0.15 | 0.11 | 0.21 | 0.11 | 0.16 | 0.20 |

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Table 4.1.4 continued from previous page

| Frequency (in Hz) | CI ears of CI group | | | | Non-CI ears of CI group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 408.48 | 0.17 | 0.07 | 0.15 | 0.11 | 0.21 | 0.11 | 0.17 | 0.21 |
| 420.45 | 0.17 | 0.08 | 0.16 | 0.11 | 0.22 | 0.11 | 0.18 | 0.21 |
| 432.77 | 0.18 | 0.08 | 0.16 | 0.11 | 0.23 | 0.11 | 0.19 | 0.21 |
| 445.45 | 0.18 | 0.08 | 0.17 | 0.12 | 0.24 | 0.11 | 0.20 | 0.21 |
| 458.50 | 0.19 | 0.08 | 0.17 | 0.12 | 0.25 | 0.12 | 0.20 | 0.20 |
| 471.94 | 0.19 | 0.09 | 0.18 | 0.12 | 0.26 | 0.12 | 0.21 | 0.22 |
| 485.77 | 0.20 | 0.09 | 0.18 | 0.12 | 0.26 | 0.12 | 0.22 | 0.23 |
| 500.00 | 0.20 | 0.09 | 0.19 | 0.12 | 0.27 | 0.13 | 0.22 | 0.24 |
| 514.65 | 0.21 | 0.10 | 0.20 | 0.13 | 0.28 | 0.13 | 0.24 | 0.25 |
| 529.73 | 0.22 | 0.09 | 0.21 | 0.13 | 0.29 | 0.13 | 0.25 | 0.25 |
| 545.25 | 0.22 | 0.09 | 0.22 | 0.13 | 0.30 | 0.14 | 0.26 | 0.25 |
| 561.23 | 0.24 | 0.09 | 0.22 | 0.13 | 0.31 | 0.14 | 0.28 | 0.25 |
| 577.68 | 0.25 | 0.09 | 0.23 | 0.13 | 0.33 | 0.14 | 0.29 | 0.23 |
| 594.60 | 0.26 | 0.10 | 0.24 | 0.14 | 0.34 | 0.14 | 0.30 | 0.21 |
| 612.03 | 0.26 | 0.10 | 0.24 | 0.14 | 0.34 | 0.14 | 0.31 | 0.21 |
| 629.96 | 0.27 | 0.10 | 0.24 | 0.15 | 0.35 | 0.14 | 0.32 | 0.20 |
| 648.42 | 0.27 | 0.10 | 0.24 | 0.16 | 0.36 | 0.14 | 0.33 | 0.18 |
| 667.42 | 0.28 | 0.10 | 0.24 | 0.15 | 0.37 | 0.14 | 0.35 | 0.17 |
| 686.98 | 0.29 | 0.11 | 0.24 | 0.16 | 0.38 | 0.15 | 0.36 | 0.17 |
| 707.11 | 0.30 | 0.11 | 0.25 | 0.17 | 0.39 | 0.15 | 0.37 | 0.16 |
| 727.83 | 0.31 | 0.11 | 0.26 | 0.18 | 0.40 | 0.15 | 0.36 | 0.16 |
| 749.15 | 0.32 | 0.12 | 0.27 | 0.20 | 0.40 | 0.15 | 0.39 | 0.20 |

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Table 4.1.4 continued from previous page

| Frequency (in Hz) | CI ears of CI group | | | | Non-CI ears of CI group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 771.11 | 0.32 | 0.13 | 0.27 | 0.22 | 0.41 | 0.16 | 0.41 | 0.23 |
| 793.70 | 0.33 | 0.13 | 0.28 | 0.22 | 0.42 | 0.16 | 0.41 | 0.21 |
| 816.96 | 0.34 | 0.14 | 0.29 | 0.22 | 0.43 | 0.16 | 0.41 | 0.18 |
| 840.90 | 0.35 | 0.14 | 0.29 | 0.23 | 0.44 | 0.16 | 0.42 | 0.20 |
| 865.54 | 0.35 | 0.15 | 0.30 | 0.23 | 0.45 | 0.16 | 0.43 | 0.22 |
| 890.90 | 0.36 | 0.15 | 0.32 | 0.23 | 0.46 | 0.16 | 0.45 | 0.22 |
| 917.00 | 0.37 | 0.16 | 0.33 | 0.24 | 0.47 | 0.16 | 0.46 | 0.24 |
| 943.87 | 0.38 | 0.17 | 0.34 | 0.24 | 0.48 | 0.16 | 0.48 | 0.25 |
| 971.53 | 0.39 | 0.17 | 0.35 | 0.25 | 0.49 | 0.17 | 0.48 | 0.25 |
| 1000.00 | 0.40 | 0.18 | 0.36 | 0.25 | 0.50 | 0.17 | 0.49 | 0.25 |
| 1029.30 | 0.42 | 0.18 | 0.37 | 0.27 | 0.51 | 0.17 | 0.50 | 0.25 |
| 1059.46 | 0.43 | 0.18 | 0.40 | 0.28 | 0.52 | 0.17 | 0.53 | 0.23 |
| 1090.51 | 0.45 | 0.18 | 0.42 | 0.30 | 0.52 | 0.17 | 0.54 | 0.22 |
| 1122.46 | 0.46 | 0.18 | 0.45 | 0.32 | 0.53 | 0.17 | 0.54 | 0.23 |
| 1155.35 | 0.48 | 0.18 | 0.47 | 0.34 | 0.54 | 0.17 | 0.55 | 0.22 |
| 1189.21 | 0.49 | 0.18 | 0.49 | 0.35 | 0.55 | 0.17 | 0.56 | 0.22 |
| 1224.05 | 0.51 | 0.18 | 0.51 | 0.35 | 0.56 | 0.17 | 0.58 | 0.24 |
| 1259.92 | 0.53 | 0.18 | 0.53 | 0.34 | 0.57 | 0.17 | 0.60 | 0.28 |
| 1296.84 | 0.54 | 0.17 | 0.57 | 0.33 | 0.57 | 0.18 | 0.61 | 0.30 |
| 1334.84 | 0.56 | 0.17 | 0.60 | 0.31 | 0.58 | 0.18 | 0.61 | 0.28 |
| 1373.95 | 0.57 | 0.18 | 0.62 | 0.31 | 0.59 | 0.18 | 0.61 | 0.28 |
| 1414.21 | 0.57 | 0.19 | 0.63 | 0.34 | 0.59 | 0.19 | 0.61 | 0.27 |

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Table 4.1.4 continued from previous page

| Frequency (in Hz) | CI ears of CI group | | | | Non-CI ears of CI group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 1455.65 | 0.58 | 0.20 | 0.63 | 0.35 | 0.60 | 0.19 | 0.61 | 0.26 |
| 1498.31 | 0.59 | 0.20 | 0.64 | 0.34 | 0.60 | 0.19 | 0.61 | 0.27 |
| 1542.21 | 0.60 | 0.20 | 0.65 | 0.32 | 0.60 | 0.19 | 0.61 | 0.27 |
| 1587.40 | 0.61 | 0.18 | 0.66 | 0.29 | 0.61 | 0.18 | 0.59 | 0.27 |
| 1633.92 | 0.62 | 0.17 | 0.66 | 0.27 | 0.61 | 0.18 | 0.58 | 0.23 |
| 1681.79 | 0.64 | 0.16 | 0.66 | 0.27 | 0.62 | 0.17 | 0.58 | 0.22 |
| 1731.07 | 0.65 | 0.16 | 0.66 | 0.27 | 0.63 | 0.17 | 0.61 | 0.22 |
| 1781.80 | 0.66 | 0.15 | 0.67 | 0.25 | 0.63 | 0.16 | 0.64 | 0.23 |
| 1834.01 | 0.67 | 0.15 | 0.67 | 0.22 | 0.64 | 0.15 | 0.66 | 0.23 |
| 1887.75 | 0.69 | 0.16 | 0.68 | 0.21 | 0.65 | 0.15 | 0.65 | 0.24 |
| 1943.06 | 0.71 | 0.16 | 0.69 | 0.21 | 0.65 | 0.15 | 0.64 | 0.23 |
| 2000.00 | 0.73 | 0.16 | 0.71 | 0.21 | 0.67 | 0.15 | 0.66 | 0.23 |
| 2058.60 | 0.75 | 0.16 | 0.74 | 0.21 | 0.68 | 0.15 | 0.67 | 0.24 |
| 2118.93 | 0.77 | 0.15 | 0.76 | 0.20 | 0.69 | 0.15 | 0.71 | 0.25 |
| 2181.02 | 0.78 | 0.15 | 0.78 | 0.20 | 0.71 | 0.15 | 0.71 | 0.27 |
| 2244.92 | 0.80 | 0.15 | 0.80 | 0.20 | 0.72 | 0.15 | 0.72 | 0.28 |
| 2310.71 | 0.81 | 0.15 | 0.83 | 0.20 | 0.74 | 0.15 | 0.74 | 0.29 |
| 2378.41 | 0.82 | 0.15 | 0.85 | 0.19 | 0.76 | 0.15 | 0.78 | 0.32 |
| 2448.11 | 0.83 | 0.15 | 0.88 | 0.16 | 0.77 | 0.15 | 0.82 | 0.34 |
| 2519.84 | 0.83 | 0.15 | 0.89 | 0.15 | 0.79 | 0.15 | 0.83 | 0.32 |
| 2593.68 | 0.84 | 0.14 | 0.89 | 0.15 | 0.80 | 0.14 | 0.83 | 0.29 |
| 2669.68 | 0.85 | 0.14 | 0.88 | 0.15 | 0.81 | 0.14 | 0.85 | 0.28 |

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Table 4.1.4 continued from previous page

| Frequency (in Hz) | CI ears of CI group | | | | Non-CI ears of CI group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 2747.91 | 0.85 | 0.14 | 0.88 | 0.15 | 0.82 | 0.13 | 0.84 | 0.26 |
| 2828.43 | 0.85 | 0.13 | 0.89 | 0.15 | 0.83 | 0.13 | 0.86 | 0.23 |
| 2911.31 | 0.85 | 0.13 | 0.89 | 0.16 | 0.83 | 0.12 | 0.88 | 0.20 |
| 2996.61 | 0.86 | 0.13 | 0.90 | 0.16 | 0.84 | 0.11 | 0.88 | 0.20 |
| 3084.42 | 0.85 | 0.13 | 0.90 | 0.19 | 0.85 | 0.11 | 0.87 | 0.20 |
| 3174.80 | 0.85 | 0.13 | 0.90 | 0.22 | 0.85 | 0.10 | 0.88 | 0.21 |
| 3267.83 | 0.85 | 0.14 | 0.90 | 0.24 | 0.85 | 0.10 | 0.88 | 0.21 |
| 3363.59 | 0.84 | 0.15 | 0.89 | 0.25 | 0.85 | 0.10 | 0.88 | 0.19 |
| 3462.15 | 0.83 | 0.15 | 0.87 | 0.25 | 0.85 | 0.10 | 0.88 | 0.17 |
| 3563.59 | 0.83 | 0.15 | 0.86 | 0.25 | 0.85 | 0.10 | 0.88 | 0.17 |
| 3668.02 | 0.82 | 0.15 | 0.86 | 0.25 | 0.85 | 0.10 | 0.88 | 0.16 |
| 3775.50 | 0.82 | 0.15 | 0.86 | 0.25 | 0.84 | 0.11 | 0.88 | 0.14 |
| 3886.13 | 0.80 | 0.15 | 0.84 | 0.26 | 0.83 | 0.11 | 0.86 | 0.16 |
| 4000.00 | 0.78 | 0.16 | 0.83 | 0.26 | 0.82 | 0.12 | 0.85 | 0.17 |
| 4117.21 | 0.76 | 0.16 | 0.82 | 0.28 | 0.81 | 0.13 | 0.83 | 0.17 |
| 4237.85 | 0.74 | 0.17 | 0.79 | 0.32 | 0.80 | 0.14 | 0.82 | 0.19 |
| 4362.03 | 0.72 | 0.18 | 0.76 | 0.34 | 0.78 | 0.15 | 0.79 | 0.24 |
| 4489.85 | 0.70 | 0.19 | 0.71 | 0.33 | 0.77 | 0.16 | 0.76 | 0.28 |
| 4621.41 | 0.68 | 0.19 | 0.66 | 0.35 | 0.76 | 0.17 | 0.74 | 0.31 |
| 4756.83 | 0.67 | 0.20 | 0.64 | 0.35 | 0.74 | 0.18 | 0.72 | 0.32 |
| 4896.21 | 0.65 | 0.20 | 0.63 | 0.34 | 0.73 | 0.19 | 0.70 | 0.33 |
| 5039.68 | 0.63 | 0.19 | 0.62 | 0.34 | 0.72 | 0.19 | 0.68 | 0.32 |

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Table 4.1.4 continued from previous page

| Frequency (in Hz) | CI ears of CI group | | | | Non-CI ears of CI group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 5187.36 | 0.61 | 0.19 | 0.60 | 0.32 | 0.70 | 0.19 | 0.64 | 0.32 |
| 5339.36 | 0.58 | 0.18 | 0.58 | 0.31 | 0.67 | 0.19 | 0.62 | 0.32 |
| 5495.81 | 0.55 | 0.17 | 0.54 | 0.30 | 0.64 | 0.18 | 0.62 | 0.33 |
| 5656.85 | 0.51 | 0.17 | 0.50 | 0.29 | 0.61 | 0.18 | 0.60 | 0.33 |
| 5822.61 | 0.48 | 0.16 | 0.45 | 0.30 | 0.57 | 0.18 | 0.57 | 0.32 |
| 5993.23 | 0.45 | 0.16 | 0.42 | 0.29 | 0.54 | 0.17 | 0.52 | 0.33 |
| 6168.84 | 0.42 | 0.16 | 0.38 | 0.28 | 0.50 | 0.17 | 0.48 | 0.33 |
| 6349.60 | 0.40 | 0.16 | 0.35 | 0.26 | 0.47 | 0.17 | 0.45 | 0.33 |
| 6535.66 | 0.38 | 0.15 | 0.33 | 0.24 | 0.44 | 0.17 | 0.42 | 0.31 |
| 6727.17 | 0.35 | 0.15 | 0.32 | 0.21 | 0.41 | 0.16 | 0.39 | 0.31 |
| 6924.29 | 0.34 | 0.14 | 0.33 | 0.19 | 0.39 | 0.16 | 0.38 | 0.31 |
| 7127.19 | 0.32 | 0.13 | 0.31 | 0.18 | 0.37 | 0.17 | 0.38 | 0.29 |
| 7336.03 | 0.31 | 0.13 | 0.31 | 0.19 | 0.35 | 0.17 | 0.37 | 0.27 |
| 7550.99 | 0.30 | 0.13 | 0.30 | 0.20 | 0.34 | 0.17 | 0.35 | 0.26 |
| 7772.26 | 0.30 | 0.13 | 0.29 | 0.20 | 0.34 | 0.17 | 0.33 | 0.26 |
| 8000.00 | 0.30 | 0.13 | 0.30 | 0.21 | 0.33 | 0.18 | 0.33 | 0.26 |

*Note.* ‘SD’- standard deviation, ‘IQR’- interquartile range

**Table 4.1.5.**

*Mean, standard deviation, median and interquartile range of absorbance at ambient pressure in the frequency range of 226 Hz to 8000 Hz in both ears of the SNHL group*

| Frequency (in Hz) | CI-matched ears of SNHL group | | | | Non-CI-matched ears of SNHL group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 226.00 | 0.16 | 0.09 | 0.14 | 0.10 | 0.15 | 0.08 | 0.13 | 0.08 |
| 250.00 | 0.17 | 0.10 | 0.15 | 0.11 | 0.16 | 0.08 | 0.13 | 0.08 |
| 257.33 | 0.17 | 0.10 | 0.15 | 0.11 | 0.16 | 0.08 | 0.13 | 0.09 |
| 264.87 | 0.18 | 0.10 | 0.15 | 0.11 | 0.16 | 0.09 | 0.14 | 0.09 |
| 272.63 | 0.18 | 0.10 | 0.16 | 0.11 | 0.17 | 0.09 | 0.14 | 0.09 |
| 280.62 | 0.19 | 0.10 | 0.16 | 0.11 | 0.17 | 0.09 | 0.15 | 0.09 |
| 288.84 | 0.19 | 0.11 | 0.17 | 0.11 | 0.18 | 0.09 | 0.15 | 0.09 |
| 297.30 | 0.20 | 0.11 | 0.18 | 0.12 | 0.19 | 0.09 | 0.16 | 0.10 |
| 306.12 | 0.21 | 0.11 | 0.18 | 0.12 | 0.19 | 0.10 | 0.16 | 0.10 |
| 314.98 | 0.21 | 0.11 | 0.19 | 0.12 | 0.20 | 0.10 | 0.17 | 0.10 |
| 324.21 | 0.22 | 0.11 | 0.19 | 0.12 | 0.20 | 0.10 | 0.17 | 0.11 |
| 333.71 | 0.22 | 0.12 | 0.20 | 0.13 | 0.21 | 0.10 | 0.19 | 0.11 |
| 343.49 | 0.23 | 0.12 | 0.21 | 0.13 | 0.22 | 0.10 | 0.20 | 0.11 |
| 353.55 | 0.24 | 0.12 | 0.21 | 0.14 | 0.22 | 0.10 | 0.21 | 0.11 |
| 363.91 | 0.25 | 0.12 | 0.22 | 0.15 | 0.23 | 0.10 | 0.22 | 0.12 |
| 374.58 | 0.25 | 0.12 | 0.23 | 0.15 | 0.24 | 0.11 | 0.22 | 0.12 |
| 385.55 | 0.26 | 0.12 | 0.24 | 0.16 | 0.25 | 0.11 | 0.23 | 0.12 |
| 396.95 | 0.27 | 0.12 | 0.25 | 0.16 | 0.25 | 0.11 | 0.23 | 0.13 |

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Table 4.1.5 continued from previous page

| Frequency (in Hz) | CI-matched ears of SNHL group | | | | Non-CI-matched ears of SNHL group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 408.48 | 0.28 | 0.12 | 0.26 | 0.16 | 0.26 | 0.11 | 0.24 | 0.13 |
| 420.45 | 0.28 | 0.13 | 0.27 | 0.17 | 0.27 | 0.11 | 0.24 | 0.14 |
| 432.77 | 0.29 | 0.13 | 0.28 | 0.17 | 0.28 | 0.11 | 0.24 | 0.15 |
| 445.45 | 0.30 | 0.13 | 0.29 | 0.17 | 0.28 | 0.11 | 0.25 | 0.16 |
| 458.50 | 0.30 | 0.13 | 0.30 | 0.18 | 0.29 | 0.11 | 0.26 | 0.16 |
| 471.94 | 0.32 | 0.13 | 0.32 | 0.18 | 0.30 | 0.11 | 0.28 | 0.17 |
| 485.77 | 0.32 | 0.13 | 0.32 | 0.18 | 0.31 | 0.11 | 0.29 | 0.17 |
| 500.00 | 0.33 | 0.13 | 0.33 | 0.18 | 0.32 | 0.11 | 0.30 | 0.17 |
| 514.65 | 0.34 | 0.13 | 0.34 | 0.18 | 0.33 | 0.11 | 0.31 | 0.17 |
| 529.73 | 0.35 | 0.13 | 0.34 | 0.17 | 0.34 | 0.12 | 0.32 | 0.18 |
| 545.25 | 0.35 | 0.13 | 0.35 | 0.17 | 0.35 | 0.12 | 0.33 | 0.18 |
| 561.23 | 0.36 | 0.14 | 0.36 | 0.17 | 0.37 | 0.12 | 0.35 | 0.18 |
| 577.68 | 0.37 | 0.14 | 0.37 | 0.16 | 0.38 | 0.13 | 0.36 | 0.18 |
| 594.60 | 0.38 | 0.14 | 0.39 | 0.15 | 0.39 | 0.13 | 0.37 | 0.18 |
| 612.03 | 0.38 | 0.14 | 0.39 | 0.14 | 0.39 | 0.13 | 0.38 | 0.17 |
| 629.96 | 0.39 | 0.14 | 0.39 | 0.13 | 0.40 | 0.14 | 0.39 | 0.17 |
| 648.42 | 0.40 | 0.15 | 0.39 | 0.12 | 0.41 | 0.14 | 0.39 | 0.17 |
| 667.42 | 0.40 | 0.15 | 0.40 | 0.12 | 0.42 | 0.14 | 0.40 | 0.18 |
| 686.98 | 0.41 | 0.15 | 0.41 | 0.12 | 0.43 | 0.14 | 0.40 | 0.19 |
| 707.11 | 0.42 | 0.16 | 0.42 | 0.13 | 0.44 | 0.14 | 0.40 | 0.19 |
| 727.83 | 0.43 | 0.16 | 0.43 | 0.14 | 0.44 | 0.14 | 0.41 | 0.19 |
| 749.15 | 0.43 | 0.16 | 0.43 | 0.14 | 0.45 | 0.14 | 0.41 | 0.21 |

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Table 4.1.5 continued from previous page

| Frequency (in Hz) | CI-matched ears of SNHL group | | | | Non-CI-matched ears of SNHL group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 771.11 | 0.44 | 0.16 | 0.43 | 0.15 | 0.46 | 0.14 | 0.42 | 0.23 |
| 793.70 | 0.45 | 0.16 | 0.44 | 0.16 | 0.46 | 0.14 | 0.42 | 0.24 |
| 816.96 | 0.46 | 0.17 | 0.44 | 0.18 | 0.47 | 0.14 | 0.43 | 0.25 |
| 840.90 | 0.47 | 0.17 | 0.44 | 0.19 | 0.48 | 0.15 | 0.43 | 0.26 |
| 865.54 | 0.48 | 0.17 | 0.45 | 0.19 | 0.49 | 0.15 | 0.44 | 0.26 |
| 890.90 | 0.48 | 0.17 | 0.46 | 0.20 | 0.50 | 0.15 | 0.45 | 0.27 |
| 917.00 | 0.49 | 0.17 | 0.46 | 0.21 | 0.51 | 0.15 | 0.47 | 0.26 |
| 943.87 | 0.50 | 0.17 | 0.47 | 0.21 | 0.53 | 0.15 | 0.49 | 0.24 |
| 971.53 | 0.51 | 0.17 | 0.48 | 0.20 | 0.54 | 0.15 | 0.51 | 0.22 |
| 1000.00 | 0.52 | 0.17 | 0.50 | 0.19 | 0.55 | 0.15 | 0.53 | 0.21 |
| 1029.30 | 0.53 | 0.16 | 0.51 | 0.18 | 0.56 | 0.15 | 0.54 | 0.20 |
| 1059.46 | 0.53 | 0.16 | 0.52 | 0.17 | 0.57 | 0.15 | 0.56 | 0.19 |
| 1090.51 | 0.54 | 0.16 | 0.52 | 0.15 | 0.58 | 0.15 | 0.58 | 0.19 |
| 1122.46 | 0.54 | 0.16 | 0.52 | 0.17 | 0.59 | 0.14 | 0.60 | 0.18 |
| 1155.35 | 0.55 | 0.15 | 0.54 | 0.19 | 0.60 | 0.14 | 0.61 | 0.18 |
| 1189.21 | 0.56 | 0.15 | 0.54 | 0.19 | 0.61 | 0.14 | 0.62 | 0.18 |
| 1224.05 | 0.56 | 0.15 | 0.53 | 0.19 | 0.62 | 0.14 | 0.63 | 0.17 |
| 1259.92 | 0.56 | 0.15 | 0.53 | 0.19 | 0.62 | 0.13 | 0.65 | 0.17 |
| 1296.84 | 0.57 | 0.14 | 0.52 | 0.19 | 0.63 | 0.13 | 0.65 | 0.18 |
| 1334.84 | 0.57 | 0.14 | 0.53 | 0.19 | 0.63 | 0.13 | 0.65 | 0.18 |
| 1373.95 | 0.57 | 0.14 | 0.54 | 0.19 | 0.63 | 0.12 | 0.64 | 0.19 |
| 1414.21 | 0.57 | 0.14 | 0.55 | 0.19 | 0.62 | 0.12 | 0.64 | 0.19 |

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Table 4.1.5 continued from previous page

| Frequency (in Hz) | CI-matched ears of SNHL group | | | | Non-CI-matched ears of SNHL group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 1455.65 | 0.57 | 0.13 | 0.56 | 0.20 | 0.62 | 0.12 | 0.62 | 0.19 |
| 1498.31 | 0.57 | 0.13 | 0.57 | 0.21 | 0.62 | 0.11 | 0.62 | 0.18 |
| 1542.21 | 0.58 | 0.12 | 0.57 | 0.21 | 0.62 | 0.11 | 0.62 | 0.19 |
| 1587.40 | 0.58 | 0.12 | 0.56 | 0.21 | 0.63 | 0.11 | 0.63 | 0.18 |
| 1633.92 | 0.58 | 0.12 | 0.57 | 0.22 | 0.63 | 0.11 | 0.63 | 0.16 |
| 1681.79 | 0.59 | 0.11 | 0.58 | 0.21 | 0.64 | 0.12 | 0.61 | 0.15 |
| 1731.07 | 0.60 | 0.11 | 0.59 | 0.22 | 0.64 | 0.12 | 0.61 | 0.15 |
| 1781.80 | 0.60 | 0.11 | 0.61 | 0.22 | 0.64 | 0.13 | 0.62 | 0.16 |
| 1834.01 | 0.61 | 0.11 | 0.61 | 0.23 | 0.64 | 0.14 | 0.64 | 0.17 |
| 1887.75 | 0.62 | 0.12 | 0.62 | 0.21 | 0.65 | 0.14 | 0.64 | 0.17 |
| 1943.06 | 0.63 | 0.12 | 0.63 | 0.20 | 0.66 | 0.15 | 0.64 | 0.17 |
| 2000.00 | 0.63 | 0.12 | 0.64 | 0.19 | 0.66 | 0.16 | 0.67 | 0.20 |
| 2058.60 | 0.64 | 0.12 | 0.65 | 0.19 | 0.67 | 0.17 | 0.68 | 0.26 |
| 2118.93 | 0.66 | 0.12 | 0.65 | 0.19 | 0.68 | 0.18 | 0.69 | 0.30 |
| 2181.02 | 0.67 | 0.12 | 0.65 | 0.20 | 0.68 | 0.18 | 0.69 | 0.33 |
| 2244.92 | 0.68 | 0.13 | 0.67 | 0.21 | 0.69 | 0.18 | 0.69 | 0.31 |
| 2310.71 | 0.69 | 0.14 | 0.68 | 0.22 | 0.70 | 0.18 | 0.68 | 0.27 |
| 2378.41 | 0.70 | 0.15 | 0.70 | 0.22 | 0.70 | 0.19 | 0.69 | 0.24 |
| 2448.11 | 0.70 | 0.15 | 0.71 | 0.23 | 0.70 | 0.19 | 0.69 | 0.25 |
| 2519.84 | 0.70 | 0.16 | 0.71 | 0.26 | 0.71 | 0.19 | 0.68 | 0.28 |
| 2593.68 | 0.70 | 0.16 | 0.71 | 0.29 | 0.71 | 0.20 | 0.69 | 0.29 |
| 2669.68 | 0.71 | 0.16 | 0.70 | 0.29 | 0.70 | 0.20 | 0.70 | 0.30 |

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Table 4.1.5 continued from previous page

| Frequency (in Hz) | CI-matched ears of SNHL group | | | | Non-CI-matched ears of SNHL group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 2747.91 | 0.71 | 0.16 | 0.72 | 0.30 | 0.70 | 0.21 | 0.72 | 0.30 |
| 2828.43 | 0.71 | 0.15 | 0.72 | 0.29 | 0.70 | 0.21 | 0.74 | 0.30 |
| 2911.31 | 0.72 | 0.15 | 0.70 | 0.27 | 0.70 | 0.22 | 0.75 | 0.30 |
| 2996.61 | 0.72 | 0.15 | 0.71 | 0.24 | 0.71 | 0.22 | 0.75 | 0.30 |
| 3084.42 | 0.72 | 0.15 | 0.71 | 0.23 | 0.71 | 0.22 | 0.73 | 0.30 |
| 3174.80 | 0.72 | 0.16 | 0.73 | 0.23 | 0.71 | 0.22 | 0.73 | 0.29 |
| 3267.83 | 0.72 | 0.18 | 0.73 | 0.24 | 0.72 | 0.22 | 0.75 | 0.31 |
| 3363.59 | 0.71 | 0.19 | 0.72 | 0.25 | 0.72 | 0.22 | 0.76 | 0.32 |
| 3462.15 | 0.71 | 0.20 | 0.73 | 0.23 | 0.72 | 0.22 | 0.74 | 0.31 |
| 3563.59 | 0.71 | 0.20 | 0.74 | 0.22 | 0.72 | 0.22 | 0.73 | 0.28 |
| 3668.02 | 0.71 | 0.19 | 0.75 | 0.21 | 0.72 | 0.21 | 0.74 | 0.27 |
| 3775.50 | 0.72 | 0.17 | 0.75 | 0.21 | 0.72 | 0.20 | 0.74 | 0.29 |
| 3886.13 | 0.73 | 0.15 | 0.75 | 0.20 | 0.71 | 0.19 | 0.74 | 0.31 |
| 4000.00 | 0.73 | 0.14 | 0.76 | 0.24 | 0.71 | 0.18 | 0.73 | 0.32 |
| 4117.21 | 0.73 | 0.13 | 0.76 | 0.21 | 0.71 | 0.18 | 0.71 | 0.31 |
| 4237.85 | 0.73 | 0.13 | 0.74 | 0.21 | 0.71 | 0.17 | 0.70 | 0.30 |
| 4362.03 | 0.72 | 0.13 | 0.72 | 0.20 | 0.70 | 0.17 | 0.71 | 0.30 |
| 4489.85 | 0.71 | 0.13 | 0.70 | 0.19 | 0.69 | 0.17 | 0.70 | 0.31 |
| 4621.41 | 0.70 | 0.13 | 0.67 | 0.20 | 0.68 | 0.17 | 0.70 | 0.31 |
| 4756.83 | 0.69 | 0.13 | 0.65 | 0.19 | 0.68 | 0.17 | 0.70 | 0.30 |
| 4896.21 | 0.67 | 0.13 | 0.65 | 0.18 | 0.67 | 0.16 | 0.71 | 0.28 |
| 5039.68 | 0.65 | 0.13 | 0.64 | 0.18 | 0.66 | 0.16 | 0.68 | 0.27 |

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Table 4.1.5 continued from previous page

| Frequency (in Hz) | CI-matched ears of SNHL group | | | | Non-CI-matched ears of SNHL group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 5187.36 | 0.63 | 0.12 | 0.63 | 0.17 | 0.65 | 0.15 | 0.65 | 0.27 |
| 5339.36 | 0.60 | 0.12 | 0.62 | 0.14 | 0.62 | 0.15 | 0.62 | 0.26 |
| 5495.81 | 0.57 | 0.13 | 0.57 | 0.13 | 0.59 | 0.15 | 0.61 | 0.23 |
| 5656.85 | 0.53 | 0.13 | 0.52 | 0.16 | 0.56 | 0.15 | 0.61 | 0.23 |
| 5822.61 | 0.50 | 0.14 | 0.49 | 0.19 | 0.52 | 0.15 | 0.57 | 0.23 |
| 5993.23 | 0.47 | 0.14 | 0.46 | 0.20 | 0.49 | 0.15 | 0.51 | 0.25 |
| 6168.84 | 0.44 | 0.15 | 0.42 | 0.22 | 0.45 | 0.15 | 0.48 | 0.23 |
| 6349.60 | 0.41 | 0.15 | 0.39 | 0.23 | 0.42 | 0.15 | 0.44 | 0.22 |
| 6535.66 | 0.39 | 0.15 | 0.37 | 0.23 | 0.39 | 0.15 | 0.41 | 0.21 |
| 6727.17 | 0.37 | 0.16 | 0.36 | 0.24 | 0.37 | 0.15 | 0.39 | 0.23 |
| 6924.29 | 0.35 | 0.16 | 0.35 | 0.24 | 0.35 | 0.15 | 0.37 | 0.24 |
| 7127.19 | 0.34 | 0.17 | 0.33 | 0.25 | 0.33 | 0.15 | 0.33 | 0.24 |
| 7336.03 | 0.34 | 0.18 | 0.30 | 0.28 | 0.32 | 0.15 | 0.31 | 0.25 |
| 7550.99 | 0.34 | 0.19 | 0.27 | 0.30 | 0.31 | 0.15 | 0.31 | 0.25 |
| 7772.26 | 0.34 | 0.20 | 0.27 | 0.30 | 0.31 | 0.16 | 0.31 | 0.26 |
| 8000.00 | 0.34 | 0.20 | 0.27 | 0.30 | 0.31 | 0.16 | 0.30 | 0.27 |

*Note.* 'SD'- standard deviation, 'IQR'- interquartile range

**Table 4.1.6.**

*Mean, standard deviation, median and interquartile range of absorbance at ambient pressure in the frequency range of 226 Hz to 8000 Hz in both ears of the NH group*

| Frequency (in Hz) | CI-matched ears of NH group | | | | Non-CI-matched ears of NH group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 226.00 | 0.14 | 0.04 | 0.15 | 0.05 | 0.13 | 0.04 | 0.13 | 0.06 |
| 250.00 | 0.15 | 0.05 | 0.16 | 0.06 | 0.14 | 0.04 | 0.14 | 0.07 |
| 257.33 | 0.15 | 0.05 | 0.16 | 0.06 | 0.14 | 0.05 | 0.14 | 0.07 |
| 264.87 | 0.15 | 0.05 | 0.16 | 0.06 | 0.14 | 0.05 | 0.14 | 0.07 |
| 272.63 | 0.16 | 0.05 | 0.16 | 0.06 | 0.15 | 0.05 | 0.14 | 0.07 |
| 280.62 | 0.16 | 0.05 | 0.17 | 0.07 | 0.15 | 0.05 | 0.15 | 0.07 |
| 288.84 | 0.17 | 0.05 | 0.18 | 0.07 | 0.16 | 0.05 | 0.15 | 0.08 |
| 297.30 | 0.18 | 0.06 | 0.19 | 0.08 | 0.16 | 0.05 | 0.16 | 0.08 |
| 306.12 | 0.18 | 0.06 | 0.19 | 0.08 | 0.17 | 0.06 | 0.17 | 0.08 |
| 314.98 | 0.18 | 0.06 | 0.20 | 0.08 | 0.17 | 0.06 | 0.17 | 0.08 |
| 324.21 | 0.19 | 0.06 | 0.20 | 0.08 | 0.18 | 0.06 | 0.18 | 0.08 |
| 333.71 | 0.20 | 0.07 | 0.21 | 0.08 | 0.18 | 0.06 | 0.18 | 0.08 |
| 343.49 | 0.20 | 0.07 | 0.21 | 0.08 | 0.19 | 0.06 | 0.19 | 0.09 |
| 353.55 | 0.21 | 0.07 | 0.21 | 0.08 | 0.19 | 0.06 | 0.20 | 0.09 |
| 363.91 | 0.22 | 0.07 | 0.22 | 0.08 | 0.20 | 0.07 | 0.20 | 0.09 |
| 374.58 | 0.23 | 0.08 | 0.23 | 0.09 | 0.21 | 0.07 | 0.21 | 0.10 |
| 385.55 | 0.23 | 0.08 | 0.24 | 0.09 | 0.21 | 0.07 | 0.22 | 0.11 |
| 396.95 | 0.24 | 0.08 | 0.24 | 0.09 | 0.22 | 0.08 | 0.22 | 0.11 |

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Table 4.1.6 continued from previous page

| Frequency (in Hz) | CI-matched ears of NH group | | | | Non-CI-matched ears of NH group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 408.48 | 0.25 | 0.09 | 0.25 | 0.10 | 0.23 | 0.08 | 0.23 | 0.12 |
| 420.45 | 0.26 | 0.09 | 0.26 | 0.10 | 0.24 | 0.08 | 0.24 | 0.12 |
| 432.77 | 0.27 | 0.10 | 0.27 | 0.11 | 0.25 | 0.09 | 0.25 | 0.13 |
| 445.45 | 0.27 | 0.10 | 0.28 | 0.12 | 0.26 | 0.09 | 0.26 | 0.13 |
| 458.50 | 0.28 | 0.10 | 0.29 | 0.12 | 0.26 | 0.09 | 0.26 | 0.13 |
| 471.94 | 0.30 | 0.11 | 0.31 | 0.13 | 0.28 | 0.10 | 0.28 | 0.14 |
| 485.77 | 0.31 | 0.11 | 0.32 | 0.13 | 0.29 | 0.10 | 0.29 | 0.15 |
| 500.00 | 0.31 | 0.11 | 0.33 | 0.13 | 0.30 | 0.10 | 0.30 | 0.15 |
| 514.65 | 0.33 | 0.12 | 0.34 | 0.13 | 0.31 | 0.11 | 0.32 | 0.16 |
| 529.73 | 0.34 | 0.12 | 0.34 | 0.14 | 0.32 | 0.11 | 0.33 | 0.16 |
| 545.25 | 0.35 | 0.12 | 0.35 | 0.14 | 0.33 | 0.11 | 0.34 | 0.16 |
| 561.23 | 0.36 | 0.12 | 0.37 | 0.14 | 0.35 | 0.12 | 0.35 | 0.16 |
| 577.68 | 0.38 | 0.13 | 0.38 | 0.15 | 0.36 | 0.12 | 0.37 | 0.17 |
| 594.60 | 0.39 | 0.13 | 0.40 | 0.16 | 0.38 | 0.13 | 0.39 | 0.18 |
| 612.03 | 0.40 | 0.13 | 0.40 | 0.16 | 0.38 | 0.13 | 0.40 | 0.19 |
| 629.96 | 0.41 | 0.13 | 0.41 | 0.17 | 0.39 | 0.13 | 0.41 | 0.19 |
| 648.42 | 0.42 | 0.13 | 0.42 | 0.17 | 0.41 | 0.13 | 0.42 | 0.19 |
| 667.42 | 0.44 | 0.14 | 0.42 | 0.18 | 0.42 | 0.13 | 0.43 | 0.19 |
| 686.98 | 0.45 | 0.14 | 0.42 | 0.19 | 0.43 | 0.13 | 0.44 | 0.18 |
| 707.11 | 0.47 | 0.15 | 0.44 | 0.20 | 0.45 | 0.13 | 0.45 | 0.18 |
| 727.83 | 0.48 | 0.15 | 0.46 | 0.21 | 0.46 | 0.13 | 0.46 | 0.18 |
| 749.15 | 0.49 | 0.16 | 0.47 | 0.22 | 0.47 | 0.13 | 0.47 | 0.19 |

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Table 4.1.6 continued from previous page

| Frequency (in Hz) | CI-matched ears of NH group | | | | Non-CI-matched ears of NH group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 771.11 | 0.51 | 0.16 | 0.49 | 0.22 | 0.49 | 0.13 | 0.48 | 0.20 |
| 793.70 | 0.52 | 0.17 | 0.50 | 0.22 | 0.50 | 0.13 | 0.48 | 0.20 |
| 816.96 | 0.53 | 0.17 | 0.51 | 0.22 | 0.51 | 0.13 | 0.49 | 0.20 |
| 840.90 | 0.55 | 0.17 | 0.53 | 0.22 | 0.52 | 0.13 | 0.50 | 0.20 |
| 865.54 | 0.56 | 0.17 | 0.54 | 0.23 | 0.53 | 0.13 | 0.51 | 0.20 |
| 890.90 | 0.57 | 0.17 | 0.55 | 0.24 | 0.55 | 0.13 | 0.51 | 0.20 |
| 917.00 | 0.59 | 0.16 | 0.56 | 0.25 | 0.56 | 0.13 | 0.52 | 0.19 |
| 943.87 | 0.60 | 0.16 | 0.57 | 0.26 | 0.58 | 0.13 | 0.54 | 0.17 |
| 971.53 | 0.61 | 0.15 | 0.59 | 0.25 | 0.59 | 0.13 | 0.55 | 0.16 |
| 1000.00 | 0.63 | 0.15 | 0.61 | 0.25 | 0.60 | 0.12 | 0.57 | 0.15 |
| 1029.30 | 0.64 | 0.14 | 0.62 | 0.24 | 0.61 | 0.12 | 0.59 | 0.15 |
| 1059.46 | 0.65 | 0.13 | 0.63 | 0.20 | 0.62 | 0.12 | 0.61 | 0.16 |
| 1090.51 | 0.66 | 0.12 | 0.63 | 0.19 | 0.63 | 0.12 | 0.63 | 0.18 |
| 1122.46 | 0.67 | 0.12 | 0.65 | 0.20 | 0.64 | 0.12 | 0.64 | 0.18 |
| 1155.35 | 0.67 | 0.11 | 0.65 | 0.20 | 0.65 | 0.12 | 0.64 | 0.18 |
| 1189.21 | 0.67 | 0.11 | 0.65 | 0.19 | 0.65 | 0.12 | 0.66 | 0.16 |
| 1224.05 | 0.68 | 0.11 | 0.65 | 0.16 | 0.66 | 0.12 | 0.67 | 0.15 |
| 1259.92 | 0.68 | 0.10 | 0.66 | 0.16 | 0.66 | 0.12 | 0.67 | 0.15 |
| 1296.84 | 0.68 | 0.10 | 0.66 | 0.18 | 0.66 | 0.12 | 0.66 | 0.16 |
| 1334.84 | 0.68 | 0.10 | 0.67 | 0.19 | 0.66 | 0.12 | 0.66 | 0.17 |
| 1373.95 | 0.68 | 0.10 | 0.67 | 0.18 | 0.66 | 0.12 | 0.67 | 0.18 |
| 1414.21 | 0.68 | 0.10 | 0.68 | 0.18 | 0.66 | 0.12 | 0.67 | 0.18 |

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Table 4.1.6 continued from previous page

| Frequency (in Hz) | CI-matched ears of NH group | | | | Non-CI-matched ears of NH group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 1455.65 | 0.68 | 0.10 | 0.68 | 0.16 | 0.66 | 0.13 | 0.66 | 0.18 |
| 1498.31 | 0.68 | 0.10 | 0.69 | 0.17 | 0.66 | 0.13 | 0.66 | 0.16 |
| 1542.21 | 0.69 | 0.11 | 0.70 | 0.16 | 0.66 | 0.12 | 0.67 | 0.15 |
| 1587.40 | 0.69 | 0.11 | 0.69 | 0.16 | 0.66 | 0.12 | 0.66 | 0.14 |
| 1633.92 | 0.70 | 0.11 | 0.67 | 0.18 | 0.66 | 0.12 | 0.67 | 0.13 |
| 1681.79 | 0.70 | 0.11 | 0.69 | 0.17 | 0.66 | 0.13 | 0.68 | 0.14 |
| 1731.07 | 0.71 | 0.11 | 0.70 | 0.15 | 0.67 | 0.13 | 0.67 | 0.14 |
| 1781.80 | 0.71 | 0.11 | 0.70 | 0.15 | 0.67 | 0.14 | 0.68 | 0.15 |
| 1834.01 | 0.72 | 0.10 | 0.72 | 0.16 | 0.68 | 0.15 | 0.70 | 0.19 |
| 1887.75 | 0.73 | 0.10 | 0.73 | 0.15 | 0.69 | 0.15 | 0.71 | 0.23 |
| 1943.06 | 0.73 | 0.10 | 0.74 | 0.14 | 0.69 | 0.16 | 0.72 | 0.26 |
| 2000.00 | 0.74 | 0.11 | 0.74 | 0.15 | 0.70 | 0.16 | 0.73 | 0.26 |
| 2058.60 | 0.75 | 0.11 | 0.75 | 0.14 | 0.71 | 0.16 | 0.73 | 0.25 |
| 2118.93 | 0.77 | 0.11 | 0.75 | 0.14 | 0.71 | 0.17 | 0.71 | 0.25 |
| 2181.02 | 0.78 | 0.11 | 0.77 | 0.14 | 0.72 | 0.17 | 0.72 | 0.26 |
| 2244.92 | 0.80 | 0.10 | 0.80 | 0.16 | 0.72 | 0.17 | 0.74 | 0.26 |
| 2310.71 | 0.81 | 0.10 | 0.82 | 0.17 | 0.73 | 0.17 | 0.76 | 0.26 |
| 2378.41 | 0.82 | 0.10 | 0.84 | 0.18 | 0.74 | 0.17 | 0.79 | 0.26 |
| 2448.11 | 0.84 | 0.10 | 0.86 | 0.18 | 0.75 | 0.18 | 0.82 | 0.25 |
| 2519.84 | 0.85 | 0.10 | 0.88 | 0.17 | 0.76 | 0.18 | 0.82 | 0.24 |
| 2593.68 | 0.85 | 0.10 | 0.89 | 0.17 | 0.76 | 0.18 | 0.83 | 0.22 |
| 2669.68 | 0.86 | 0.10 | 0.89 | 0.16 | 0.77 | 0.18 | 0.84 | 0.20 |

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Table 4.1.6 continued from previous page

| Frequency (in Hz) | CI-matched ears of NH group | | | | Non-CI-matched ears of NH group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 2747.91 | 0.86 | 0.10 | 0.89 | 0.17 | 0.78 | 0.18 | 0.85 | 0.18 |
| 2828.43 | 0.86 | 0.10 | 0.89 | 0.18 | 0.78 | 0.18 | 0.85 | 0.17 |
| 2911.31 | 0.87 | 0.09 | 0.88 | 0.16 | 0.79 | 0.17 | 0.84 | 0.17 |
| 2996.61 | 0.87 | 0.09 | 0.87 | 0.14 | 0.80 | 0.17 | 0.85 | 0.18 |
| 3084.42 | 0.87 | 0.10 | 0.89 | 0.15 | 0.80 | 0.17 | 0.84 | 0.16 |
| 3174.80 | 0.87 | 0.10 | 0.89 | 0.15 | 0.80 | 0.17 | 0.82 | 0.18 |
| 3267.83 | 0.87 | 0.11 | 0.89 | 0.15 | 0.79 | 0.17 | 0.82 | 0.20 |
| 3363.59 | 0.86 | 0.11 | 0.89 | 0.15 | 0.79 | 0.18 | 0.83 | 0.21 |
| 3462.15 | 0.85 | 0.12 | 0.87 | 0.16 | 0.78 | 0.18 | 0.82 | 0.25 |
| 3563.59 | 0.84 | 0.12 | 0.84 | 0.16 | 0.78 | 0.19 | 0.82 | 0.28 |
| 3668.02 | 0.83 | 0.13 | 0.82 | 0.17 | 0.78 | 0.19 | 0.83 | 0.29 |
| 3775.50 | 0.82 | 0.13 | 0.82 | 0.18 | 0.78 | 0.18 | 0.84 | 0.27 |
| 3886.13 | 0.82 | 0.14 | 0.83 | 0.18 | 0.78 | 0.18 | 0.84 | 0.27 |
| 4000.00 | 0.81 | 0.15 | 0.83 | 0.18 | 0.78 | 0.18 | 0.83 | 0.23 |
| 4117.21 | 0.80 | 0.15 | 0.82 | 0.17 | 0.77 | 0.18 | 0.81 | 0.23 |
| 4237.85 | 0.79 | 0.16 | 0.80 | 0.16 | 0.76 | 0.18 | 0.81 | 0.20 |
| 4362.03 | 0.77 | 0.16 | 0.78 | 0.16 | 0.75 | 0.18 | 0.80 | 0.20 |
| 4489.85 | 0.75 | 0.16 | 0.77 | 0.18 | 0.73 | 0.19 | 0.78 | 0.22 |
| 4621.41 | 0.74 | 0.16 | 0.76 | 0.17 | 0.71 | 0.19 | 0.76 | 0.22 |
| 4756.83 | 0.72 | 0.16 | 0.75 | 0.15 | 0.69 | 0.19 | 0.73 | 0.24 |
| 4896.21 | 0.71 | 0.15 | 0.74 | 0.14 | 0.68 | 0.19 | 0.70 | 0.26 |
| 5039.68 | 0.69 | 0.15 | 0.73 | 0.15 | 0.66 | 0.18 | 0.68 | 0.25 |

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Table 4.1.6 continued from previous page

| Frequency (in Hz) | CI-matched ears of NH group | | | | Non-CI-matched ears of NH group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| 5187.36 | 0.67 | 0.15 | 0.70 | 0.16 | 0.63 | 0.17 | 0.65 | 0.24 |
| 5339.36 | 0.64 | 0.15 | 0.66 | 0.17 | 0.60 | 0.16 | 0.62 | 0.23 |
| 5495.81 | 0.59 | 0.14 | 0.61 | 0.18 | 0.57 | 0.15 | 0.57 | 0.23 |
| 5656.85 | 0.55 | 0.14 | 0.55 | 0.20 | 0.53 | 0.14 | 0.54 | 0.24 |
| 5822.61 | 0.51 | 0.14 | 0.50 | 0.19 | 0.50 | 0.14 | 0.50 | 0.24 |
| 5993.23 | 0.47 | 0.14 | 0.45 | 0.19 | 0.46 | 0.13 | 0.46 | 0.22 |
| 6168.84 | 0.43 | 0.14 | 0.41 | 0.20 | 0.43 | 0.12 | 0.44 | 0.21 |
| 6349.60 | 0.40 | 0.14 | 0.37 | 0.21 | 0.41 | 0.12 | 0.41 | 0.21 |
| 6535.66 | 0.38 | 0.15 | 0.33 | 0.20 | 0.38 | 0.12 | 0.38 | 0.23 |
| 6727.17 | 0.36 | 0.16 | 0.30 | 0.18 | 0.36 | 0.12 | 0.37 | 0.22 |
| 6924.29 | 0.35 | 0.18 | 0.28 | 0.19 | 0.35 | 0.13 | 0.34 | 0.22 |
| 7127.19 | 0.34 | 0.19 | 0.28 | 0.22 | 0.34 | 0.14 | 0.32 | 0.23 |
| 7336.03 | 0.34 | 0.19 | 0.28 | 0.22 | 0.33 | 0.15 | 0.31 | 0.26 |
| 7550.99 | 0.33 | 0.19 | 0.28 | 0.23 | 0.33 | 0.16 | 0.30 | 0.26 |
| 7772.26 | 0.33 | 0.19 | 0.27 | 0.24 | 0.33 | 0.16 | 0.29 | 0.25 |
| 8000.00 | 0.33 | 0.19 | 0.27 | 0.25 | 0.33 | 0.17 | 0.29 | 0.25 |

*Note*. ‘SD’- standard deviation, ‘IQR’- interquartile range

The comparison among the groups was done using Kruskal-Wallis *H* test. The results showed a significant difference in the absorbance at peak and ambient pressure conditions for several frequencies ($p < 0.05$). The specific Chi-square values and *p*-values obtained from the Kruskal-Wallis *H* Test are shown in Table 4.1.7 for peak pressure condition and Table 4.1.8 for ambient pressure condition. As there was a significant difference in absorbance at some frequencies, Mann-Whitney *U* test was done for pair-wise comparisons at those frequencies. The results of pair-wise comparisons are presented within the sub-headings of their respective group comparison.

**Table 4.1.7.**

*The outcome of Kruskal-Wallis H test for comparison of absorbance at peak pressure at each frequency among CI, SNHL and NH group (N=20 for each group)*

| Frequency (in Hz) | CI ears and CI-matched ears | | Non-CI ears and non-CI-matched ears | |
|---|---|---|---|---|
| | $\chi^2(2)$ | *p*-value | $\chi^2(2)$ | *p*-value |
| 226.00 | 11.59 | 0.003 | 0.99 | 0.608 |
| 250.00 | 10.86 | 0.004 | 0.85 | 0.653 |
| 257.33 | 10.75 | 0.004 | 0.95 | 0.621 |
| 264.87 | 10.55 | 0.005 | 1.02 | 0.597 |
| 272.63 | 10.04 | 0.006 | 1.03 | 0.595 |
| 280.62 | 9.90 | 0.007 | 1.09 | 0.579 |
| 288.84 | 9.64 | 0.008 | 1.10 | 0.575 |
| 297.30 | 9.45 | 0.008 | 1.18 | 0.551 |
| 306.12 | 9.75 | 0.007 | 1.22 | 0.542 |
| 314.98 | 9.66 | 0.007 | 1.47 | 0.477 |
| 324.21 | 9.81 | 0.007 | 1.51 | 0.468 |
| 333.71 | 9.78 | 0.007 | 1.31 | 0.518 |
| 343.49 | 10.06 | 0.006 | 1.58 | 0.452 |
| 353.55 | 10.35 | 0.005 | 1.65 | 0.436 |
| 363.91 | 10.82 | 0.004 | 1.69 | 0.428 |
| 374.58 | 10.92 | 0.004 | 1.78 | 0.410 |
| 385.55 | 11.05 | 0.003 | 1.91 | 0.384 |
| 396.95 | 11.16 | 0.003 | 1.84 | 0.397 |
| 408.48 | 11.60 | 0.003 | 1.70 | 0.427 |
| 420.45 | 11.32 | 0.003 | 1.71 | 0.423 |
| 432.77 | 11.46 | 0.003 | 1.85 | 0.396 |
| 445.45 | 11.88 | 0.002 | 1.66 | 0.435 |
| 458.50 | 11.89 | 0.002 | 1.45 | 0.482 |
| 471.94 | 12.37 | 0.002 | 1.24 | 0.537 |
| 485.77 | 12.66 | 0.001 | 1.22 | 0.542 |
| 500.00 | 12.80 | 0.001 | 1.10 | 0.575 |
| 514.65 | 12.77 | 0.001 | 1.19 | 0.549 |
| 529.73 | 13.20 | 0.001 | 1.14 | 0.564 |
| 545.25 | 13.26 | 0.001 | 1.09 | 0.578 |
| 561.23 | 13.18 | 0.001 | 0.90 | 0.634 |
| 577.68 | 14.00 | <0.001 | 0.78 | 0.673 |
| 594.60 | 14.65 | <0.001 | 0.63 | 0.729 |
| 612.03 | 14.55 | <0.001 | 0.54 | 0.760 |

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Table 4.1.7 continued from previous page

| Frequency (in Hz) | CI ears and CI-matched ears | | Non-CI ears and non-CI-matched ears | |
|---|---|---|---|---|
| | $\chi^2(2)$ | *p*-value | $\chi^2(2)$ | *p*-value |
| 629.96 | 14.71 | <0.001 | 0.54 | 0.762 |
| 648.42 | 15.17 | <0.001 | 0.61 | 0.736 |
| 667.42 | 15.66 | <0.001 | 0.42 | 0.810 |
| 686.98 | 15.42 | <0.001 | 0.25 | 0.879 |
| 707.11 | 15.51 | <0.001 | 0.11 | 0.944 |
| 727.83 | 15.40 | <0.001 | 0.18 | 0.911 |
| 749.15 | 15.48 | <0.001 | 0.33 | 0.845 |
| 771.11 | 15.37 | <0.001 | 0.50 | 0.775 |
| 793.70 | 15.64 | <0.001 | 0.53 | 0.765 |
| 816.96 | 15.90 | <0.001 | 0.70 | 0.704 |
| 840.90 | 15.87 | <0.001 | 0.90 | 0.636 |
| 865.54 | 16.25 | <0.001 | 1.13 | 0.565 |
| 890.90 | 17.10 | <0.001 | 1.27 | 0.527 |
| 917.00 | 18.14 | <0.001 | 1.51 | 0.468 |
| 943.87 | 18.03 | <0.001 | 1.56 | 0.457 |
| 971.53 | 18.34 | <0.001 | 2.08 | 0.352 |
| 1000.00 | 18.62 | <0.001 | 2.15 | 0.340 |
| 1029.30 | 18.42 | <0.001 | 2.00 | 0.367 |
| 1059.46 | 17.19 | <0.001 | 1.93 | 0.380 |
| 1090.51 | 16.61 | <0.001 | 1.89 | 0.387 |
| 1122.46 | 15.66 | <0.001 | 1.67 | 0.432 |
| 1155.35 | 14.38 | <0.001 | 1.60 | 0.447 |
| 1189.21 | 12.08 | 0.002 | 1.64 | 0.438 |
| 1224.05 | 10.48 | 0.005 | 1.80 | 0.405 |
| 1259.92 | 9.07 | 0.010 | 1.78 | 0.409 |
| 1296.84 | 7.38 | 0.024 | 2.12 | 0.345 |
| 1334.84 | 7.00 | 0.030 | 2.18 | 0.335 |
| 1373.95 | 7.35 | 0.025 | 2.31 | 0.313 |
| 1414.21 | 6.78 | 0.033 | 3.14 | 0.207 |
| 1455.65 | 7.46 | 0.023 | 3.44 | 0.178 |
| 1498.31 | 7.83 | 0.019 | 3.86 | 0.145 |
| 1542.21 | 7.10 | 0.028 | 3.95 | 0.138 |
| 1587.40 | 7.09 | 0.028 | 3.11 | 0.210 |
| 1633.92 | 7.02 | 0.029 | 2.78 | 0.248 |
| 1681.79 | 7.19 | 0.027 | 2.58 | 0.275 |
| 1731.07 | 8.07 | 0.017 | 2.45 | 0.292 |
| 1781.80 | 8.09 | 0.017 | 2.46 | 0.291 |

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Table 4.1.7 continued from previous page

| Frequency (in Hz) | CI ears and CI-matched ears | | Non-CI ears and non-CI-matched ears | |
|---|---|---|---|---|
| | $\chi^2(2)$ | *p*-value | $\chi^2(2)$ | *p*-value |
| 1834.01 | 9.07 | 0.010 | 2.05 | 0.358 |
| 1887.75 | 10.42 | 0.005 | 1.52 | 0.467 |
| 1943.06 | 10.97 | 0.004 | 1.03 | 0.594 |
| 2000.00 | 11.40 | 0.003 | 1.06 | 0.587 |
| 2058.60 | 12.23 | 0.002 | 0.89 | 0.638 |
| 2118.93 | 13.24 | 0.001 | 0.57 | 0.750 |
| 2181.02 | 13.56 | 0.001 | 0.65 | 0.722 |
| 2244.92 | 14.35 | <0.001 | 0.63 | 0.726 |
| 2310.71 | 14.64 | <0.001 | 0.67 | 0.712 |
| 2378.41 | 13.30 | 0.001 | 1.18 | 0.551 |
| 2448.11 | 13.60 | 0.001 | 1.34 | 0.510 |
| 2519.84 | 13.72 | 0.001 | 2.18 | 0.335 |
| 2593.68 | 14.47 | <0.001 | 3.51 | 0.172 |
| 2669.68 | 15.37 | <0.001 | 4.47 | 0.106 |
| 2747.91 | 15.32 | <0.001 | 4.98 | 0.082 |
| 2828.43 | 14.19 | <0.001 | 6.77 | 0.033 |
| 2911.31 | 12.81 | 0.001 | 7.02 | 0.029 |
| 2996.61 | 12.45 | 0.001 | 6.50 | 0.038 |
| 3084.42 | 11.82 | 0.002 | 6.36 | 0.041 |
| 3174.80 | 11.56 | 0.003 | 5.98 | 0.050 |
| 3267.83 | 11.04 | 0.003 | 5.61 | 0.060 |
| 3363.59 | 9.80 | 0.007 | 5.26 | 0.071 |
| 3462.15 | 8.97 | 0.011 | 4.92 | 0.085 |
| 3563.59 | 8.32 | 0.015 | 4.65 | 0.097 |
| 3668.02 | 6.61 | 0.036 | 4.76 | 0.092 |
| 3775.5 | 5.50 | 0.063 | 4.47 | 0.106 |
| 3886.13 | 4.82 | 0.089 | 4.41 | 0.110 |
| 4000.00 | 3.98 | 0.136 | 3.79 | 0.149 |
| 4117.21 | 3.13 | 0.208 | 3.60 | 0.164 |
| 4237.85 | 2.67 | 0.262 | 3.37 | 0.184 |
| 4362.03 | 1.84 | 0.397 | 3.03 | 0.219 |
| 4489.85 | 1.67 | 0.431 | 2.57 | 0.276 |
| 4621.41 | 1.28 | 0.526 | 2.23 | 0.327 |
| 4756.83 | 1.25 | 0.533 | 1.59 | 0.451 |
| 4896.21 | 1.02 | 0.598 | 1.25 | 0.533 |
| 5039.68 | 1.22 | 0.542 | 0.82 | 0.660 |
| 5187.36 | 1.25 | 0.534 | 0.70 | 0.703 |

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Table 4.1.7 continued from previous page

| Frequency (in Hz) | CI ears and CI-matched ears | | Non-CI ears and non-CI-matched ears | |
|---|---|---|---|---|
| | $\chi^2(2)$ | *p*-value | $\chi^2(2)$ | *p*-value |
| 5339.36 | 0.80 | 0.669 | 0.69 | 0.706 |
| 5495.81 | 0.51 | 0.771 | 0.75 | 0.686 |
| 5656.85 | 0.40 | 0.816 | 0.90 | 0.636 |
| 5822.61 | 0.31 | 0.854 | 0.74 | 0.690 |
| 5993.23 | 0.27 | 0.873 | 0.64 | 0.725 |
| 6168.84 | 0.13 | 0.932 | 0.63 | 0.727 |
| 6349.60 | 0.13 | 0.934 | 0.47 | 0.787 |
| 6535.66 | 0.08 | 0.960 | 0.41 | 0.812 |
| 6727.17 | 0.05 | 0.972 | 0.47 | 0.788 |
| 6924.29 | 0.06 | 0.969 | 0.48 | 0.786 |
| 7127.19 | 0.03 | 0.981 | 0.39 | 0.819 |
| 7336.03 | 0.03 | 0.980 | 0.37 | 0.830 |
| 7550.99 | 0.12 | 0.937 | 0.14 | 0.932 |
| 7772.26 | 0.16 | 0.920 | 0.05 | 0.972 |
| 8000.00 | 0.17 | 0.916 | 0.00 | 0.998 |

**Table 4.1.8.**

*The outcome of Kruskal-Wallis H test for comparison of absorbance at ambient pressure at each frequency among CI, SNHL and NH group (N=20 for each group)*

| Frequency (in Hz) | CI ears and CI-matched ears | | Non-CI ears and non-CI-matched ears | |
|---|---|---|---|---|
| | $\chi^2(2)$ | *p*-value | $\chi^2(2)$ | *p*-value |
| 226.00 | 10.15 | 0.006 | 1.34 | 0.510 |
| 250.00 | 10.00 | 0.007 | 1.65 | 0.436 |
| 257.33 | 10.25 | 0.006 | 1.63 | 0.442 |
| 264.87 | 10.24 | 0.006 | 1.61 | 0.446 |
| 272.63 | 10.35 | 0.006 | 1.57 | 0.456 |
| 280.62 | 10.41 | 0.005 | 1.68 | 0.430 |
| 288.84 | 10.26 | 0.006 | 1.76 | 0.413 |
| 297.30 | 10.02 | 0.007 | 2.01 | 0.365 |
| 306.12 | 9.97 | 0.007 | 2.06 | 0.356 |
| 314.98 | 10.20 | 0.006 | 2.11 | 0.347 |
| 324.21 | 10.37 | 0.006 | 2.11 | 0.348 |
| 333.71 | 10.44 | 0.005 | 2.32 | 0.312 |
| 343.49 | 10.47 | 0.005 | 2.44 | 0.295 |
| 353.55 | 10.59 | 0.005 | 2.63 | 0.267 |
| 363.91 | 10.42 | 0.005 | 2.74 | 0.253 |
| 374.58 | 10.89 | 0.004 | 2.65 | 0.265 |
| 385.55 | 11.23 | 0.004 | 2.71 | 0.257 |
| 396.95 | 11.53 | 0.003 | 2.57 | 0.276 |
| 408.48 | 11.13 | 0.004 | 2.54 | 0.281 |
| 420.45 | 11.29 | 0.004 | 2.42 | 0.297 |
| 432.77 | 11.12 | 0.004 | 2.26 | 0.323 |
| 445.45 | 11.15 | 0.004 | 2.04 | 0.359 |
| 458.50 | 11.52 | 0.003 | 1.81 | 0.403 |
| 471.94 | 11.91 | 0.003 | 1.71 | 0.424 |
| 485.77 | 12.42 | 0.002 | 1.72 | 0.422 |
| 500.00 | 13.12 | 0.001 | 1.77 | 0.411 |
| 514.65 | 13.55 | 0.001 | 2.12 | 0.346 |
| 529.73 | 13.29 | 0.001 | 2.14 | 0.341 |
| 545.25 | 13.27 | 0.001 | 1.99 | 0.368 |
| 561.23 | 12.78 | 0.002 | 1.92 | 0.382 |
| 577.68 | 12.67 | 0.002 | 2.01 | 0.365 |
| 594.60 | 13.05 | 0.001 | 2.06 | 0.356 |
| 612.03 | 12.85 | 0.002 | 2.08 | 0.353 |

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Table 4.1.8 continued from previous page

| Frequency (in Hz) | CI ears and CI-matched ears | | Non-CI ears and non-CI-matched ears | |
|---|---|---|---|---|
| | $\chi^2(2)$ | *p*-value | $\chi^2(2)$ | *p*-value |
| 629.96 | 12.94 | 0.002 | 2.03 | 0.361 |
| 648.42 | 13.28 | 0.001 | 2.31 | 0.314 |
| 667.42 | 13.03 | 0.001 | 2.48 | 0.288 |
| 686.98 | 12.92 | 0.002 | 2.10 | 0.349 |
| 707.11 | 13.15 | 0.001 | 2.16 | 0.339 |
| 727.83 | 13.50 | 0.001 | 2.50 | 0.285 |
| 749.15 | 12.88 | 0.002 | 2.71 | 0.257 |
| 771.11 | 12.60 | 0.002 | 3.09 | 0.212 |
| 793.70 | 12.39 | 0.002 | 3.25 | 0.196 |
| 816.96 | 12.37 | 0.002 | 3.32 | 0.190 |
| 840.90 | 12.60 | 0.002 | 3.34 | 0.187 |
| 865.54 | 12.61 | 0.002 | 3.85 | 0.146 |
| 890.90 | 12.91 | 0.002 | 4.30 | 0.116 |
| 917.00 | 12.94 | 0.002 | 4.60 | 0.100 |
| 943.87 | 12.98 | 0.002 | 5.15 | 0.076 |
| 971.53 | 14.15 | 0.001 | 5.65 | 0.059 |
| 1000.00 | 14.22 | 0.001 | 5.63 | 0.060 |
| 1029.30 | 14.15 | 0.001 | 5.60 | 0.061 |
| 1059.46 | 15.15 | 0.001 | 5.00 | 0.082 |
| 1090.51 | 14.53 | 0.001 | 4.49 | 0.106 |
| 1122.46 | 14.48 | 0.001 | 4.35 | 0.113 |
| 1155.35 | 13.00 | 0.001 | 4.11 | 0.128 |
| 1189.21 | 11.28 | 0.004 | 3.46 | 0.177 |
| 1224.05 | 10.25 | 0.006 | 3.38 | 0.184 |
| 1259.92 | 8.69 | 0.013 | 3.07 | 0.215 |
| 1296.84 | 7.40 | 0.025 | 2.59 | 0.273 |
| 1334.84 | 6.95 | 0.031 | 1.90 | 0.385 |
| 1373.95 | 6.54 | 0.038 | 1.79 | 0.408 |
| 1414.21 | 6.55 | 0.038 | 1.57 | 0.456 |
| 1455.65 | 6.07 | 0.048 | 1.50 | 0.470 |
| 1498.31 | 6.62 | 0.036 | 1.62 | 0.443 |
| 1542.21 | 6.80 | 0.033 | 1.61 | 0.447 |
| 1587.40 | 6.58 | 0.037 | 1.53 | 0.465 |
| 1633.92 | 6.33 | 0.042 | 1.20 | 0.549 |
| 1681.79 | 6.26 | 0.044 | 1.08 | 0.580 |
| 1731.07 | 5.90 | 0.052 | 1.25 | 0.533 |
| 1781.80 | 6.42 | 0.040 | 1.10 | 0.574 |

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Table 4.1.8 continued from previous page

| Frequency (in Hz) | CI ears and CI-matched ears | | Non-CI ears and non-CI-matched ears | |
|---|---|---|---|---|
| | $\chi^2(2)$ | *p*-value | $\chi^2(2)$ | *p*-value |
| 1834.01 | 6.60 | 0.037 | 1.06 | 0.588 |
| 1887.75 | 7.24 | 0.027 | 1.23 | 0.540 |
| 1943.06 | 7.64 | 0.022 | 1.17 | 0.556 |
| 2000.00 | 7.55 | 0.023 | 0.99 | 0.607 |
| 2058.60 | 9.11 | 0.011 | 0.65 | 0.720 |
| 2118.93 | 9.94 | 0.007 | 0.41 | 0.814 |
| 2181.02 | 10.33 | 0.006 | 0.41 | 0.813 |
| 2244.92 | 11.03 | 0.004 | 0.40 | 0.816 |
| 2310.71 | 10.36 | 0.006 | 0.44 | 0.799 |
| 2378.41 | 9.98 | 0.007 | 0.59 | 0.744 |
| 2448.11 | 9.99 | 0.007 | 0.91 | 0.633 |
| 2519.84 | 10.48 | 0.005 | 1.55 | 0.460 |
| 2593.68 | 11.27 | 0.004 | 2.27 | 0.320 |
| 2669.68 | 13.06 | 0.001 | 2.56 | 0.278 |
| 2747.91 | 13.25 | 0.001 | 2.98 | 0.225 |
| 2828.43 | 13.59 | 0.001 | 3.84 | 0.146 |
| 2911.31 | 12.56 | 0.002 | 4.31 | 0.116 |
| 2996.61 | 12.34 | 0.002 | 4.01 | 0.134 |
| 3084.42 | 11.98 | 0.002 | 4.12 | 0.127 |
| 3174.80 | 11.12 | 0.004 | 4.27 | 0.118 |
| 3267.83 | 10.17 | 0.006 | 4.03 | 0.133 |
| 3363.59 | 9.49 | 0.009 | 3.91 | 0.141 |
| 3462.15 | 8.65 | 0.013 | 3.84 | 0.146 |
| 3563.59 | 7.87 | 0.019 | 3.84 | 0.146 |
| 3668.02 | 6.66 | 0.036 | 3.69 | 0.158 |
| 3775.50 | 5.70 | 0.058 | 3.99 | 0.136 |
| 3886.13 | 4.42 | 0.110 | 4.04 | 0.133 |
| 4000.00 | 3.29 | 0.192 | 3.31 | 0.191 |
| 4117.21 | 2.28 | 0.319 | 3.36 | 0.186 |
| 4237.85 | 1.77 | 0.412 | 3.06 | 0.216 |
| 4362.03 | 1.53 | 0.465 | 2.65 | 0.265 |
| 4489.85 | 1.47 | 0.477 | 2.27 | 0.320 |
| 4621.41 | 1.26 | 0.531 | 2.02 | 0.364 |
| 4756.83 | 1.03 | 0.595 | 1.31 | 0.519 |
| 4896.21 | 1.26 | 0.531 | 0.99 | 0.609 |
| 5039.68 | 1.37 | 0.502 | 0.85 | 0.652 |
| 5187.36 | 1.77 | 0.412 | 0.93 | 0.628 |

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Table 4.1.8 continued from previous page

| Frequency (in Hz) | CI ears and CI-matched ears | | Non-CI ears and non-CI-matched ears | |
|---|---|---|---|---|
| | $\chi^2(2)$ | *p*-value | $\chi^2(2)$ | *p*-value |
| 5339.36 | 1.65 | 0.438 | 1.04 | 0.592 |
| 5495.81 | 1.18 | 0.552 | 1.57 | 0.456 |
| 5656.85 | 0.85 | 0.653 | 1.83 | 0.400 |
| 5822.61 | 0.61 | 0.736 | 1.85 | 0.395 |
| 5993.23 | 0.45 | 0.795 | 1.66 | 0.436 |
| 6168.84 | 0.30 | 0.858 | 1.57 | 0.456 |
| 6349.60 | 0.16 | 0.919 | 1.50 | 0.471 |
| 6535.66 | 0.10 | 0.950 | 1.44 | 0.485 |
| 6727.17 | 0.05 | 0.975 | 1.33 | 0.513 |
| 6924.29 | 0.07 | 0.964 | 1.04 | 0.593 |
| 7127.19 | 0.06 | 0.970 | 0.93 | 0.626 |
| 7336.03 | 0.06 | 0.966 | 0.68 | 0.709 |
| 7550.99 | 0.18 | 0.911 | 0.29 | 0.863 |
| 7772.26 | 0.16 | 0.922 | 0.12 | 0.939 |
| 8000.00 | 0.21 | 0.900 | 0.04 | 0.979 |

### 4.1.1 Comparison of WBA at peak pressure between CI group and SNHL group

Mann-Whitney *U* test was done for pair-wise comparison between CI group and SNHL group, separately for the two ears. The mean and standard deviation of absorbance values across frequencies in cochlear implanted ears (henceforth called CI ears) and matched ears of the SNHL group (henceforth called CI-matched ears of SNHL group) are shown in Figure 4.1.1.1.

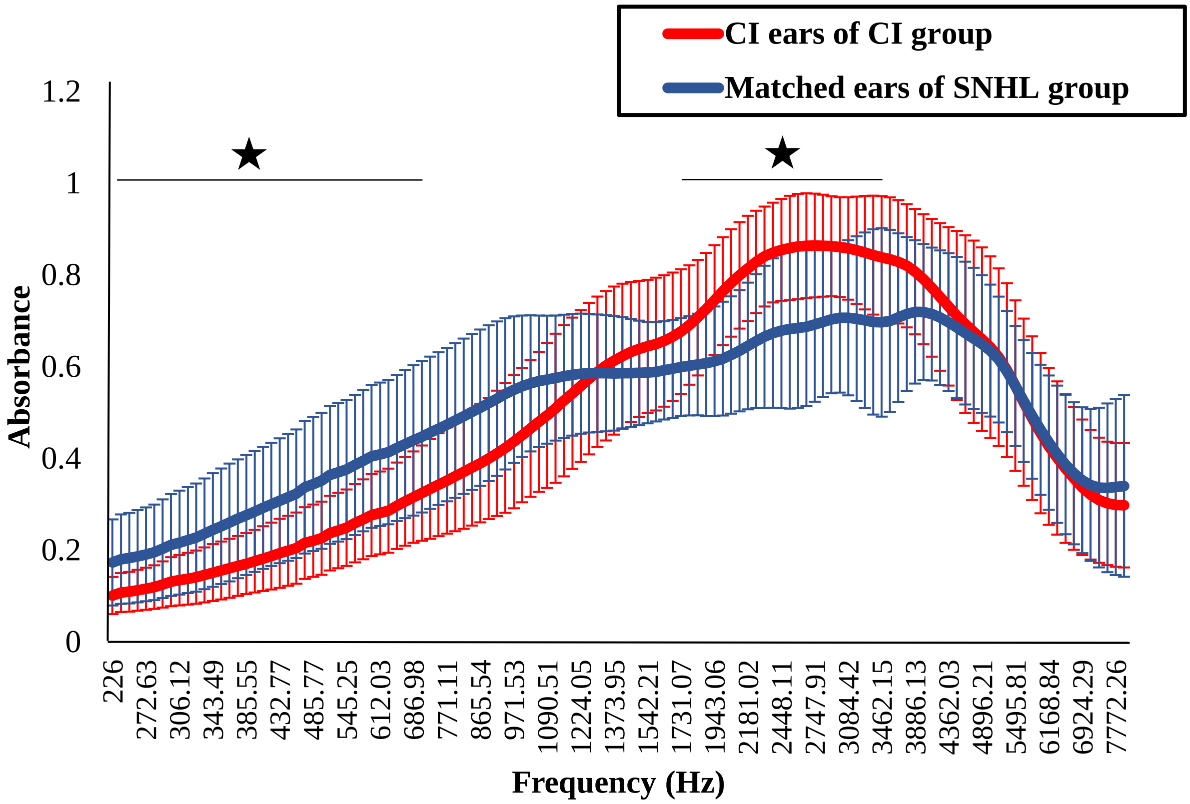


*Figure 4.1.1.1:* Mean and standard deviation of absorbance at peak pressure across frequencies in CI ears of the CI group and the CI-matched ears of the SNHL group. The star-marked comparisons have a statistically significant difference after α-correction ($p < 0.016$).

The absorbance values were significantly lower in the CI ears of CI group than the CI-matched ears of the SNHL group in the frequency range of 226-749.15 Hz after α-correction ($p < 0.016$). Further, there was a significantly higher absorbance in the CI ears of CI group than the CI-matched ears of the SNHL group in the frequency range of 1834.01-3563.59 Hz after α-correction ($p < 0.016$). There was no significant difference between them at all other frequencies after α-correction ($p > 0.016$). The specific Z-values and *p*-values for the pair-wise comparisons are shown in Table 4.1.1.1.

**Table 4.1.1.1.**

*The outcome of Mann-Whitney U test for pair-wise comparison of absorbance at peak pressure between the CI ears of the CI group and the CI-matched ears of the SNHL group*

| Frequency (in Hz) | Z-value | *p*-value | Frequency (in Hz) | Z-value | *p*-value |
|---|---|---|---|---|---|
| 226.00 | -2.69 | 0.007 | 971.53 | -2.28 | 0.022 |
| 250.00 | -2.66 | 0.008 | 1000.00 | -2.24 | 0.025 |
| 257.33 | -2.66 | 0.008 | 1029.30 | -2.08 | 0.037 |
| 264.87 | -2.67 | 0.007 | 1059.46 | -1.94 | 0.051 |
| 272.63 | -2.59 | 0.009 | 1090.51 | -1.69 | 0.091 |
| 280.62 | -2.55 | 0.011 | 1122.46 | -1.37 | 0.168 |
| 288.84 | -2.46 | 0.014 | 1155.35 | -1.00 | 0.317 |
| 297.30 | -2.42 | 0.015 | 1189.21 | -0.64 | 0.516 |
| 306.12 | -2.46 | 0.014 | 1224.05 | -0.33 | 0.735 |
| 314.98 | -2.48 | 0.013 | 1259.92 | -0.08 | 0.935 |
| 324.21 | -2.50 | 0.012 | 1296.84 | -0.40 | 0.685 |
| 333.71 | -2.54 | 0.011 | 1334.84 | -0.73 | 0.465 |
| 343.49 | -2.61 | 0.009 | 1373.95 | -0.90 | 0.365 |
| 353.55 | -2.65 | 0.008 | 1414.21 | -1.01 | 0.310 |
| 363.91 | -2.71 | 0.007 | 1455.65 | -1.12 | 0.262 |
| 374.58 | -2.70 | 0.007 | 1498.31 | -1.44 | 0.148 |
| 385.55 | -2.78 | 0.005 | 1542.21 | -1.50 | 0.133 |
| 396.95 | -2.78 | 0.005 | 1587.40 | -1.59 | 0.110 |
| 408.48 | -2.84 | 0.005 | 1633.92 | -1.70 | 0.088 |
| 420.45 | -2.81 | 0.005 | 1681.79 | -1.86 | 0.062 |
| 432.77 | -2.85 | 0.004 | 1731.07 | -2.02 | 0.042 |
| 445.45 | -2.97 | 0.003 | 1781.80 | -2.27 | 0.023 |
| 458.50 | -3.00 | 0.003 | 1834.01 | -2.51 | 0.012 |
| 471.94 | -3.02 | 0.002 | 1887.75 | -2.80 | 0.005 |
| 485.77 | -3.02 | 0.002 | 1943.06 | -3.00 | 0.003 |
| 500.00 | -3.09 | 0.002 | 2000.00 | -3.13 | 0.002 |
| 514.65 | -3.08 | 0.002 | 2058.60 | -3.31 | 0.001 |
| 529.73 | -3.13 | 0.002 | 2118.93 | -3.36 | 0.001 |
| 545.25 | -3.11 | 0.002 | 2181.02 | -3.36 | 0.001 |
| 561.23 | -3.05 | 0.002 | 2244.92 | -3.50 | <0.001 |
| 577.68 | -3.05 | 0.002 | 2310.71 | -3.53 | <0.001 |
| 594.60 | -3.00 | 0.003 | 2378.41 | -3.32 | 0.001 |
| 612.03 | -3.00 | 0.003 | 2448.11 | -3.32 | 0.001 |
| 629.96 | -2.97 | 0.003 | 2519.84 | -3.35 | 0.001 |

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Table 4.1.1.1 continued from previous page

| Frequency (in Hz) | Z-value | *p*-value | Frequency (in Hz) | Z-value | *p*-value |
|---|---|---|---|---|---|
| 648.42 | -2.90 | 0.004 | 2593.68 | -3.38 | 0.001 |
| 667.42 | -2.82 | 0.005 | 2669.68 | -3.44 | 0.001 |
| 686.98 | -2.63 | 0.008 | 2747.91 | -3.42 | 0.001 |
| 707.11 | -2.51 | 0.012 | 2828.43 | -3.28 | 0.001 |
| 727.83 | -2.46 | 0.014 | 2911.31 | -3.15 | 0.002 |
| 749.15 | -2.43 | 0.015 | 2996.61 | -3.02 | 0.002 |
| 771.11 | -2.29 | 0.021 | 3084.42 | -2.86 | 0.004 |
| 793.70 | -2.21 | 0.027 | 3174.80 | -2.82 | 0.005 |
| 816.96 | -2.21 | 0.027 | 3267.83 | -2.71 | 0.007 |
| 840.90 | -2.19 | 0.028 | 3363.59 | -2.56 | 0.010 |
| 865.54 | -2.21 | 0.027 | 3462.15 | -2.46 | 0.014 |
| 890.90 | -2.21 | 0.027 | 3563.59 | -2.43 | 0.015 |
| 917.00 | -2.27 | 0.023 | 3668.02 | -2.21 | 0.027 |
| 943.87 | -2.24 | 0.025 | | | |

*Note.* Pair-wise comparison was done at these frequencies due to a significant group difference on Kruskal-Wallis *H* test only at these frequencies.

In addition to the group-wise comparison, the individual data were also analyzed to obtain the proportion of ears with an abnormal absorbance. Figure 4.1.1.2 shows the participants with an abnormal absorbance at peak pressure at various frequencies in CI ears of the CI group and CI-matched ears of the SNHL group. Figure 4.1.1.3 shows the individual absorbance curves across frequencies when compared against the mean absorbance curve and standard deviation of the NH group at peak pressure condition.

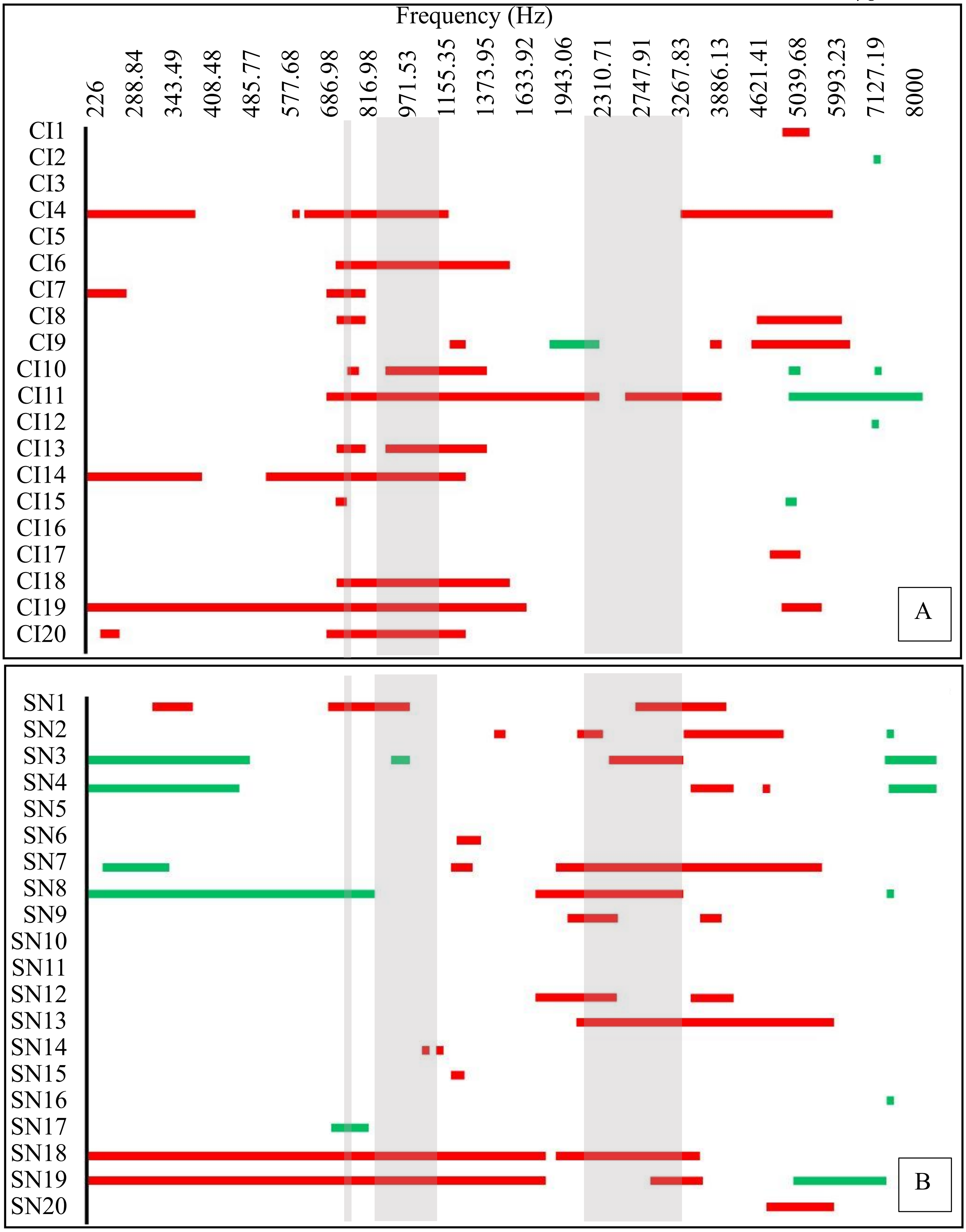


*Figure 4.1.1.2:* Abnormal absorbance across frequencies in the peak pressure in (A) CI ears of the CI group and (B) CI-matched ears of the SNHL group. The digits on the Y-axis represent participant number and the prefix of 'CI' and 'SN' indicates CI group and SNHL group, respectively. The red-colour lines represent significantly lower absorbance and green-colour lines indicate significantly higher absorbance. The grey shaded regions indicate statistically significantly difference in proportions of abnormal results.

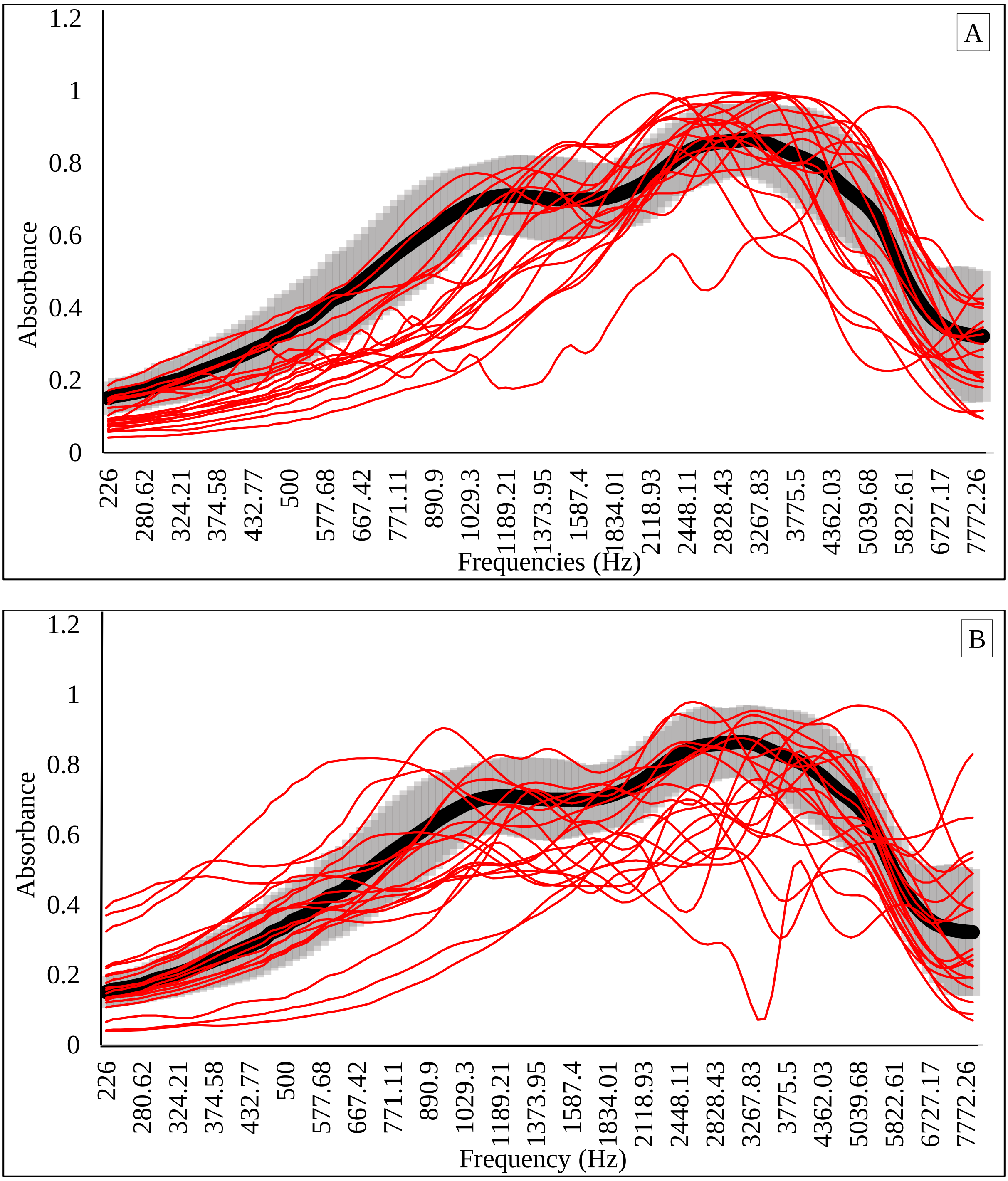


*Figure 4.1.1.3:* Absorbance curves at peak pressure in (A) CI ears of the CI group, and (B) CI-matched ears of the SNHL group. The thin red lines represent absorbance curve of each participant in his/her respective group. In each panel, the thick black line represents the mean absorbance values and the gray shaded region covers 2 standard deviations of absorbance found in the CI-matched ears of the NH group (normative data).

At peak pressure, the proportion of ears with an abnormal absorbance was compared between the groups using the Equality of test for proportions. This was done at each frequency separately. The results showed a significant difference in proportion of abnormal absorbance at 727.83 Hz, and in the frequency range of 865.54-1090.51 Hz and 2181.02-3174.8 Hz between the groups for the comparison of CI ears of the CI group with the CI matched ears of the SNHL group ($p$ < 0.05). The specific Z-values and *p*-values for the comparisons are shown in Table 4.1.1.2.

**Table 4.1.1.2.**

*The results of the Equality of test for proportions for comparison of the proportion of ears with abnormal absorbance at peak pressure across frequencies between the CI ears of the CI group and the CI-matched ears of the SNHL group*

| Frequency (in Hz) | Z-value | *p*-value | Frequency (in Hz) | Z-value | *p*-value |
|---|---|---|---|---|---|
| 226.00 | 0.37 | 0.705 | 1414.21 | 0.88 | 0.375 |
| 250.00 | 0.73 | 0.465 | 1455.65 | 0.47 | 0.632 |
| 257.33 | 0.35 | 0.723 | 1498.31 | 0.00 | 1.000 |
| 264.87 | 0.35 | 0.723 | 1542.21 | 0.47 | 0.632 |
| 272.63 | 0.35 | 0.723 | 1587.40 | 0.88 | 0.375 |
| 280.62 | 0.73 | 0.465 | 1633.92 | 1.43 | 0.151 |
| 288.84 | 1.13 | 0.256 | 1681.79 | 1.05 | 0.291 |
| 297.30 | 1.13 | 0.256 | 1731.07 | 0.47 | 0.632 |
| 306.12 | 1.46 | 0.144 | 1781.80 | 0.88 | 0.375 |
| 314.98 | 1.46 | 0.144 | 1834.01 | 1.58 | 0.113 |
| 324.21 | 1.46 | 0.144 | 1887.75 | 1.89 | 0.058 |
| 333.71 | 1.46 | 0.144 | 1943.06 | 1.89 | 0.058 |
| 343.49 | 1.13 | 0.256 | 2000.00 | 1.89 | 0.058 |
| 353.55 | 1.13 | 0.256 | 2058.60 | 1.58 | 0.113 |
| 363.91 | 1.13 | 0.256 | 2118.93 | 1.89 | 0.058 |
| 374.58 | 1.13 | 0.256 | 2181.02 | 2.37 | 0.017 |
| 385.55 | 1.24 | 0.211 | 2244.92 | 2.39 | 0.016 |
| 396.95 | 1.77 | 0.076 | 2310.71 | 2.39 | 0.016 |
| 408.48 | 1.77 | 0.076 | 2378.41 | 2.08 | 0.037 |
| 420.45 | 1.77 | 0.076 | 2448.11 | 2.08 | 0.037 |
| 432.77 | 1.77 | 0.076 | 2519.84 | 2.37 | 0.017 |
| 445.45 | 1.77 | 0.076 | 2593.68 | 2.37 | 0.017 |
| 458.50 | 1.43 | 0.151 | 2669.68 | 2.08 | 0.037 |
| 471.94 | 1.43 | 0.151 | 2747.91 | 2.08 | 0.037 |
| 485.77 | 1.05 | 0.291 | 2828.43 | 2.08 | 0.037 |
| 500.00 | 0.47 | 0.632 | 2911.31 | 2.37 | 0.017 |
| 514.65 | 0.47 | 0.632 | 2996.61 | 2.19 | 0.028 |
| 529.73 | 0.47 | 0.632 | 3084.42 | 2.47 | 0.013 |
| 545.25 | 0.47 | 0.632 | 3174.80 | 2.19 | 0.028 |
| 561.23 | 0.47 | 0.632 | 3267.83 | 1.89 | 0.058 |
| 577.68 | 0.47 | 0.632 | 3363.59 | 1.46 | 0.144 |
| 594.60 | 0.47 | 0.632 | 3462.15 | 1.13 | 0.256 |
| 612.03 | 0.00 | 1.000 | 3563.59 | 0.79 | 0.429 |
| 629.96 | 0.00 | 1.000 | 3668.02 | 1.05 | 0.291 |
| 648.42 | 0.37 | 0.705 | 3775.50 | 1.05 | 0.291 |
| 667.42 | 0.35 | 0.723 | 3886.13 | 1.05 | 0.291 |
| 686.98 | 1.93 | 0.052 | 4000.00 | 0.47 | 0.632 |

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Table 4.1.1.2 continued from previous page

| Frequency (in Hz) | Z-value | *p*-value | Frequency (in Hz) | Z-value | *p*-value |
|---|---|---|---|---|---|
| 707.11 | 1.93 | 0.052 | 4117.21 | 0.79 | 0.429 |
| 727.83 | 2.23 | 0.025 | 4237.85 | 0.416 | 0.677 |
| 749.15 | 1.93 | 0.052 | 4362.03 | 0.00 | 1.000 |
| 771.11 | 1.63 | 0.102 | 4489.85 | 0.00 | 1.000 |
| 793.70 | 1.38 | 0.167 | 4621.41 | 0.73 | 0.465 |
| 816.96 | 1.77 | 0.076 | 4756.83 | 1.68 | 0.09 |
| 840.90 | 1.38 | 0.167 | 4896.21 | 1.68 | 0.09 |
| 865.54 | 2.36 | 0.018 | 5039.68 | 1.06 | 0.288 |
| 890.90 | 1.98 | 0.046 | 5187.36 | 0.73 | 0.465 |
| 917.00 | 1.98 | 0.046 | 5339.36 | 0.79 | 0.429 |
| 943.87 | 2.76 | 0.005 | 5495.81 | 0.79 | 0.429 |
| 971.53 | 2.36 | 0.018 | 5656.85 | 1.43 | 0.151 |
| 1000.00 | 2.76 | 0.005 | 5822.61 | 1.43 | 0.151 |
| 1029.30 | 2.36 | 0.018 | 5993.23 | 1.05 | 0.291 |
| 1059.46 | 2.76 | 0.005 | 6168.84 | 0.60 | 0.548 |
| 1090.51 | 2.28 | 0.022 | 6349.60 | 0.00 | 1.000 |
| 1122.46 | 1.93 | 0.052 | 6535.66 | 0.00 | 1.000 |
| 1155.35 | 1.32 | 0.184 | 6727.17 | 0.60 | 0.548 |
| 1189.21 | 1.68 | 0.091 | 6924.29 | 0.73 | 0.465 |
| 1224.05 | 0.79 | 0.429 | 7127.19 | 1.05 | 0.291 |
| 1259.92 | 1.24 | 0.211 | 7336.03 | 0.60 | 0.548 |
| 1296.84 | 1.24 | 0.211 | 7550.99 | 0.60 | 0.548 |
| 1334.84 | 0.41 | 0.677 | 7772.26 | 0.60 | 0.548 |
| 1373.95 | 0.41 | 0.677 | 8000.00 | 0.60 | 0.548 |

The mean and standard deviation of absorbance values across frequencies in the non-implanted ears of the CI group (henceforth called non-CI ears) and the same side ears of the SNHL group as the non-CI ears (henceforth called as non-CI-matched ears of the SNHL group) are shown in Figure 4.1.1.4.

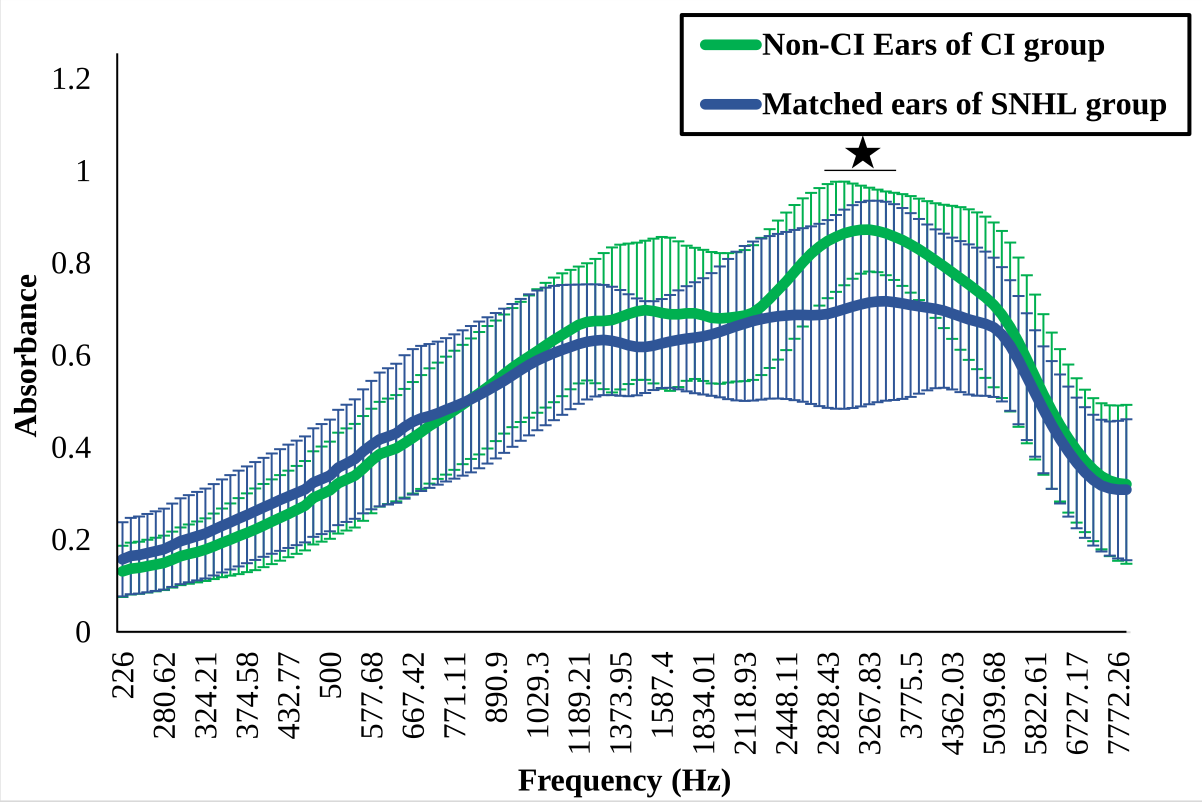


*Figure 4.1.1.4:* Mean and standard deviation of absorbance at peak pressure across frequencies in the non-CI ears of the CI group and the non-CI-matched ears of the SNHL group. The star-marked comparisons have a significant difference after α-correction ($p < 0.016$).

The absorbance values in the non-CI ears of the CI group were significantly higher than the non-CI-matched ears of the SNHL group in the frequency range of 2828.43-3084.42 Hz ($p < 0.016$) but not at other frequencies. The specific Z-values and *p*-values for the pair-wise comparisons are shown in Table 4.1.1.3.

**Table 4.1.1.3.**

*The outcome of Mann-Whitney U test for pair-wise comparison of absorbance at peak pressure between the non-CI ears of the CI group and the non-CI-matched ears of the SNHL group*

| Frequency (Hz) | Z-value | *p*-value |
|---|---|---|
| 2828.43 | -2.475 | 0.013 |
| 2911.31 | -2.597 | 0.009 |
| 2996.61 | -2.489 | 0.013 |
| 3084.42 | -2.421 | 0.015 |

*Note.* Pair-wise comparison was done at these frequencies due to a significant group difference on Kruskal-Wallis *H* test only at these frequencies.

In addition to the group-wise comparison, the individual data were also analyzed to obtain the proportion of ears with an abnormal absorbance. Figure 4.1.1.5 shows the participants with an abnormal absorbance at peak pressure at various frequencies in non-CI ears of the CI group and non-CI matched ears of the SNHL group. Figure 4.1.1.6 shows the individual absorbance curves across frequencies when compared against the mean absorbance curve and standard deviation of the NH group at peak pressure condition.

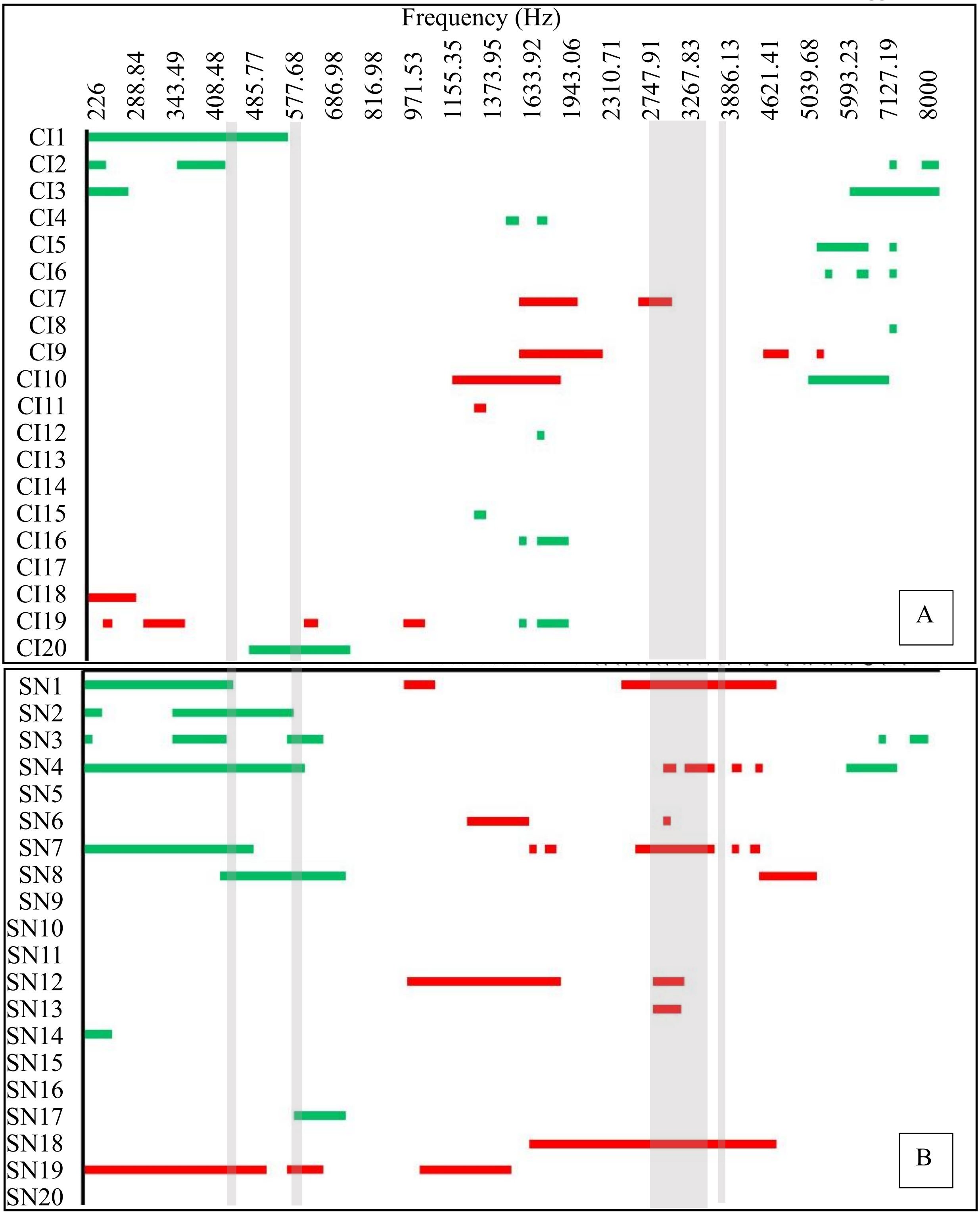


*Figure 4.1.1.5*: Abnormal absorbance across frequencies in the peak pressure in (A) non-CI ears of the CI group and (B) non-CI matched ears of the SNHL group. The digits on the Y-axis represent participant number and prefix of 'CI' and 'SN' indicates CI group and SNHL group, respectively. The red-colour lines represent significantly lower absorbance and green-colour lines indicate significantly higher absorbance. The grey shaded regions indicate statistically significant difference ib proportions of abnormal results.

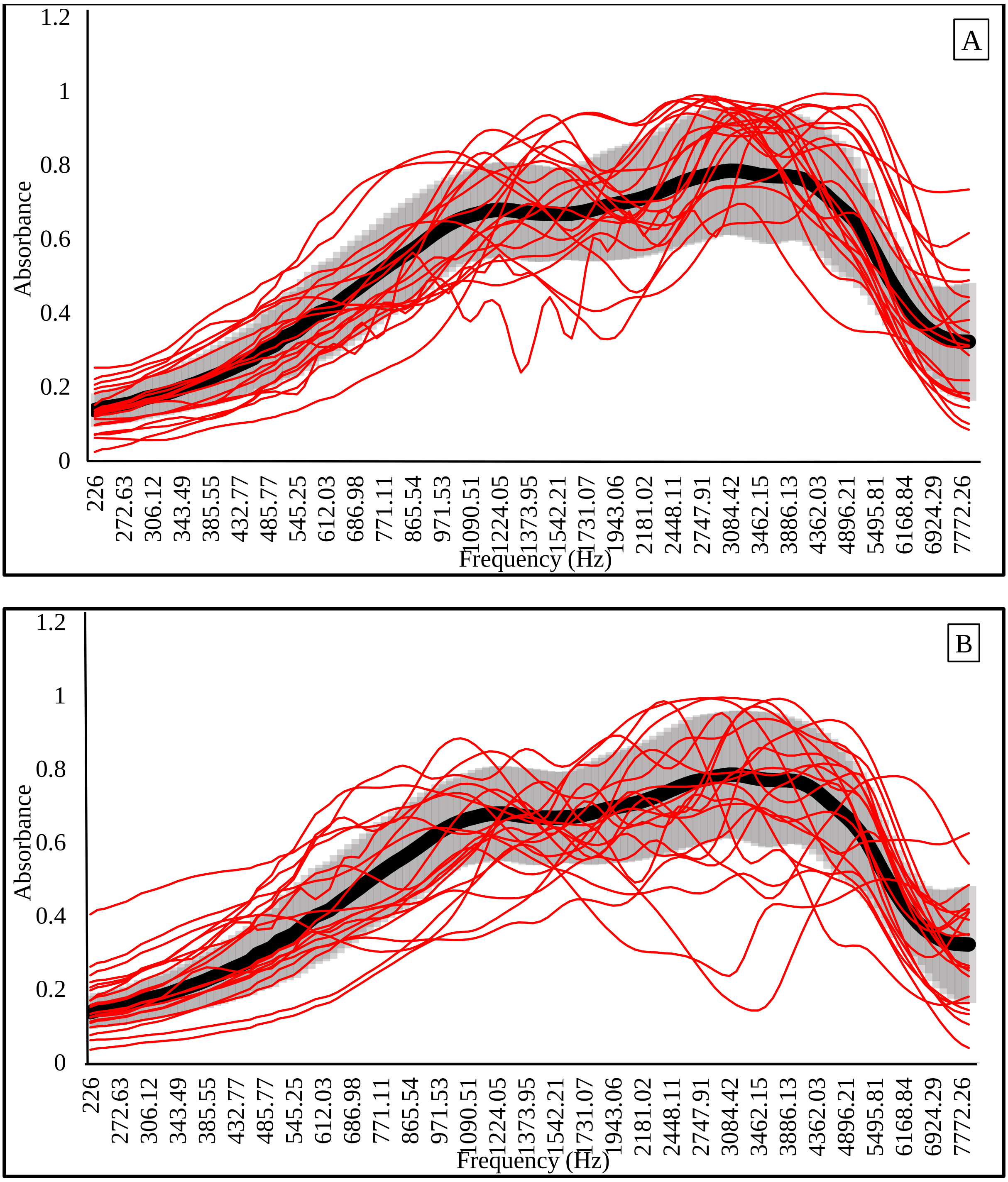


*Figure 4.1.1.6:* Absorbance curves at peak pressure in (A) non-CI ears of the CI group, and (B) non-CI matched ears of the SNHL group. The thin red lines represent absorbance curve of each participant in his/her respective group. In each panel, the thick black line represents the mean absorbance values and the gray shaded region covers 2 standard deviations of absorbance found in the CI-matched ears of the NH group (normative data).

At peak pressure, the proportion of ears with an abnormal absorbance was compared between the groups using the Equality of test for proportions. This was done separately at each frequency. The results showed a significant difference in proportion of abnormal absorbance at 432.77-445.45 Hz, 561.23-577.68 Hz, and 2747.91-3363.59 Hz and 3775.5 Hz between the groups for the comparison of non-CI ears of the CI group with the non-CI matched ears of the SNHL group ($p < 0.05$). The specific Z-values and *p*-values for the comparisons are shown in Table 4.1.1.4.

**Table 4.1.1.4.**

*The results of the Equality of test for proportions for comparison of the proportion of ears with abnormal absorbance at peak pressure across frequencies between the non-CI ears of the CI group and the non-CI matched ears of the SNHL group*

| Frequency (in Hz) | Z-value | *p*-value | Frequency (in Hz) | Z-value | *p*-value |
|---|---|---|---|---|---|
| 226.00 | 0.69 | 0.490 | 1414.21 | 0.47 | 0.632 |
| 250.00 | 0.73 | 0.465 | 1455.65 | 1.13 | 0.256 |
| 257.33 | 0.35 | 0.723 | 1498.31 | 0.47 | 0.632 |
| 264.87 | 0.73 | 0.465 | 1542.21 | 1.58 | 0.113 |
| 272.63 | 0.41 | 0.677 | 1587.40 | 1.06 | 0.288 |
| 280.62 | 0.88 | 0.375 | 1633.92 | 1.58 | 0.113 |
| 288.84 | 1.43 | 0.151 | 1681.79 | 0.79 | 0.429 |
| 297.30 | 0.88 | 0.375 | 1731.07 | 0.41 | 0.677 |
| 306.12 | 0.88 | 0.375 | 1781.80 | 0.88 | 0.375 |
| 314.98 | 0.88 | 0.375 | 1834.01 | 0.60 | 0.548 |
| 324.21 | 0.88 | 0.375 | 1887.75 | 0.00 | 1.000 |
| 333.71 | 0.88 | 0.375 | 1943.06 | 0.00 | 1.000 |
| 343.49 | 1.13 | 0.256 | 2000.00 | 0.00 | 1.000 |
| 353.55 | 1.13 | 0.256 | 2058.60 | 0.00 | 1.000 |
| 363.91 | 1.58 | 0.113 | 2118.93 | 1.01 | 0.311 |
| 374.58 | 1.58 | 0.113 | 2181.02 | 1.01 | 0.311 |
| 385.55 | 1.58 | 0.113 | 2244.92 | 1.01 | 0.311 |
| 396.95 | 1.58 | 0.113 | 2310.71 | 1.45 | 0.146 |
| 408.48 | 1.58 | 0.113 | 2378.41 | 0.60 | 0.548 |
| 420.45 | 1.89 | 0.058 | 2448.11 | 1.05 | 0.291 |
| 432.77 | 2.37 | 0.017 | 2519.84 | 1.05 | 0.291 |
| 445.45 | 2.08 | 0.037 | 2593.68 | 1.05 | 0.291 |
| 458.50 | 1.77 | 0.076 | 2669.68 | 1.77 | 0.076 |
| 471.94 | 1.24 | 0.211 | 2747.91 | 2.37 | 0.017 |
| 485.77 | 1.24 | 0.211 | 2828.43 | 2.65 | 0.007 |
| 500.00 | 0.88 | 0.375 | 2911.31 | 2.10 | 0.035 |
| 514.65 | 0.47 | 0.632 | 2996.61 | 2.39 | 0.016 |
| 529.73 | 0.47 | 0.632 | 3084.42 | 2.10 | 0.035 |
| 545.25 | 0.47 | 0.632 | 3174.80 | 2.10 | 0.035 |
| 561.23 | 2.08 | 0.037 | 3267.83 | 2.10 | 0.035 |
| 577.68 | 2.08 | 0.037 | 3363.59 | 2.10 | 0.035 |
| 594.60 | 1.24 | 0.211 | 3462.15 | 1.80 | 0.071 |
| 612.03 | 1.24 | 0.211 | 3563.59 | 1.45 | 0.146 |
| 629.96 | 1.43 | 0.151 | 3668.02 | 1.80 | 0.071 |
| 648.42 | 1.43 | 0.151 | 3775.50 | 2.10 | 0.035 |
| 667.42 | 0.60 | 0.548 | 3886.13 | 1.45 | 0.146 |
| 686.98 | 0.60 | 0.548 | 4000.00 | 1.43 | 0.151 |

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Table 4.1.1.4 continued from previous page

| Frequency (in Hz) | Z-value | *p*-value | Frequency (in Hz) | Z-value | *p*-value |
|---|---|---|---|---|---|
| 707.11 | 0.60 | 0.548 | 4117.21 | 1.43 | 0.151 |
| 727.83 | # | # | 4237.85 | 1.05 | 0.291 |
| 749.15 | # | # | 4362.03 | 1.05 | 0.291 |
| 771.11 | # | # | 4489.85 | 0.00 | 1.000 |
| 793.70 | # | # | 4621.41 | 1.01 | 0.311 |
| 816.96 | # | # | 4756.83 | 1.01 | 0.311 |
| 840.90 | # | # | 4896.21 | 0.00 | 1.000 |
| 865.54 | # | # | 5039.68 | 1.05 | 0.291 |
| 890.90 | 1.01 | 0.311 | 5187.36 | 0.60 | 0.548 |
| 917.00 | 0.00 | 1.000 | 5339.36 | 1.05 | 0.291 |
| 943.87 | 1.05 | 0.291 | 5495.81 | 1.45 | 0.146 |
| 971.53 | 1.05 | 0.291 | 5656.85 | 1.45 | 0.146 |
| 1000.00 | 1.80 | 0.071 | 5822.61 | 1.80 | 0.071 |
| 1029.30 | 1.45 | 0.146 | 5993.23 | 1.43 | 0.151 |
| 1059.46 | 1.45 | 0.146 | 6168.84 | 1.43 | 0.151 |
| 1090.51 | 0.60 | 0.548 | 6349.60 | 0.60 | 0.548 |
| 1122.46 | 0.60 | 0.548 | 6535.66 | 0.60 | 0.548 |
| 1155.35 | 0.60 | 0.548 | 6727.17 | 0.60 | 0.548 |
| 1189.21 | 0.47 | 0.632 | 6924.29 | 1.58 | 0.113 |
| 1224.05 | 0.00 | 1.000 | 7127.19 | 0.00 | 1.000 |
| 1259.92 | 0.00 | 1.000 | 7336.03 | 0.00 | 1.000 |
| 1296.84 | 1.05 | 0.291 | 7550.99 | 0.60 | 0.548 |
| 1334.84 | 1.05 | 0.291 | 7772.26 | 0.60 | 0.548 |
| 1373.95 | 0.47 | 0.632 | 8000.00 | 0.60 | 0.548 |

*Note*. **‘#’-** Equality of test for proportions could not be performed because of no abnormal results at those particular frequencies in both the groups.

### 4.1.2 Comparison of WBA at peak pressure between CI group and NH group

Mann-Whitney *U* test was done for pair-wise comparison between the CI group and the NH group, separately for the two ears. The mean and standard deviation of absorbance values across frequencies in the CI ears of the CI group and the CI-matched ears of the NH group are shown in Figure 4.1.2.1.

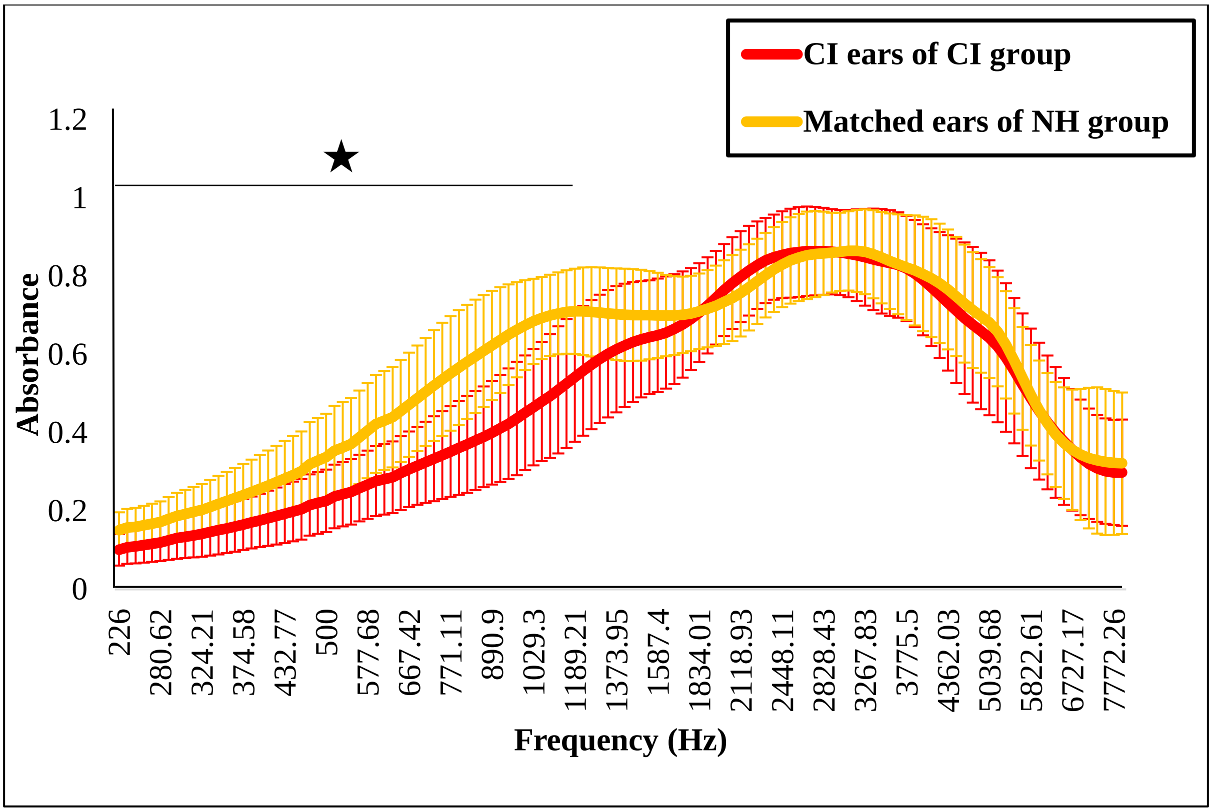


*Figure 4.1.2.1:* Mean and standard deviation of absorbance at peak pressure across frequencies in the CI ears of the CI group and the CI-matched ears of the NH group. The star-marked comparisons have a statistically significant difference after α-correction ($p < 0.016$).

The absorbance values in the CI ears were significantly lower than in the CI-matched ears of the NH group in the frequency range of 226 Hz-1259.92 Hz after α-correction ($p < 0.016$). There was no significant difference in absorbance between the CI ears and the CI-matched ears of the NH group at any other frequency after α-correction ($p > 0.016$). The specific Z-values and *p*-values for the pair-wise comparisons are shown in Table 4.1.2.1.

**Table 4.1.2.1.**

*The outcome of Mann-Whitney U test for pair-wise comparison of absorbance at peak pressure between the CI ears of the CI group and the CI-matched ears of the NH group*

| Frequency (in Hz) | Z-value | *p*-value | Frequency (in Hz) | Z-value | *p*-value |
|---|---|---|---|---|---|
| 226.00 | -3.17 | 0.001 | 971.53 | -4.11 | <0.001 |
| 250.00 | -3.01 | 0.003 | 1000.00 | -4.11 | <0.001 |
| 257.33 | -2.98 | 0.003 | 1029.30 | -4.00 | <0.001 |
| 264.87 | -2.92 | 0.003 | 1059.46 | -3.76 | <0.001 |
| 272.63 | -2.86 | 0.004 | 1090.51 | -3.70 | <0.001 |
| 280.62 | -2.86 | 0.004 | 1122.46 | -3.57 | <0.001 |
| 288.84 | -2.89 | 0.004 | 1155.35 | -3.38 | 0.001 |
| 297.30 | -2.88 | 0.004 | 1189.21 | -3.04 | 0.002 |
| 306.12 | -2.92 | 0.003 | 1224.05 | -2.78 | 0.005 |
| 314.98 | -2.86 | 0.004 | 1259.92 | -2.56 | 0.010 |
| 324.21 | -2.89 | 0.004 | 1296.84 | -2.13 | 0.033 |
| 333.71 | -2.84 | 0.005 | 1334.84 | -1.81 | 0.070 |
| 343.49 | -2.84 | 0.005 | 1373.95 | -1.56 | 0.117 |
| 353.55 | -2.86 | 0.004 | 1414.21 | -1.40 | 0.160 |
| 363.91 | -2.92 | 0.003 | 1455.65 | -1.44 | 0.148 |
| 374.58 | -2.94 | 0.003 | 1498.31 | -1.33 | 0.180 |
| 385.55 | -2.89 | 0.004 | 1542.21 | -1.13 | 0.256 |
| 396.95 | -2.92 | 0.003 | 1587.40 | -0.91 | 0.358 |
| 408.48 | -2.98 | 0.003 | 1633.92 | -0.73 | 0.465 |
| 420.45 | -2.94 | 0.003 | 1681.79 | -0.52 | 0.598 |
| 432.77 | -2.94 | 0.003 | 1731.07 | -0.41 | 0.675 |
| 445.45 | -2.92 | 0.003 | 1781.80 | -0.10 | 0.914 |
| 458.50 | -2.89 | 0.004 | 1834.01 | -0.25 | 0.797 |
| 471.94 | -3.00 | 0.003 | 1887.75 | -0.52 | 0.598 |
| 485.77 | -3.08 | 0.002 | 1943.06 | -0.73 | 0.465 |
| 500.00 | -3.04 | 0.002 | 2000.00 | -0.94 | 0.344 |
| 514.65 | -3.05 | 0.002 | 2058.60 | -1.05 | 0.291 |
| 529.73 | -3.11 | 0.002 | 2118.93 | -1.36 | 0.172 |
| 545.25 | -3.16 | 0.002 | 2181.02 | -1.31 | 0.189 |
| 561.23 | -3.20 | 0.001 | 2244.92 | -1.24 | 0.213 |
| 577.68 | -3.39 | 0.001 | 2310.71 | -1.14 | 0.250 |
| 594.60 | -3.57 | <0.001 | 2378.41 | -0.97 | 0.330 |
| 612.03 | -3.54 | <0.001 | 2448.11 | -0.77 | 0.441 |
| 629.96 | -3.59 | <0.001 | 2519.84 | -0.64 | 0.516 |

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Table 4.1.2.1 continued from previous page

| Frequency (in Hz) | Z-value | *p*-value | Frequency (in Hz) | Z-value | *p*-value |
|---|---|---|---|---|---|
| 648.42 | -3.71 | <0.001 | 2593.68 | -0.52 | 0.598 |
| 667.42 | -3.84 | <0.001 | 2669.68 | -0.04 | 0.968 |
| 686.98 | -3.88 | <0.001 | 2747.91 | -0.12 | 0.903 |
| 707.11 | -3.90 | <0.001 | 2828.43 | -0.39 | 0.695 |
| 727.83 | -3.89 | <0.001 | 2911.31 | -0.20 | 0.839 |
| 749.15 | -3.89 | <0.001 | 2996.61 | -0.12 | 0.903 |
| 771.11 | -3.92 | <0.001 | 3084.42 | -0.14 | 0.882 |
| 793.70 | -4.01 | <0.001 | 3174.80 | -0.17 | 0.860 |
| 816.96 | -4.00 | <0.001 | 3267.83 | -0.17 | 0.860 |
| 840.90 | -3.99 | <0.001 | 3363.59 | -0.05 | 0.957 |
| 865.54 | -4.00 | <0.001 | 3462.15 | -0.02 | 0.978 |
| 890.9 | -4.08 | <0.001 | 3563.59 | -0.05 | 0.957 |
| 917.00 | -4.13 | <0.001 | 3668.02 | -0.06 | 0.946 |
| 943.87 | -4.11 | <0.001 | | | |

*Note*. Pair-wise comparison was done at these frequencies due to a significant group difference on Kruskal-Wallis *H* test only at these frequencies.

The mean and standard deviation of absorbance across frequencies in the non-CI ears of the CI group and the non-CI-matched ears of the NH group are shown in Figure 4.1.2.2. There was no significant difference in absorbance between the non-CI ears of the CI group and the non-CI-matched ears of the NH group at any frequency after α-correction ($p > 0.016$). The specific Z-values and *p*-values for the pair-wise comparisons are shown in Table 4.1.2.2.

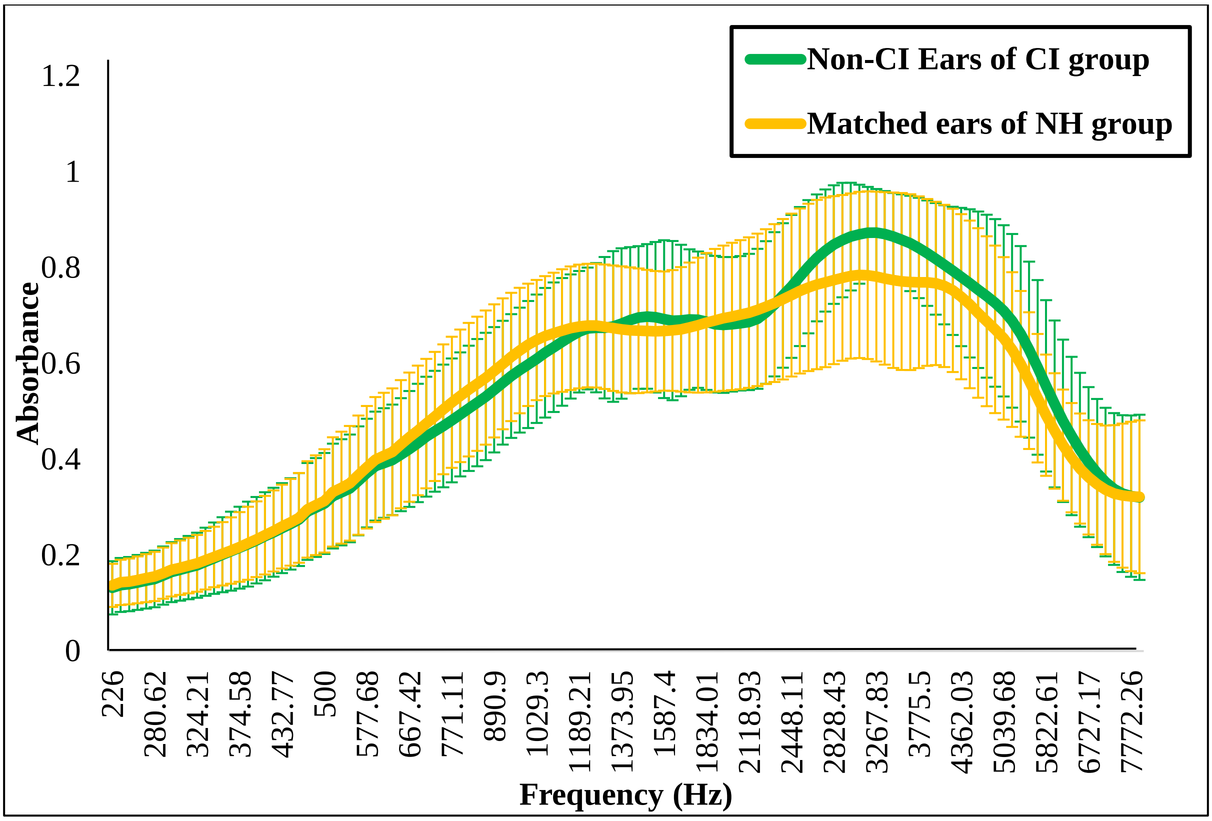


*Figure 4.1.2.2:* Mean and standard deviation of absorbance at peak pressure across frequencies in the non-CI ears of the CI group and the non-CI-matched ears of the NH group.

**Table 4.1.2.2**

*The outcome of Mann-Whitney U test for pair-wise comparison of absorbance at peak pressure between the CI ears of the CI group and the CI-matched ears of the NH group*

| Frequency (in Hz) | Z-value | *p*-value |
|---|---|---|
| 2828.43 | -1.39 | 0.164 |
| 2911.31 | -1.43 | 0.152 |
| 2996.61 | -1.46 | 0.144 |
| 3084.42 | -1.48 | 0.137 |

*Note.* Pair-wise comparison was done at these frequencies due to a significant group difference on Kruskal-Wallis *H* test only at these frequencies.

### 4.1.3 Comparison of WBA at peak pressure between SNHL group and NH group

Mann-Whitney *U* test was done for pair-wise comparison between SNHL group and NH group, separately for the two ears. The mean and standard deviation of absorbance across frequencies in the CI-matched ears of the SNHL group and the CI-matched ears of the NH group are shown in Figure 4.1.3.1. The CI-matched ears of the SNHL group had significantly lower absorbance than the CI-matched ears of the NH group in the frequency range of 1000-3563.59 Hz after α-correction ($p < 0.016$). For the remaining frequencies, there was no significant difference in absorbance values between the CI-matched ears of the SNHL group and the CI-matched ears of the NH group ($p > 0.016$). The specific Z-values and *p*-values for the pair-wise comparisons are shown in Table 4.1.3.1.

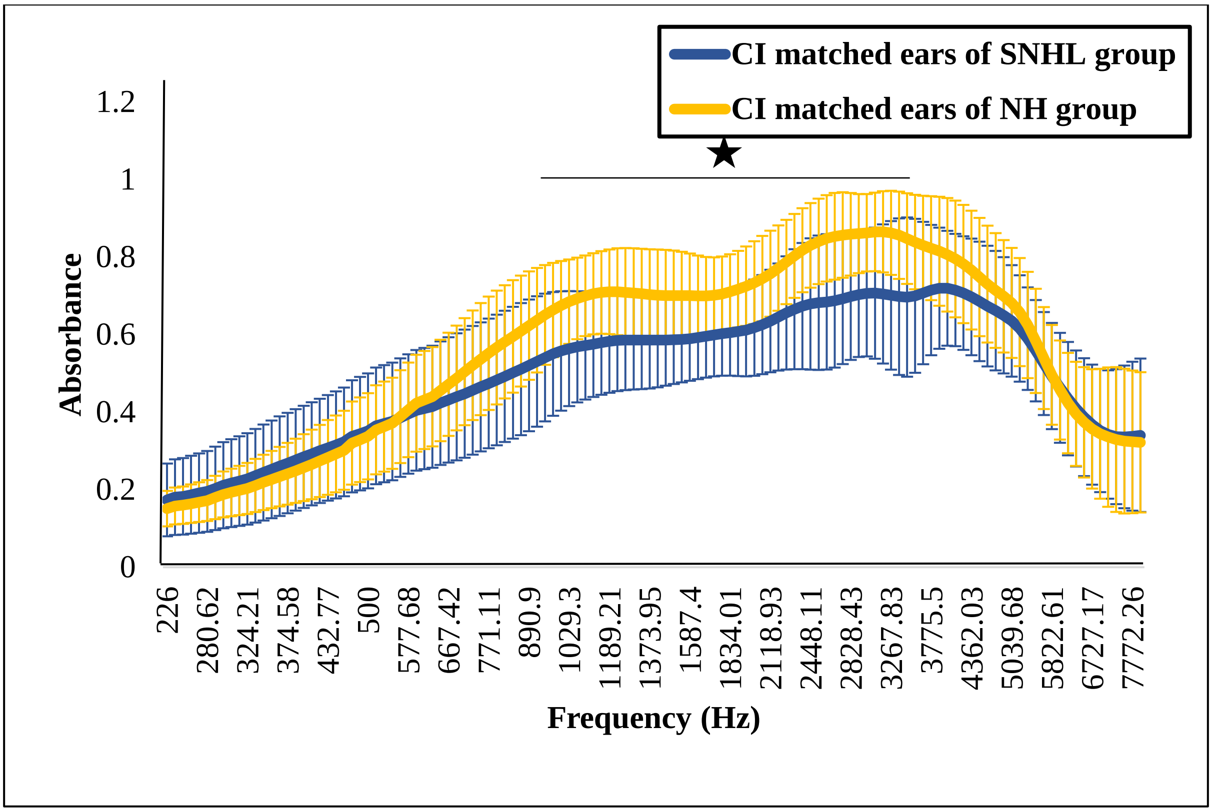


*Figure 4.1.3.1:* Mean and standard deviation of absorbance at peak pressure across frequencies in CI-matched ears of the SNHL group and CI-matched ears of the NH group. The star-marked comparisons have a statistically significant difference after α-correction ($p < 0.016$).

**Table 4.1.3.1.**

*The outcome of Mann-Whitney U test for pair-wise comparison of absorbance at peak pressure between the CI-matched ears of the SNHL group and the CI-matched ears of the NH group*

| Frequency (in Hz) | Z-value | *p*-value | Frequency (in Hz) | Z-value | *p*-value |
|---|---|---|---|---|---|
| 226.00 | -0.40 | 0.685 | 971.53 | -2.28 | 0.022 |
| 250.00 | -0.37 | 0.705 | 1000.00 | -2.42 | 0.015 |
| 257.33 | -0.32 | 0.745 | 1029.30 | -2.69 | 0.007 |
| 264.87 | -0.32 | 0.745 | 1059.46 | -2.82 | 0.005 |
| 272.63 | -0.32 | 0.745 | 1090.51 | -2.89 | 0.004 |
| 280.62 | -0.32 | 0.745 | 1122.46 | -2.97 | 0.003 |
| 288.84 | -0.32 | 0.745 | 1155.35 | -3.01 | 0.003 |
| 297.30 | -0.36 | 0.715 | 1189.21 | -2.89 | 0.004 |
| 306.12 | -0.40 | 0.685 | 1224.05 | -2.78 | 0.005 |
| 314.98 | -0.40 | 0.685 | 1259.92 | -2.62 | 0.009 |
| 324.21 | -0.45 | 0.646 | 1296.84 | -2.50 | 0.012 |
| 333.71 | -0.45 | 0.646 | 1334.84 | -2.57 | 0.010 |
| 343.49 | -0.54 | 0.588 | 1373.95 | -2.77 | 0.006 |
| 353.55 | -0.62 | 0.534 | 1414.21 | -2.66 | 0.008 |
| 363.91 | -0.64 | 0.516 | 1455.65 | -2.78 | 0.005 |
| 374.58 | -0.75 | 0.449 | 1498.31 | -2.78 | 0.005 |
| 385.55 | -0.74 | 0.457 | 1542.21 | -2.65 | 0.008 |
| 396.95 | -0.75 | 0.449 | 1587.40 | -2.67 | 0.007 |
| 408.48 | -0.71 | 0.473 | 1633.92 | -2.65 | 0.008 |
| 420.45 | -0.67 | 0.499 | 1681.79 | -2.63 | 0.008 |
| 432.77 | -0.62 | 0.534 | 1731.07 | -2.78 | 0.005 |
| 445.45 | -0.63 | 0.525 | 1781.80 | -2.62 | 0.009 |
| 458.50 | -0.62 | 0.534 | 1834.01 | -2.67 | 0.007 |
| 471.94 | -0.55 | 0.579 | 1887.75 | -2.73 | 0.006 |
| 485.77 | -0.51 | 0.607 | 1943.06 | -2.61 | 0.009 |
| 500.00 | -0.51 | 0.607 | 2000.00 | -2.50 | 0.012 |
| 514.65 | -0.45 | 0.646 | 2058.60 | -2.47 | 0.013 |
| 529.73 | -0.41 | 0.675 | 2118.93 | -2.56 | 0.010 |
| 545.25 | -0.29 | 0.766 | 2181.02 | -2.69 | 0.007 |
| 561.23 | -0.14 | 0.882 | 2244.92 | -2.75 | 0.006 |
| 577.68 | 0.00 | 1.000 | 2310.71 | -2.84 | 0.005 |
| 594.60 | -0.27 | 0.787 | 2378.41 | -2.79 | 0.005 |
| 612.03 | -0.32 | 0.745 | 2448.11 | -2.93 | 0.003 |
| 629.96 | -0.35 | 0.725 | 2519.84 | -2.96 | 0.003 |

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Table 4.1.3.1 continued from previous page

| Frequency (in Hz) | Z-value | *p*-value | Frequency (in Hz) | Z-value | *p*-value |
|---|---|---|---|---|---|
| 648.42 | -0.55 | 0.579 | 2593.68 | -3.13 | 0.002 |
| 667.42 | -0.75 | 0.449 | 2669.68 | -3.31 | 0.001 |
| 686.98 | -0.97 | 0.330 | 2747.91 | -3.32 | 0.001 |
| 707.11 | -1.21 | 0.223 | 2828.43 | -3.19 | 0.001 |
| 727.83 | -1.29 | 0.194 | 2911.31 | -3.01 | 0.003 |
| 749.15 | -1.39 | 0.164 | 2996.61 | -3.05 | 0.002 |
| 771.11 | -1.48 | 0.137 | 3084.42 | -3.05 | 0.002 |
| 793.70 | -1.50 | 0.133 | 3174.80 | -3.02 | 0.002 |
| 816.96 | -1.65 | 0.099 | 3267.83 | -3.00 | 0.003 |
| 840.90 | -1.70 | 0.088 | 3363.59 | -2.82 | 0.005 |
| 865.54 | -1.79 | 0.072 | 3462.15 | -2.70 | 0.007 |
| 890.90 | -1.96 | 0.050 | 3563.59 | -2.54 | 0.011 |
| 917.00 | -2.17 | 0.029 | 3668.02 | -2.21 | 0.027 |
| 943.87 | -2.21 | 0.027 | | | |

*Note.* Pair-wise comparison was done at these frequencies due to a significant group difference on Kruskal-Wallis *H* test only at these frequencies.

The mean and standard deviation of absorbance across frequencies in the non-CI-matched ears of the SNHL group and the non-CI-matched ears of the NH group are shown in Figure 4.1.3.2. While the frequency range of 1000-3563.59 Hz had lower mean absorbance values in the non-CI-matched SNHL ears than the non-CI-matched NH ear, there was no significant difference between them after α-correction ($p > 0.016$). The specific Z-values and *p*-values for the pair-wise comparisons are shown in Table 4.1.3.2.

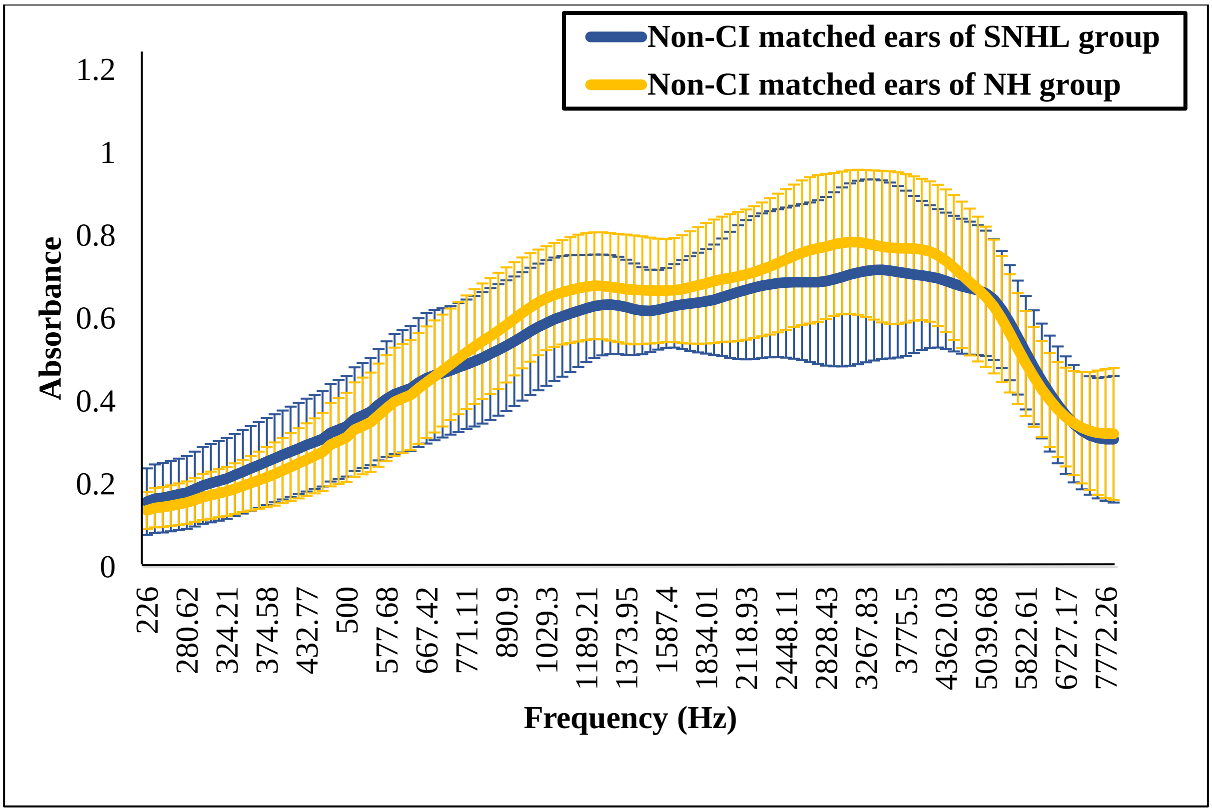


*Figure 4.1.3.2:* Mean and standard deviation of absorbance at peak pressure across frequencies in the non-CI-matched ears of the SNHL group and non-CI-matched ears of the NH group.

**Table 4.1.3.2.**

*The outcome of Mann-Whitney U test for pair-wise comparison of absorbance at peak pressure between the non-CI-matched ears of the SNHL group and the non-CI-matched ears of the NH group*

| Frequency (Hz) | Z-value | *p*-value |
|---|---|---|
| 2828.43 | -1.43 | 0.152 |
| 2911.31 | -1.28 | 0.199 |
| 2996.61 | -1.16 | 0.245 |
| 3084.42 | -1.19 | 0.234 |

*Note.* Pair-wise comparison was done at these frequencies due to a significant group difference on Kruskal-Wallis *H* test only at these frequencies.

**4.1.4 Comparison of WBA at ambient pressure between CI group and SNHL group**

Mann-Whitney *U* test was done for pair-wise comparison between CI group and SNHL group, separately for the two ears. The mean and standard deviation of absorbance across frequencies in CI ears of the CI group and CI-matched ears of the SNHL group are shown in Figure 4.1.4.1.

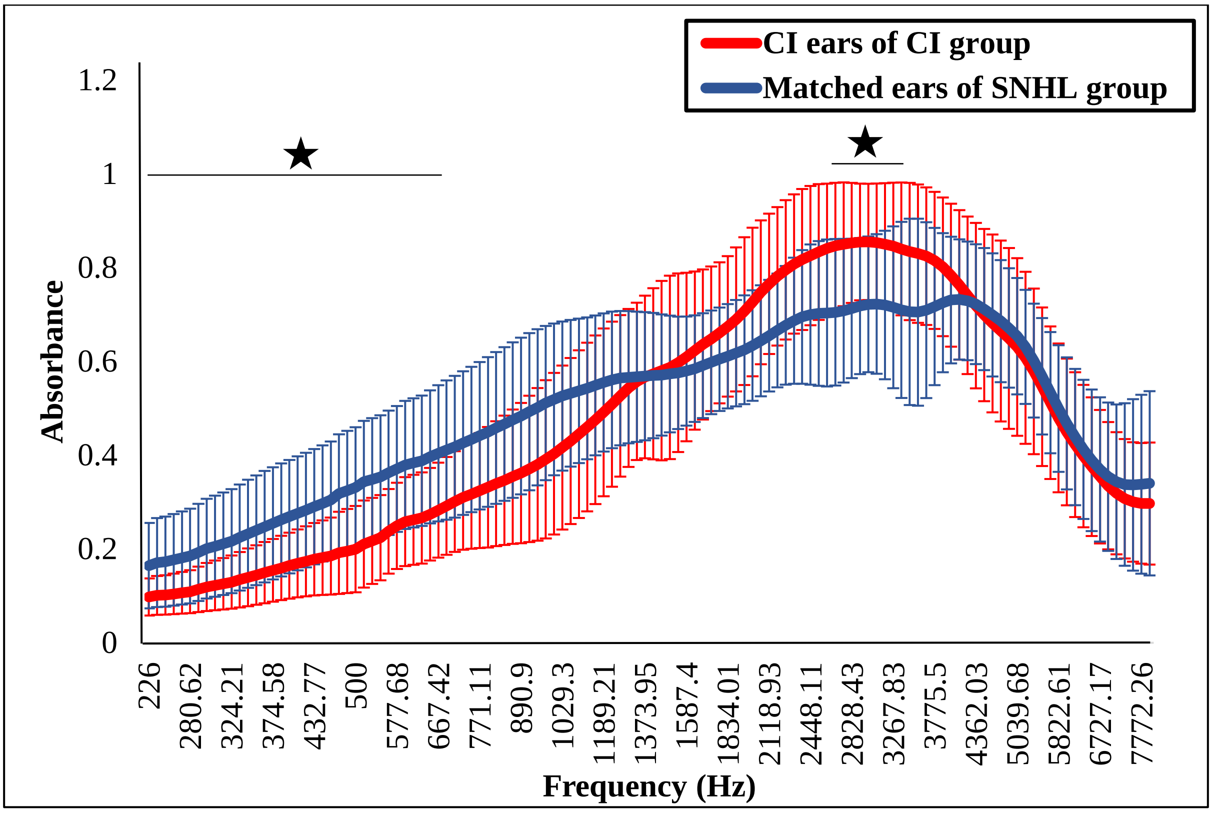


*Figure 4.1.4.1:* Mean and standard deviation of absorbance at ambient pressure across frequencies in the CI ears of the CI group and the CI-matched ears of the SNHL group. The star-marked comparisons have a statistically significant difference after α-correction ($p < 0.016$).

The absorbance values were significantly lower in the CI ears of the CI group than in the CI-matched ears of the SNHL group in the frequency range of 226-686.98 Hz after α-correction ($p < 0.016$). Further, there was a significantly higher absorbance in the CI ears of the CI group than the CI-matched ears of the SNHL group in the frequency range of 2058.6-3174.8 Hz after α-correction ($p < 0.016$). There was no significant difference between them at all other frequencies after α-correction ($p > 0.016$). The specific Z-values and *p*-values for the pair-wise comparisons are shown in Table 4.1.4.1.

**Table 4.1.4.1.**

*The outcome of Mann-Whitney U test for pair-wise comparison of absorbance at ambient pressure between the CI ears of the CI group and the CI-matched ears of the SNHL group*

| Frequency (in Hz) | Z-value | *p*-value | Frequency (in Hz) | Z-value | *p*-value |
|---|---|---|---|---|---|
| 226.00 | -2.58 | 0.010 | 943.87 | -1.96 | 0.050 |
| 250.00 | -2.55 | 0.011 | 971.53 | -1.98 | 0.047 |
| 257.33 | -2.58 | 0.010 | 1000.00 | -1.96 | 0.050 |
| 264.87 | -2.56 | 0.010 | 1029.30 | -1.90 | 0.056 |
| 272.63 | -2.59 | 0.009 | 1059.46 | -1.90 | 0.056 |
| 280.62 | -2.62 | 0.009 | 1090.51 | -1.86 | 0.062 |
| 288.84 | -2.65 | 0.008 | 1122.46 | -1.67 | 0.094 |
| 297.30 | -2.62 | 0.009 | 1155.35 | -1.39 | 0.164 |
| 306.12 | -2.59 | 0.009 | 1189.21 | -1.08 | 0.279 |
| 314.98 | -2.67 | 0.007 | 1224.05 | -0.81 | 0.417 |
| 324.21 | -2.70 | 0.007 | 1259.92 | -0.44 | 0.655 |
| 333.71 | -2.73 | 0.006 | 1296.84 | -0.20 | 0.839 |
| 343.49 | -2.74 | 0.006 | 1334.84 | 0.00 | 1.000 |
| 353.55 | -2.78 | 0.005 | 1373.95 | -0.27 | 0.787 |
| 363.91 | -2.73 | 0.006 | 1414.21 | -0.32 | 0.745 |
| 374.58 | -2.81 | 0.005 | 1455.65 | -0.37 | 0.705 |
| 385.55 | -2.90 | 0.004 | 1498.31 | -0.62 | 0.534 |
| 396.95 | -2.94 | 0.003 | 1542.21 | -0.68 | 0.490 |
| 408.48 | -2.92 | 0.003 | 1587.40 | -0.79 | 0.425 |
| 420.45 | -2.92 | 0.003 | 1633.92 | -0.94 | 0.344 |
| 432.77 | -2.92 | 0.003 | 1681.79 | -1.01 | 0.310 |
| 445.45 | -2.94 | 0.003 | 1781.80 | -1.33 | 0.181 |
| 458.50 | -3.04 | 0.002 | 1834.01 | -1.46 | 0.144 |
| 471.94 | -3.08 | 0.002 | 1887.75 | -1.71 | 0.086 |
| 485.77 | -3.13 | 0.002 | 1943.06 | -1.98 | 0.047 |
| 500.00 | -3.16 | 0.002 | 2000.00 | -2.10 | 0.035 |
| 514.65 | -3.17 | 0.001 | 2058.60 | -2.58 | 0.010 |
| 529.73 | -3.08 | 0.002 | 2118.93 | -2.65 | 0.008 |
| 545.25 | -3.08 | 0.002 | 2181.02 | -2.70 | 0.007 |
| 561.23 | -2.97 | 0.003 | 2244.92 | -2.86 | 0.004 |
| 577.68 | -2.92 | 0.003 | 2310.71 | -2.81 | 0.005 |
| 594.60 | -2.89 | 0.004 | 2378.41 | -2.67 | 0.007 |
| 612.03 | -2.84 | 0.005 | 2448.11 | -2.69 | 0.007 |
| 629.96 | -2.82 | 0.005 | 2519.84 | -2.73 | 0.006 |

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Table 4.1.4.1 continued from previous page

| Frequency (in Hz) | Z-value | *p*-value | Frequency (in Hz) | Z-value | *p*-value |
|---|---|---|---|---|---|
| 648.42 | -2.73 | 0.006 | 2593.68 | -2.89 | 0.004 |
| 667.42 | -2.62 | 0.009 | 2669.68 | -3.11 | 0.002 |
| 686.98 | -2.55 | 0.011 | 2747.91 | -3.05 | 0.002 |
| 707.11 | -2.36 | 0.018 | 2828.43 | -3.08 | 0.002 |
| 727.83 | -2.28 | 0.022 | 2911.31 | -2.97 | 0.003 |
| 749.15 | -2.19 | 0.028 | 2996.61 | -3.00 | 0.003 |
| 771.11 | -2.05 | 0.040 | 3084.42 | -2.79 | 0.005 |
| 793.70 | -2.00 | 0.045 | 3174.80 | -2.56 | 0.010 |
| 816.96 | -1.93 | 0.053 | 3267.83 | -2.40 | 0.016 |
| 840.90 | -1.94 | 0.051 | 3363.59 | -2.40 | 0.016 |
| 865.54 | -1.88 | 0.060 | 3462.15 | -2.29 | 0.021 |
| 890.90 | -1.97 | 0.048 | 3563.59 | -2.29 | 0.021 |
| 917.00 | -1.97 | 0.048 | 3668.02 | -2.16 | 0.030 |

*Note*. Pair-wise comparison was done at these frequencies due to a significant group difference on Kruskal-Wallis *H* test only at these frequencies.

In addition to the group-wise comparison, the individual data were also analyzed to obtain the proportion of ears with an abnormal absorbance. Figure 4.1.4.2 shows the abnormal absorbance at ambient pressure at various frequencies in each individual in the CI ears of the CI group and the CI-matched ears of the SNHL group. Figure 4.1.4.3 shows the individual absorbance curves compared against the mean absorbance and standard deviation of absorbance of the NH group at ambient pressure condition across frequencies.

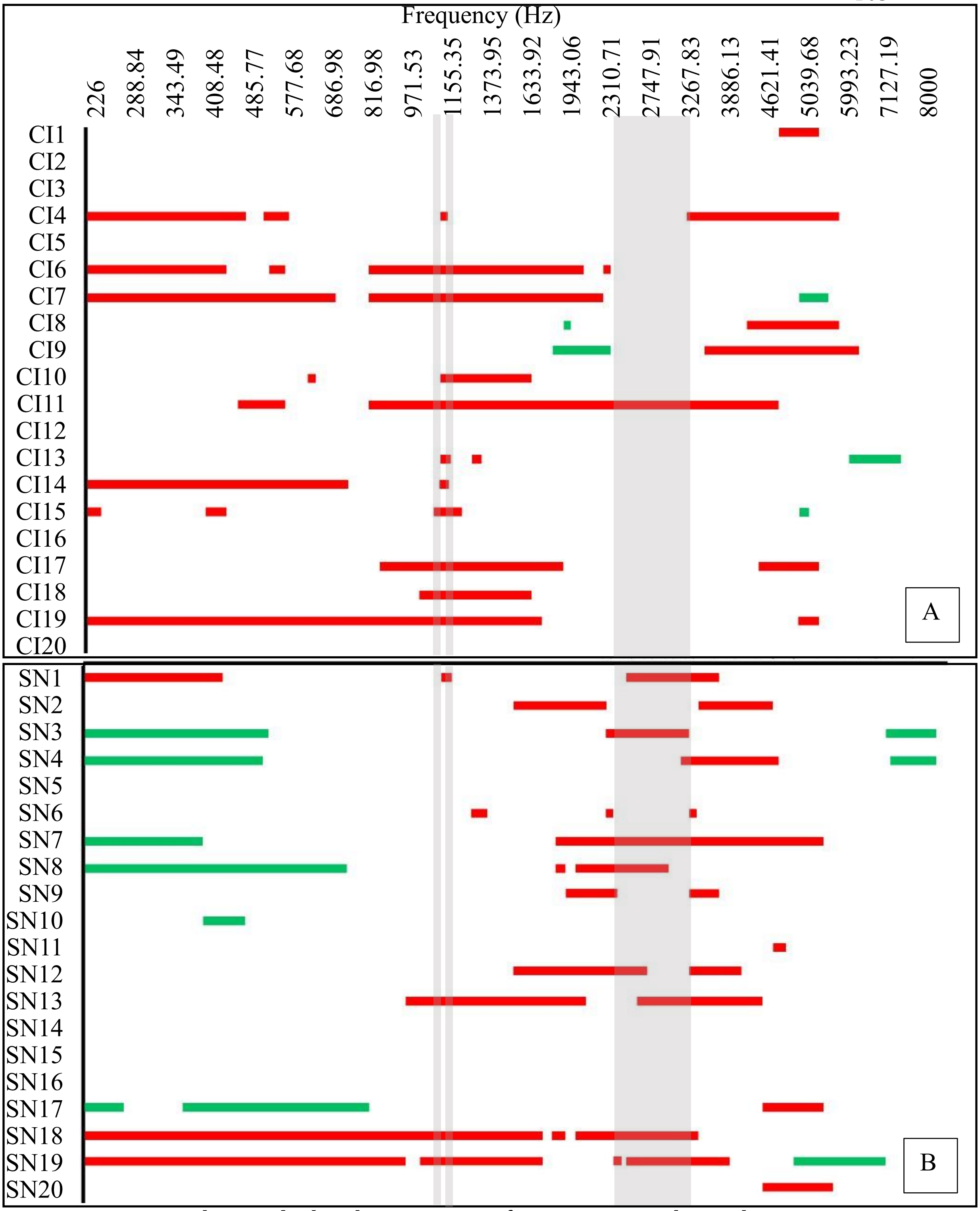


*Figure 4.1.4.2:* Abnormal absorbance across frequencies in the ambient pressure condition in (A) CI ears of the CI group and (B) CI-matched ears of the SNHL group. The digits on the Y-axis represent participant number and prefix of 'CI' and 'SN' indicates CI group and SNHL group, respectively. The red-colour lines represent significantly lower absorbance and green-colour lines indicate significantly higher absorbance. The grey shaded region indicate statistically significant difference in proportions of abnormal results.

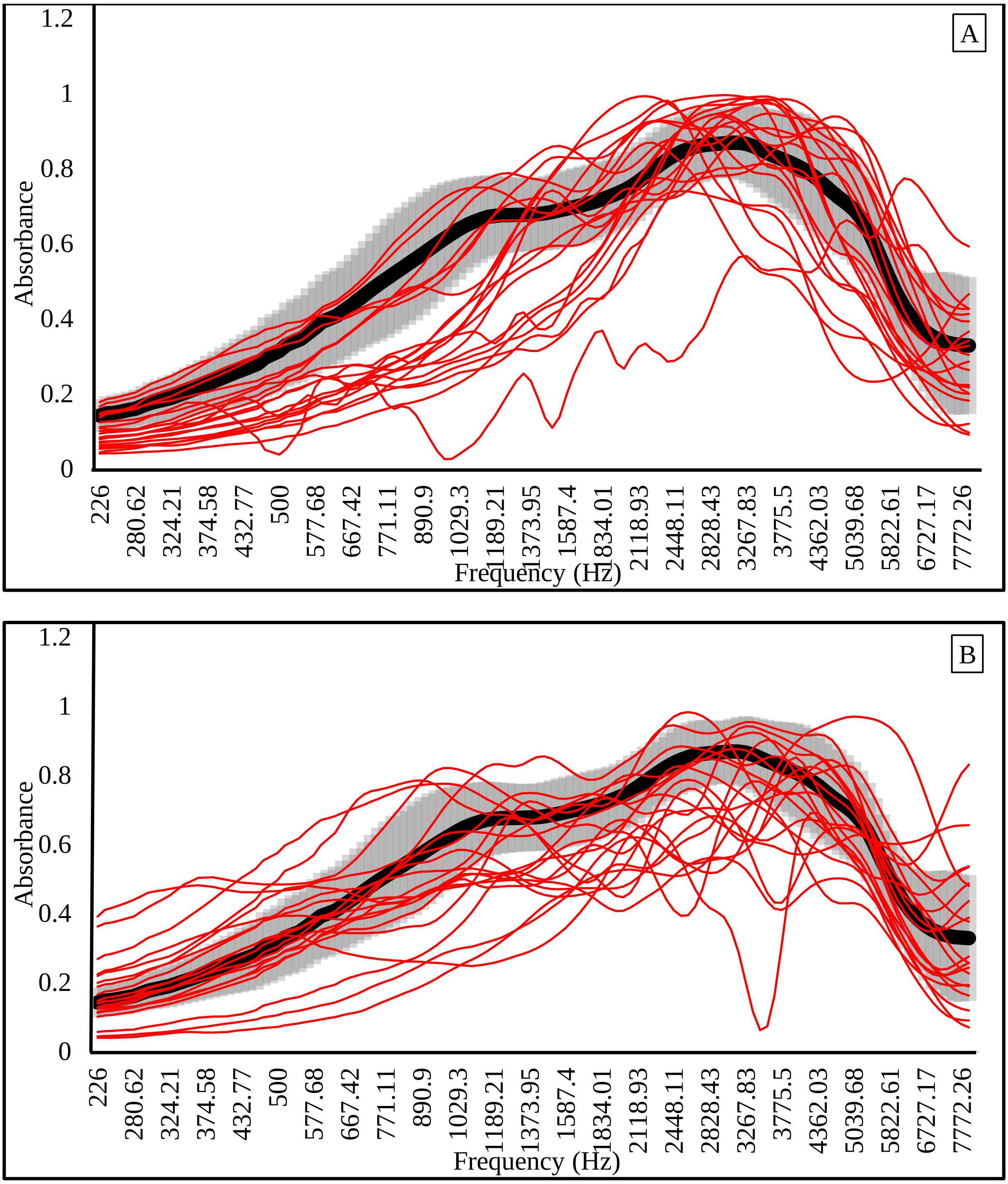


Figure 4.1.4.3: Absorbance curves at ambient pressure in (A) CI ears of the CI group, and (B) CI-matched ears of the SNHL group. The thin red lines represent absorbance curve of each participant in his/her respective group. In each panel, the thick black line represents the mean absorbance values and the gray shaded region covers 2 standard deviations of absorbance found in the CI-matched ears of the NH group (normative data).

At ambient pressure condition, the proportion of ears with an abnormal absorbance was compared between the groups using the Equality of test for proportions. This was done at each frequency separately. The results showed a significant difference in the proportion of abnormal absorbance at 1059.46 Hz, 1090.51 Hz, and in the frequency range of 2310.71-3174.8 Hz ($p < 0.05$). The specific Z-values and *p*-values for the comparisons are shown in Table 4.1.4.2.

**Table 4.1.4.2.**

*The results of Equality of test for proportions for comparison of proportion of abnormal absorbance at ambient pressure across frequencies between the CI ears of the CI group and the CI-matched ears of the SNHL group*

| Frequency (in Hz) | Z-value | *p*-value | Frequency (in Hz) | Z-value | *p*-value |
|---|---|---|---|---|---|
| 226.00 | 0.66 | 0.507 | 1414.21 | 1.46 | 0.144 |
| 250.00 | 0.66 | 0.507 | 1455.65 | 0.69 | 0.490 |
| 257.33 | 1.01 | 0.311 | 1498.31 | 0.69 | 0.490 |
| 264.87 | 1.01 | 0.311 | 1542.21 | 0.69 | 0.490 |
| 272.63 | 1.01 | 0.311 | 1587.40 | 0.69 | 0.490 |
| 280.62 | 1.01 | 0.311 | 1633.92 | 0.00 | 1.000 |
| 288.84 | 0.69 | 0.490 | 1681.79 | 0.00 | 1.000 |
| 297.30 | 0.69 | 0.490 | 1731.07 | 0.35 | 0.723 |
| 306.12 | 0.69 | 0.490 | 1781.80 | 0.00 | 1.000 |
| 314.98 | 0.69 | 0.490 | 1834.01 | 0.37 | 0.705 |
| 324.21 | 0.69 | 0.490 | 1887.75 | 1.06 | 0.288 |
| 333.71 | 0.69 | 0.490 | 1943.06 | 1.06 | 0.288 |
| 343.49 | 0.69 | 0.490 | 2000.00 | 1.13 | 0.256 |
| 353.55 | 1.01 | 0.311 | 2058.60 | 1.13 | 0.256 |
| 363.91 | 1.01 | 0.311 | 2118.93 | 1.38 | 0.167 |
| 374.58 | 1.01 | 0.311 | 2181.02 | 1.89 | 0.058 |
| 385.55 | 1.32 | 0.184 | 2244.92 | 1.77 | 0.076 |
| 396.95 | 0.97 | 0.327 | 2310.71 | 2.37 | 0.017 |
| 408.48 | 0.66 | 0.507 | 2378.41 | 2.37 | 0.017 |
| 420.45 | 0.66 | 0.507 | 2448.11 | 2.65 | 0.008 |
| 432.77 | 1.06 | 0.288 | 2519.84 | 2.65 | 0.008 |
| 445.45 | 0.69 | 0.490 | 2593.68 | 2.37 | 0.017 |
| 458.50 | 0.69 | 0.490 | 2669.68 | 2.37 | 0.017 |
| 471.94 | 1.06 | 0.288 | 2747.91 | 2.37 | 0.017 |
| 485.77 | 0.73 | 0.465 | 2828.43 | 2.08 | 0.037 |
| 500.00 | 0.35 | 0.723 | 2911.31 | 2.37 | 0.017 |
| 514.65 | 0.35 | 0.723 | 2996.61 | 2.76 | 0.005 |
| 529.73 | 0.73 | 0.465 | 3084.42 | 2.47 | 0.013 |
| 545.25 | 0.73 | 0.465 | 3174.80 | 2.47 | 0.013 |
| 561.23 | 0.00 | 1.000 | 3267.83 | 1.77 | 0.070 |
| 577.68 | 0.41 | 0.677 | 3363.59 | 1.77 | 0.070 |
| 594.60 | 0.00 | 1.000 | 3462.15 | 1.46 | 0.144 |
| 612.03 | 0.00 | 1.000 | 3563.59 | 0.79 | 0.429 |
| 629.96 | 0.00 | 1.000 | 3668.02 | 0.79 | 0.429 |
| 648.42 | 0.41 | 0.677 | 3775.50 | 0.41 | 0.677 |
| 667.42 | 0.41 | 0.677 | 3886.13 | 0.00 | 1.000 |
| 686.98 | 0.41 | 0.677 | 4000.00 | 0.37 | 0.705 |

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Table 4.1.4.2 continued from previous page

| Frequency (in Hz) | Z-value | *p*-value | Frequency (in Hz) | Z-value | *p*-value |
|---|---|---|---|---|---|
| 707.11 | 0.88 | 0.375 | 4117.21 | 0.37 | 0.705 |
| 727.83 | 0.88 | 0.375 | 4237.85 | 0.00 | 1.000 |
| 749.15 | 1.05 | 0.291 | 4362.03 | 0.73 | 0.465 |
| 771.11 | 0.00 | 1.000 | 4489.85 | 1.24 | 0.211 |
| 793.70 | 0.41 | 0.677 | 4621.41 | 0.79 | 0.429 |
| 816.96 | 1.24 | 0.211 | 4756.83 | 1.77 | 0.076 |
| 840.90 | 1.24 | 0.211 | 4896.21 | 1.77 | 0.076 |
| 865.54 | 1.24 | 0.211 | 5039.68 | 1.77 | 0.076 |
| 890.90 | 1.24 | 0.211 | 5187.36 | 1.46 | 0.144 |
| 917.00 | 0.79 | 0.429 | 5339.36 | 1.58 | 0.113 |
| 943.87 | 1.24 | 0.211 | 5495.81 | 0.88 | 0.375 |
| 971.53 | 1.13 | 0.256 | 5656.85 | 1.05 | 0.291 |
| 1000.00 | 1.46 | 0.144 | 5822.61 | 0.60 | 0.548 |
| 1029.30 | 1.46 | 0.144 | 5993.23 | 0.60 | 0.548 |
| 1059.46 | 2.28 | 0.022 | 6168.84 | 0.60 | 0.548 |
| 1090.51 | 1.98 | 0.046 | 6349.60 | 0.00 | 1.000 |
| 1122.46 | 1.77 | 0.076 | 6535.66 | 0.00 | 1.000 |
| 1155.35 | 1.77 | 0.076 | 6727.17 | 0.60 | 0.548 |
| 1189.21 | 1.77 | 0.076 | 6924.29 | 1.05 | 0.291 |
| 1224.05 | 1.38 | 0.167 | 7127.19 | 0.60 | 0.548 |
| 1259.92 | 1.38 | 0.167 | 7336.03 | 0.60 | 0.548 |
| 1296.84 | 1.46 | 0.144 | 7550.99 | 0.60 | 0.548 |
| 1334.84 | 1.46 | 0.144 | 7772.26 | 1.45 | 0.146 |
| 1373.95 | 1.46 | 0.144 | 8000.00 | 1.45 | 0.146 |

The mean and standard deviation of absorbance across frequencies in the non-CI ears of the CI group and the non-CI-matched ears of the SNHL group are shown in Figure 4.1.4.4. There was no significant difference in absorbance between the non-CI ears of the CI group and the non-CI-matched ears of the SNHL group at any frequency after α-correction ($p < 0.016$).

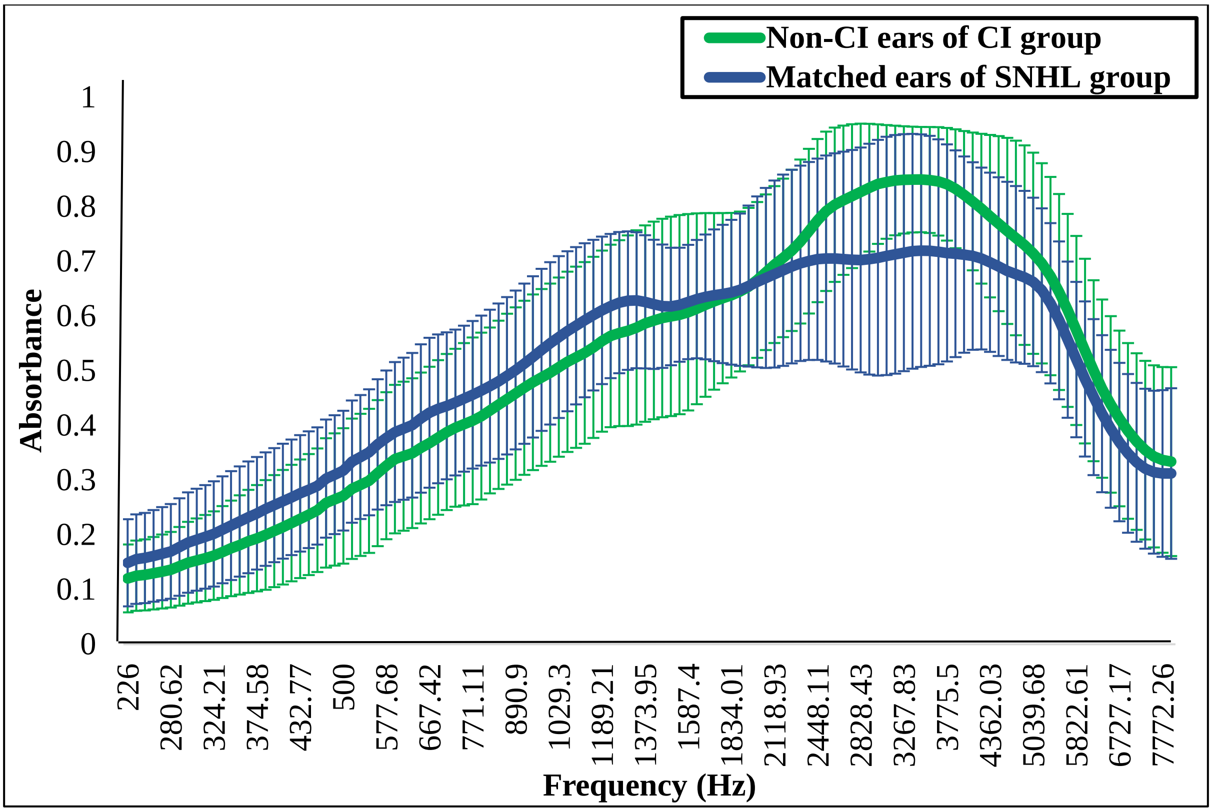


*Figure 4.1.4.4:* Mean and standard deviation of absorbance at ambient pressure across frequencies in the non-CI ears of the CI group and the non-CI-matched ears of the SNHL group. The star-marked comparisons have a statistically significant difference after α-correction ($p < 0.016$).

There was no significant difference in absorbance at ambient pressure between the non-CI ears of the CI group and the non-CI matched ears of the SNHL group at any frequency for Kruskal-Wallis *H* test ($p > 0.05$). Hence, Mann-Whitney *U* test was not performed further.

In addition to the group-wise comparison, the individual data were also analyzed to obtain the proportion of ears with an abnormal absorbance. Figure 4.1.4.5 shows the participants with an abnormal absorbance at ambient pressure at various frequencies in the non-CI ears of the CI group and non-CI matched ears of the SNHL group. Figure 4.1.4.6 shows the individual absorbance curves across frequencies when compared against the mean absorbance curve and standard deviation of the NH group at ambient pressure condition.

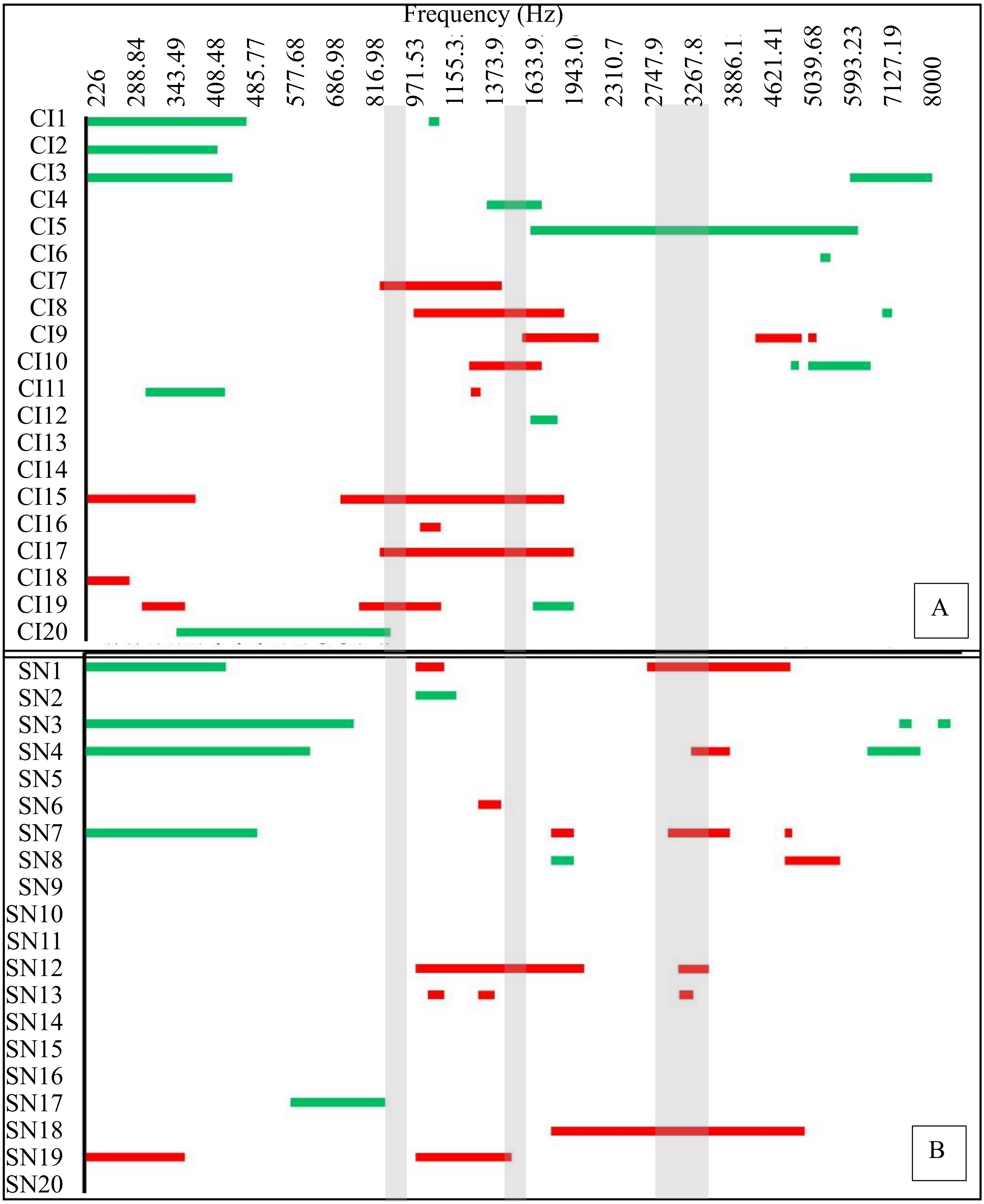


*Figure 4.1.4.5:* Abnormal absorbance across frequencies in ambient pressure in (A) non-CI ears of CI group and (B) non-CI matched ears of SNHL group. The digits on the Y-axis represent participant number and prefix of 'CI' and 'SN' indicates the CI group and the SNHL group, respectively. The red-colour lines represent significantly lower absorbance and green-colour lines indicate significantly higher absorbance. The grey shaded region indicate statistically significant difference in proportion of abnormal result.

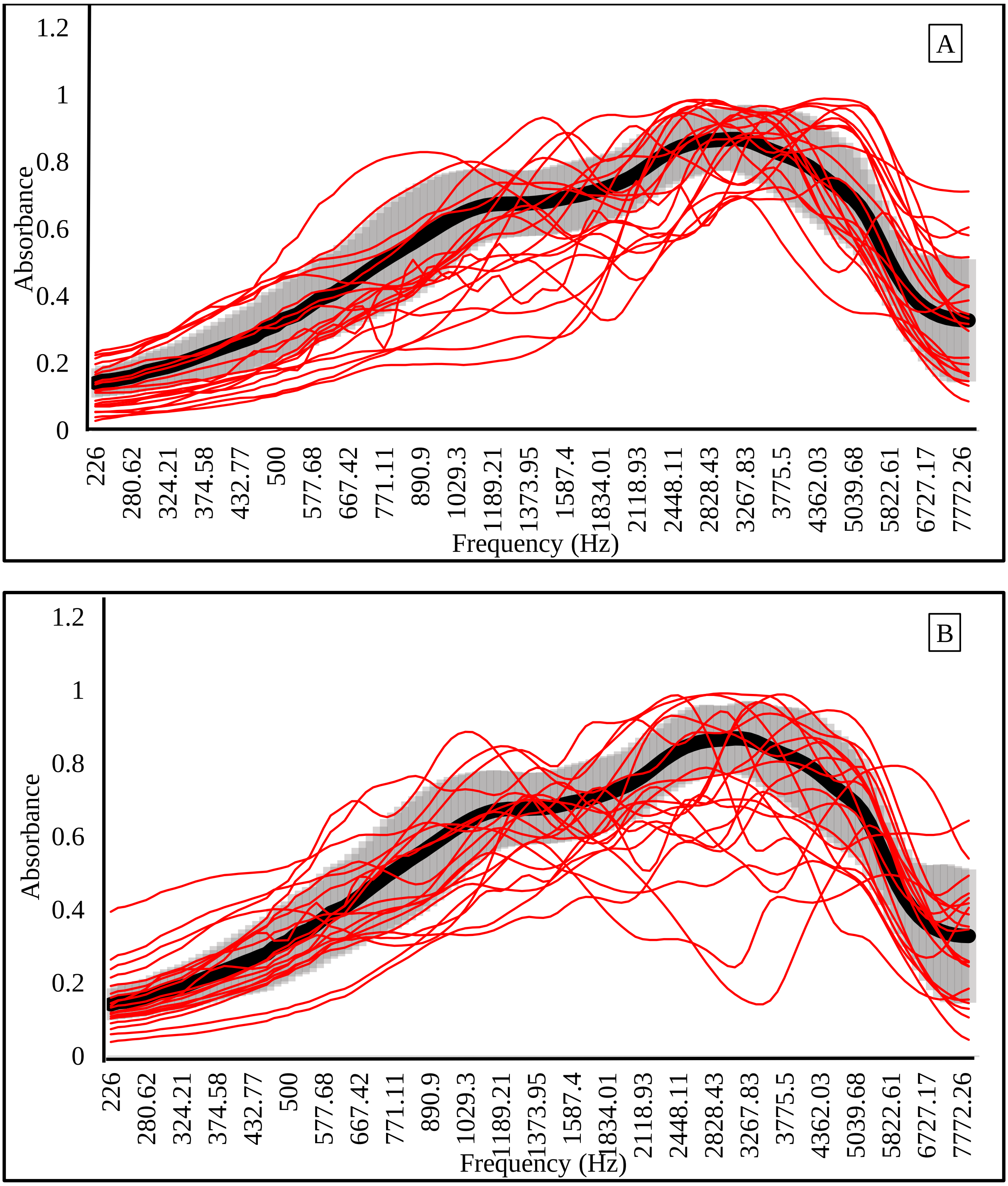


*Figure 4.1.4.6:* Absorbance curves at ambient pressure in (A) non-CI ears of the CI group, and (B) non-CI-matched ears of the SNHL group. The thin red lines represent absorbance curve of each participant in his/her respective group. In each panel, the thick black line represents the mean absorbance and the gray shaded region covers 2 standard deviations of absorbance found in the non-CI matched ears of the NH group (normative group).

At ambient pressure, the proportion of ears with an abnormal absorbance at each frequency was compared between the groups using the Equality of test for proportions. This was done at each frequency separately. The results showed a significant difference in proportion of abnormal absorbance in frequency range of 840.9-890.9 Hz, 1498.31-1587.4 Hz and 2747.91-3363.59 Hz ($p < 0.05$). The specific Z-values and *p*-values for the comparisons are shown in Table 4.1.4.3.

**Table 4.1.4.3.**

*The results of Equality of test for proportions for comparison of proportion of abnormal absorbance at ambient pressure across frequencies between the non-CI ears of the CI group and the non-CI matched ears of the SNHL group*

| Frequency (in Hz) | Z-value | *p*-value | Frequency (in Hz) | Z-value | *p*-value |
|---|---|---|---|---|---|
| 226.00 | 0.00 | 1.000 | 1414.21 | 1.77 | 0.076 |
| 250.00 | 0.00 | 1.000 | 1455.65 | 1.77 | 0.076 |
| 257.33 | 0.00 | 1.000 | 1498.31 | 2.08 | 0.037 |
| 264.87 | 0.00 | 1.000 | 1542.21 | 2.37 | 0.017 |
| 272.63 | 0.00 | 1.000 | 1587.40 | 2.65 | 0.008 |
| 280.62 | 0.00 | 1.000 | 1633.92 | 1.38 | 0.167 |
| 288.84 | 0.37 | 0.705 | 1681.79 | 0.73 | 0.465 |
| 297.30 | 0.35 | 0.723 | 1731.07 | 0.37 | 0.705 |
| 306.12 | 0.35 | 0.723 | 1781.80 | 0.37 | 0.705 |
| 314.98 | 0.35 | 0.723 | 1834.01 | 0.47 | 0.632 |
| 324.21 | 0.35 | 0.723 | 1887.75 | 0.00 | 1.000 |
| 333.71 | 0.35 | 0.723 | 1943.06 | 0.00 | 1.000 |
| 343.49 | 0.69 | 0.490 | 2000.00 | 0.00 | 1.000 |
| 353.55 | 0.69 | 0.490 | 2058.60 | 0.00 | 1.000 |
| 363.91 | 0.35 | 0.723 | 2118.93 | 1.01 | 0.311 |
| 374.58 | 0.73 | 0.465 | 2181.02 | 1.01 | 0.311 |
| 385.55 | 0.37 | 0.705 | 2244.92 | 1.01 | 0.311 |
| 396.95 | 0.37 | 0.705 | 2310.71 | 1.01 | 0.311 |
| 408.48 | 0.37 | 0.705 | 2378.41 | 1.45 | 0.146 |
| 420.45 | 0.00 | 1.000 | 2448.11 | 1.45 | 0.146 |
| 432.77 | 0.41 | 0.677 | 2519.84 | 1.45 | 0.146 |
| 445.45 | 0.47 | 0.632 | 2593.68 | 1.80 | 0.071 |
| 458.50 | 0.47 | 0.632 | 2669.68 | 1.80 | 0.071 |
| 471.94 | 0.47 | 0.632 | 2747.91 | 2.39 | 0.016 |
| 485.77 | 1.05 | 0.291 | 2828.43 | 2.65 | 0.007 |
| 500.00 | 0.60 | 0.548 | 2911.31 | 2.65 | 0.007 |
| 514.65 | 0.60 | 0.548 | 2996.61 | 2.39 | 0.016 |
| 529.73 | 0.60 | 0.548 | 3084.42 | 2.39 | 0.016 |
| 545.25 | 1.05 | 0.291 | 3174.80 | 2.10 | 0.035 |
| 561.23 | 1.05 | 0.291 | 3267.83 | 2.10 | 0.035 |
| 577.68 | 1.05 | 0.291 | 3363.59 | 2.10 | 0.035 |
| 594.60 | 1.05 | 0.291 | 3462.15 | 1.80 | 0.071 |
| 612.03 | 0.60 | 0.548 | 3563.59 | 1.45 | 0.146 |
| 629.96 | 0.60 | 0.548 | 3668.02 | 1.45 | 0.146 |
| 648.42 | 0.60 | 0.548 | 3775.50 | 1.45 | 0.146 |
| 667.42 | 0.60 | 0.548 | 3886.13 | 1.45 | 0.146 |
| 686.98 | 0.00 | 1.000 | 4000.00 | 0.60 | 0.548 |

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Table 4.1.4.3 continued from previous page

| Frequency (in Hz) | Z-value | *p*-value | Frequency (in Hz) | Z-value | *p*-value |
|---|---|---|---|---|---|
| 707.11 | 0.00 | 1.000 | 4117.21 | 0.60 | 0.548 |
| 727.83 | 0.60 | 0.548 | 4237.85 | 1.43 | 0.151 |
| 749.15 | 1.05 | 0.291 | 4362.03 | 1.05 | 0.291 |
| 771.11 | 1.05 | 0.291 | 4489.85 | 0.60 | 0.548 |
| 793.70 | 1.05 | 0.291 | 4621.41 | 0.00 | 1.000 |
| 816.96 | 1.77 | 0.076 | 4756.83 | 0.00 | 1.000 |
| 840.90 | 2.39 | 0.016 | 4896.21 | 1.01 | 0.311 |
| 865.54 | 2.39 | 0.016 | 5039.68 | 0.60 | 0.548 |
| 890.90 | 2.10 | 0.035 | 5187.36 | 0.60 | 0.548 |
| 917.00 | 0.79 | 0.429 | 5339.36 | 1.05 | 0.291 |
| 943.87 | 0.73 | 0.465 | 5495.81 | 1.80 | 0.071 |
| 971.53 | 0.69 | 0.490 | 5656.85 | 1.45 | 0.146 |
| 1000.00 | 0.66 | 0.507 | 5822.61 | 1.45 | 0.146 |
| 1029.30 | 0.66 | 0.507 | 5993.23 | 1.05 | 0.291 |
| 1059.46 | 0.37 | 0.705 | 6168.84 | 1.05 | 0.291 |
| 1090.51 | 0.41 | 0.677 | 6349.60 | 0.60 | 0.548 |
| 1122.46 | 0.41 | 0.677 | 6535.66 | 0.60 | 0.548 |
| 1155.35 | 0.88 | 0.375 | 6727.17 | 0.60 | 0.548 |
| 1189.21 | 0.37 | 0.705 | 6924.29 | 0.00 | 1.000 |
| 1224.05 | 0.73 | 0.465 | 7127.19 | 0.00 | 1.000 |
| 1259.92 | 0.73 | 0.465 | 7336.03 | 0.00 | 1.000 |
| 1296.84 | 1.13 | 0.256 | 7550.99 | 1.01 | 0.311 |
| 1334.84 | 1.13 | 0.256 | 7772.26 | 0.00 | 1.000 |
| 1373.95 | 1.58 | 0.113 | 8000.00 | 0.00 | 1.000 |

### 4.1.5 Comparison of WBA at ambient pressure between CI group and NH group

Mann-Whitney *U* test was done for pair-wise comparison between CI group and NH group, separately for the two ears. The mean and standard deviation of absorbance across frequencies in the CI ears of the CI group and the CI-matched ears of the NH group are shown in Figure 4.1.5.1.

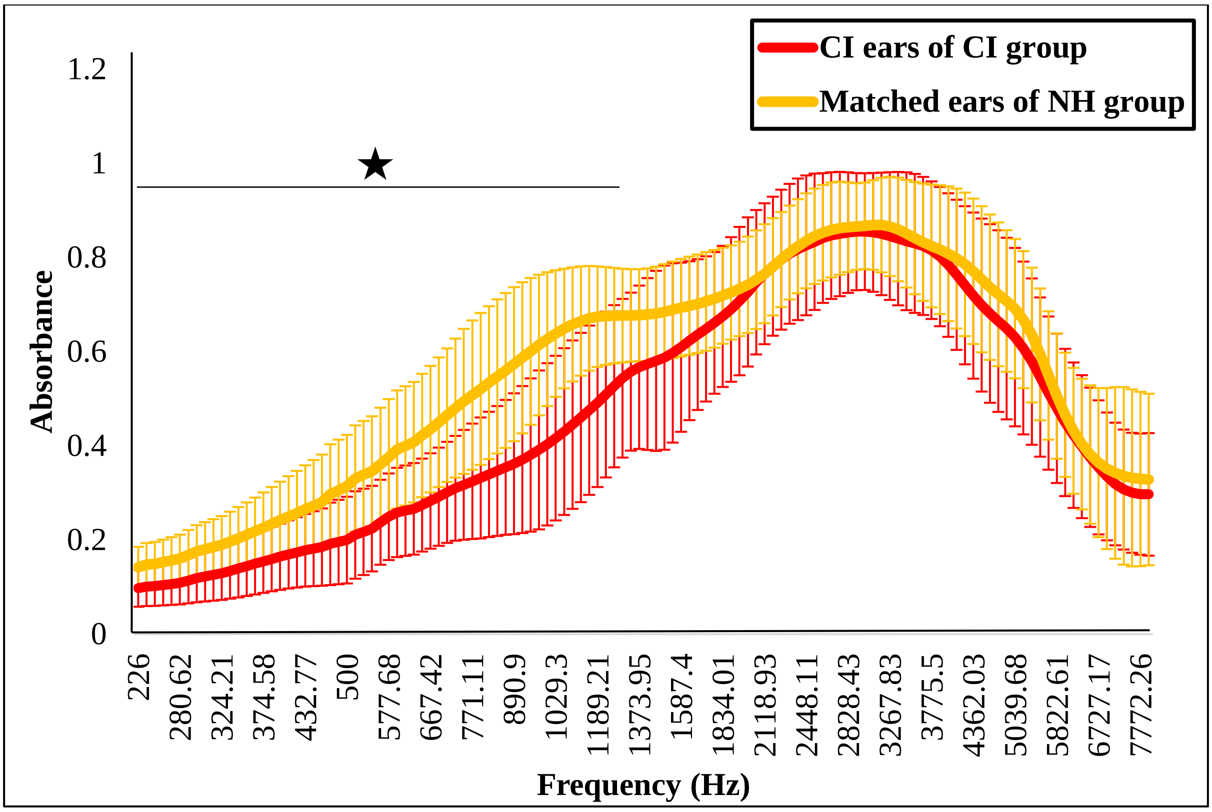


*Figure 4.1.5.1:* Mean and standard deviation of absorbance at ambient pressure across frequencies in the CI ears of the CI group and the CI-matched ears of the NH group. The star-marked comparisons have a statistically significant difference after α-correction ($p < 0.016$).

The absorbance was significantly lower in CI ears of the CI group than the CI-matched ears of the NH group in the frequency range of 226 Hz-1296.84 Hz after α-correction ($p < 0.016$). There was no significant difference in absorbance between the CI ears of the CI group and the CI-matched ears of the NH group at any other frequency after α-correction ($p > 0.016$). The specific Z-values and $p$-values for the pair-wise comparisons are shown in Table 4.1.5.1.

**Table 4.1.5.1.**

*The outcome of Mann-Whitney U test for pair-wise comparison of absorbance at ambient pressure between the CI ears of the CI group and the CI-matched ears of the NH group.*

| Frequency (in Hz) | Z-value | *p*-value | Frequency (in Hz) | Z-value | *p*-value |
|---|---|---|---|---|---|
| 226.00 | -2.90 | 0.004 | 943.87 | -3.57 | <0.001 |
| 250.00 | -2.89 | 0.004 | 971.53 | -3.67 | <0.001 |
| 257.33 | -2.93 | 0.003 | 1000.00 | -3.67 | <0.001 |
| 264.87 | -2.94 | 0.003 | 1029.30 | -3.65 | <0.001 |
| 272.63 | -2.94 | 0.003 | 1059.46 | -3.67 | <0.001 |
| 280.62 | -2.93 | 0.003 | 1090.51 | -3.57 | <0.001 |
| 288.84 | -2.86 | 0.004 | 1122.46 | -3.47 | 0.001 |
| 297.30 | -2.82 | 0.005 | 1155.35 | -3.30 | 0.001 |
| 306.12 | -2.84 | 0.005 | 1189.21 | -3.04 | 0.002 |
| 314.98 | -2.81 | 0.005 | 1224.05 | -2.94 | 0.003 |
| 324.21 | -2.82 | 0.005 | 1259.92 | -2.78 | 0.005 |
| 333.71 | -2.81 | 0.005 | 1296.84 | -2.46 | 0.014 |
| 343.49 | -2.79 | 0.005 | 1334.84 | -2.11 | 0.035 |
| 353.55 | -2.78 | 0.005 | 1373.95 | -1.82 | 0.068 |
| 363.91 | -2.79 | 0.005 | 1414.21 | -1.73 | 0.083 |
| 374.58 | -2.84 | 0.005 | 1455.65 | -1.44 | 0.148 |
| 385.55 | -2.82 | 0.005 | 1498.31 | -1.33 | 0.181 |
| 396.95 | -2.85 | 0.004 | 1542.21 | -1.33 | 0.181 |
| 408.48 | -2.77 | 0.006 | 1587.40 | -1.16 | 0.245 |
| 420.45 | -2.81 | 0.005 | 1633.92 | -0.97 | 0.330 |
| 432.77 | -2.75 | 0.006 | 1681.79 | -1.05 | 0.291 |
| 445.45 | -2.73 | 0.006 | 1781.80 | -1.08 | 0.279 |
| 458.50 | -2.73 | 0.006 | 1834.01 | -0.83 | 0.402 |
| 471.94 | -2.81 | 0.005 | 1887.75 | -0.54 | 0.588 |
| 485.77 | -2.89 | 0.004 | 1943.06 | -0.21 | 0.829 |
| 500.00 | -3.04 | 0.002 | 2000.00 | -0.04 | 0.968 |
| 514.65 | -3.15 | 0.002 | 2058.60 | -0.01 | 0.989 |
| 529.73 | -3.19 | 0.001 | 2118.93 | -0.21 | 0.829 |
| 545.25 | -3.19 | 0.001 | 2181.02 | -0.13 | 0.892 |
| 561.23 | -3.19 | 0.001 | 2244.92 | -0.43 | 0.665 |
| 577.68 | -3.21 | 0.001 | 2310.71 | -0.36 | 0.715 |
| 594.60 | -3.32 | 0.001 | 2378.41 | -0.12 | 0.903 |
| 612.03 | -3.32 | 0.001 | 2448.11 | -0.20 | 0.839 |
| 629.96 | -3.35 | 0.001 | 2519.84 | -0.05 | 0.957 |

Table continued on next page

Table 4.1.5.1 continued from previous page

| Frequency (in Hz) | Z-value | *p*-value | Frequency (in Hz) | Z-value | *p*-value |
|---|---|---|---|---|---|
| 648.42 | -3.47 | 0.001 | 2593.68 | -0.14 | 0.882 |
| 667.42 | -3.49 | <0.001 | 2669.68 | -0.08 | 0.935 |
| 686.98 | -3.49 | <0.001 | 2747.91 | -0.09 | 0.925 |
| 707.11 | -3.65 | <0.001 | 2828.43 | -0.08 | 0.935 |
| 727.83 | -3.73 | <0.001 | 2911.31 | -0.01 | 0.989 |
| 749.15 | -3.62 | <0.001 | 2996.61 | -0.10 | 0.914 |
| 771.11 | -3.61 | <0.001 | 3084.42 | -0.08 | 0.935 |
| 793.70 | -3.58 | <0.001 | 3174.80 | -0.09 | 0.925 |
| 816.96 | -3.59 | <0.001 | 3267.83 | -0.10 | 0.914 |
| 840.90 | -3.61 | <0.001 | 3363.59 | -0.08 | 0.935 |
| 865.54 | -3.59 | <0.001 | 3462.15 | -0.12 | 0.903 |
| 890.90 | -3.59 | <0.001 | 3563.59 | -0.14 | 0.882 |
| 917.00 | -3.59 | <0.001 | 3668.02 | -0.05 | 0.957 |

*Note.* Pair-wise comparison was done at these frequencies due to a significant group difference on Kruskal-Wallis *H* test only at these frequencies.

The mean and standard deviation of absorbance across frequencies in the non-CI ears of the CI group and the non-CI-matched ears of the NH group are shown in Figure 4.1.5.2. There was no significant difference in absorbance between the non-CI ears of the CI group and the non-CI-matched ears of the NH group at any frequency after α-correction ($p > 0.016$).

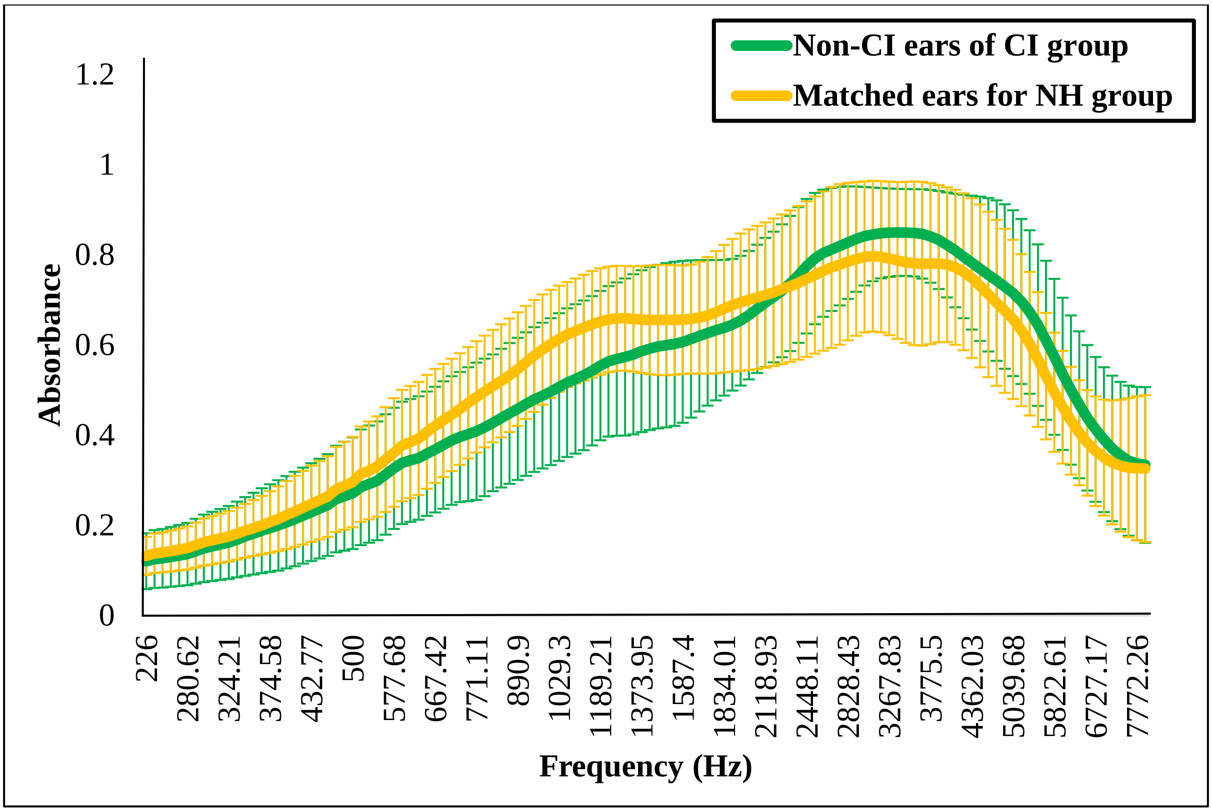


*Figure 4.1.5.2:* Mean and standard deviation of absorbance at ambient pressure across frequencies in the non-CI ears of the CI group and the non-CI-matched ears of the NH group.

### 4.1.6 Comparison of WBA at ambient pressure between SNHL group and NH group

Mann-Whitney *U* test was done for pair-wise comparison between SNHL group and NH group, separately for the two ears. The mean and standard deviation of absorbance across frequencies in the CI-matched ears of the SNHL group and the CI-matched ears NH group are shown in Figure 4.1.6.1.

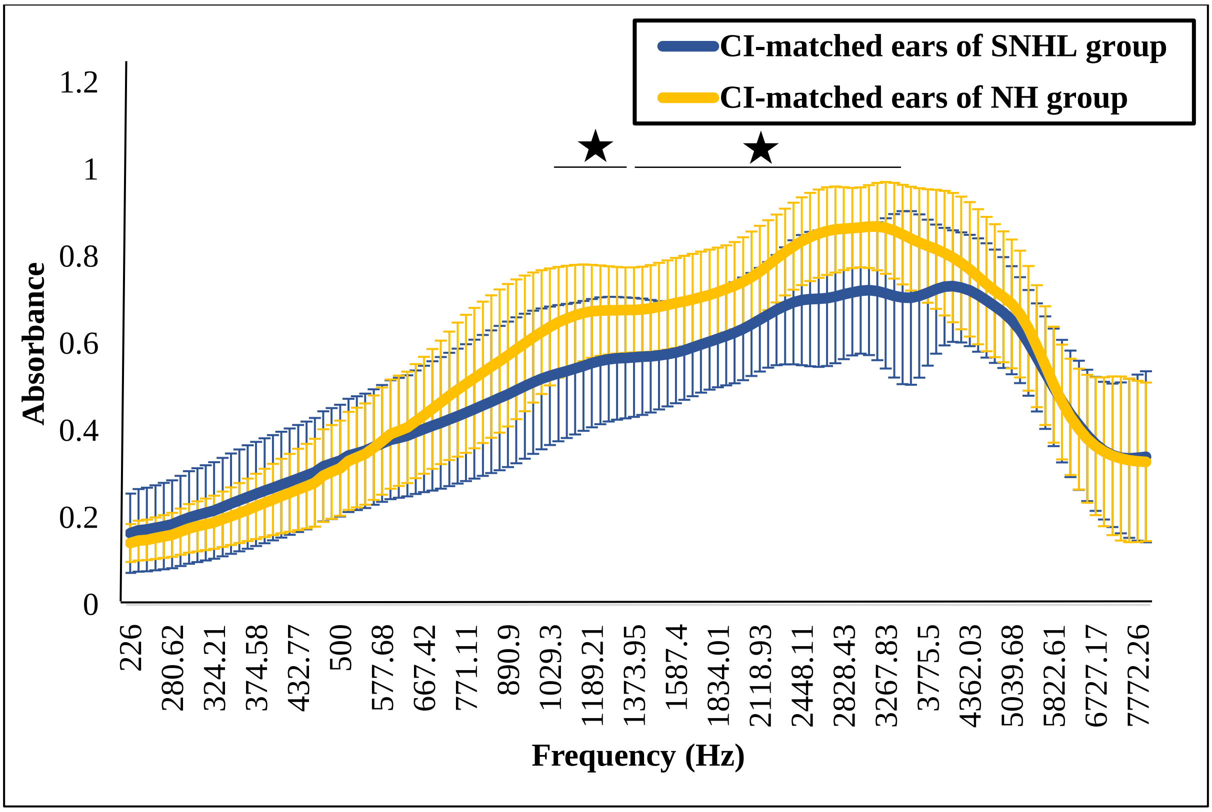


*Figure 4.1.6.1:* Mean and standard deviation of absorbance at ambient pressure across frequencies in the CI-matched ears of the SNHL group and the CI-matched ears of the NH group. The star-marked comparisons have a statistically significant difference after α-correction ($p < 0.016$).

The CI-matched ears of the SNHL group had significantly lower absorbance than the CI-matched ears of the NH group in the frequency range of 1122.46-1224.05 and 1334.84-3563.59 Hz after α-correction ($p < 0.016$). For the remaining frequencies, there was no significant difference in absorbance between the CI-matched ears of the SNHL group and the CI-matched ears of the NH group after α-correction ($p > 0.016$). The specific Z-values and *p*-values for the pair-wise comparisons are shown in Table 4.1.6.1.

**Table 4.1.6.1.**

*The outcome of Mann-Whitney U test for pair-wise comparison of absorbance at ambient pressure between the CI-matched ears of the SNHL group and the CI-matched ears of the NH group*

| Frequency (in Hz) | Z-value | *p*-value | Frequency (in Hz) | Z-value | *p*-value |
|---|---|---|---|---|---|
| 226.00 | -0.37 | 0.705 | 943.87 | -1.65 | 0.099 |
| 250.00 | -0.37 | 0.705 | 971.53 | -1.89 | 0.058 |
| 257.33 | -0.39 | 0.695 | 1000.00 | -1.94 | 0.051 |
| 264.87 | -0.37 | 0.705 | 1029.30 | -2.02 | 0.042 |
| 272.63 | -0.37 | 0.705 | 1059.46 | -2.33 | 0.019 |
| 280.62 | -0.39 | 0.695 | 1090.51 | -2.35 | 0.019 |
| 288.84 | -0.39 | 0.695 | 1122.46 | -2.62 | 0.009 |
| 297.30 | -0.40 | 0.685 | 1155.35 | -2.58 | 0.010 |
| 306.12 | -0.41 | 0.675 | 1189.21 | -2.54 | 0.011 |
| 314.98 | -0.47 | 0.636 | 1224.05 | -2.43 | 0.015 |
| 324.21 | -0.50 | 0.617 | 1259.92 | -2.23 | 0.026 |
| 333.71 | -0.52 | 0.598 | 1296.84 | -2.21 | 0.027 |
| 343.49 | -0.58 | 0.561 | 1334.84 | -2.43 | 0.015 |
| 353.55 | -0.59 | 0.552 | 1373.95 | -2.52 | 0.011 |
| 363.91 | -0.59 | 0.552 | 1414.21 | -2.59 | 0.009 |
| 374.58 | -0.59 | 0.552 | 1455.65 | -2.65 | 0.008 |
| 385.55 | -0.59 | 0.552 | 1498.31 | -2.81 | 0.005 |
| 396.95 | -0.64 | 0.516 | 1542.21 | -2.84 | 0.005 |
| 408.48 | -0.64 | 0.516 | 1587.40 | -2.84 | 0.005 |
| 420.45 | -0.67 | 0.499 | 1633.92 | -2.79 | 0.005 |
| 432.77 | -0.71 | 0.473 | 1681.79 | -2.70 | 0.007 |
| 445.45 | -0.73 | 0.465 | 1781.8 | -2.56 | 0.010 |
| 458.50 | -0.68 | 0.490 | 1834.01 | -2.65 | 0.008 |
| 471.94 | -0.58 | 0.561 | 1887.75 | -2.75 | 0.006 |
| 485.77 | -0.54 | 0.589 | 1943.06 | -2.73 | 0.006 |
| 500.00 | -0.55 | 0.579 | 2000.00 | -2.62 | 0.009 |
| 514.65 | -0.41 | 0.675 | 2058.60 | -2.62 | 0.009 |
| 529.73 | -0.40 | 0.685 | 2118.93 | -2.78 | 0.005 |
| 545.25 | -0.35 | 0.725 | 2181.02 | -2.84 | 0.005 |
| 561.23 | -0.20 | 0.839 | 2244.92 | -2.84 | 0.005 |
| 577.68 | -0.10 | 0.914 | 2310.71 | -2.71 | 0.007 |
| 594.60 | -0.10 | 0.914 | 2378.41 | -2.77 | 0.006 |
| 612.03 | -0.16 | 0.871 | 2448.11 | -2.75 | 0.006 |
| 629.96 | -0.21 | 0.829 | 2519.84 | -2.85 | 0.004 |

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Table 4.1.6.1 continued from previous page

| Frequency (in Hz) | Z-value | *p*-value | Frequency (in Hz) | Z-value | *p*-value |
|---|---|---|---|---|---|
| 648.42 | -0.48 | 0.626 | 2593.68 | -2.89 | 0.004 |
| 667.42 | -0.59 | 0.552 | 2669.68 | -3.12 | 0.002 |
| 686.98 | -0.73 | 0.465 | 2747.91 | -3.21 | 0.001 |
| 707.11 | -0.83 | 0.402 | 2828.43 | -3.27 | 0.001 |
| 727.83 | -1.00 | 0.317 | 2911.31 | -3.13 | 0.002 |
| 749.15 | -1.12 | 0.262 | 2996.61 | -3.05 | 0.002 |
| 771.11 | -1.23 | 0.218 | 3084.42 | -3.16 | 0.002 |
| 793.70 | -1.27 | 0.204 | 3174.80 | -3.16 | 0.002 |
| 816.96 | -1.32 | 0.185 | 3267.83 | -3.07 | 0.002 |
| 840.90 | -1.39 | 0.164 | 3363.59 | -2.89 | 0.004 |
| 865.54 | -1.51 | 0.130 | 3462.15 | -2.77 | 0.006 |
| 890.90 | -1.54 | 0.123 | 3563.59 | -2.54 | 0.011 |
| 917.00 | -1.55 | 0.120 | 3668.02 | -2.28 | 0.022 |

*Note.* Pair-wise comparison was done at these frequencies due to a significant group difference on Kruskal-Wallis *H* test only at these frequencies.

The mean and standard deviation of absorbance across frequencies in the non-CI-matched ears of the SNHL group and the non-CI-matched ears of the NH group are shown in Figure 4.1.6.1. Although the non-CI-matched ears of the SNHL group had lower absorbance than the non-CI-matched ears of the NH group, there was no significant difference between them at any frequency after α-correction ($p > 0.016$).

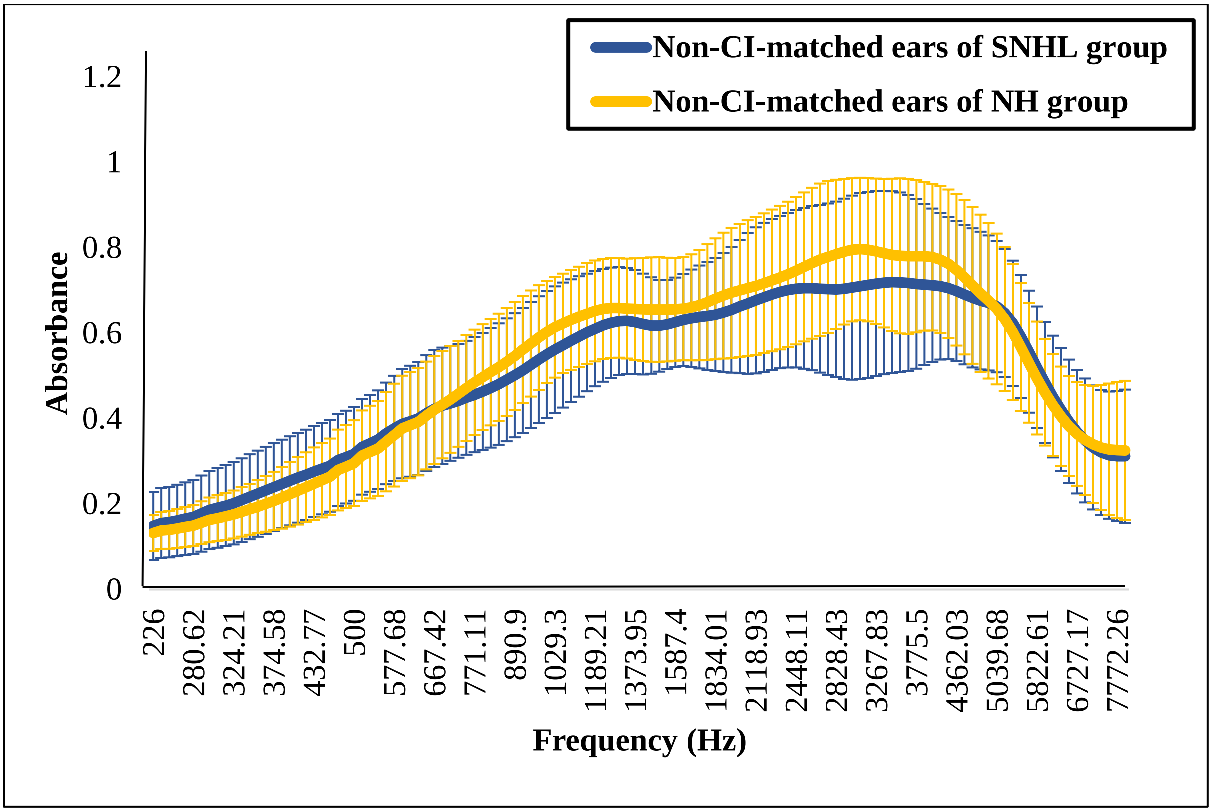


*Figure 4.1.6.2:* Mean and standard deviation of absorbance at ambient pressure across frequencies in the non-CI-matched ears of the SNHL group and the non-CI-matched ears of the NH group.

**4.1.7 Comparison of resonance frequency among the groups**

In addition to the absorbance at peak and ambient pressure across frequencies, WBT also provided resonance frequency. In order to obtain the mean, median, standard deviation, and interquartile range, resonance frequency values were subjected to descriptive statistics. The outcome of the descriptive statistics is shown in Table 4.1.7.1.

**Table 4.1.7.1.**

*Mean, standard deviation, median and interquartile range of resonance frequency of middle ear in both ears of CI group, SNHL group and NH group*

| Group | CI ears of CI group or CI matched ears of other groups | | | | Non-CI ears of CI group or non-CI-matched ears of other groups | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | Mean | SD | Median | IQR |
| CI group | 876.40 | 433.65 | 946.00 | 725.00 | 841.80 | 265.19 | 833.50 | 386.00 |
| SNHL group | 809.65 | 376.17 | 695.00 | 400.75 | 775.40 | 262.80 | 707.50 | 388.00 |
| NH group | 865.00 | 223.28 | 883.00 | 328.75 | 891.15 | 199.16 | 951.00 | 254.50 |

*Note. 'SD'- Standard Deviation, 'IQR'- Interquartile Range*

The comparison among groups was done using Kruskal-Wallis *H* Test. The results showed no significant differences in resonance frequency among the three groups for CI ears [$\chi^2$ (2) = 2.038, $p$ = 0.361] and for non-CI ears [$\chi^2$ (2) = 2.425, $p$ = 0.297].

## 4.2 Comparison of WBA at peak and ambient pressure within the CI Group between implanted and non-implanted ears

The absorbance in both ears of the CI group was compared with each other at each of the 122 frequencies. These comparisons were made separately for absorbance at the peak pressure and the ambient pressure. The mean and standard deviation of absorbance across frequencies of CI ears of CI group and non-CI ears of the CI group for peak and ambient pressure conditions are shown in Figure 4.2.1.

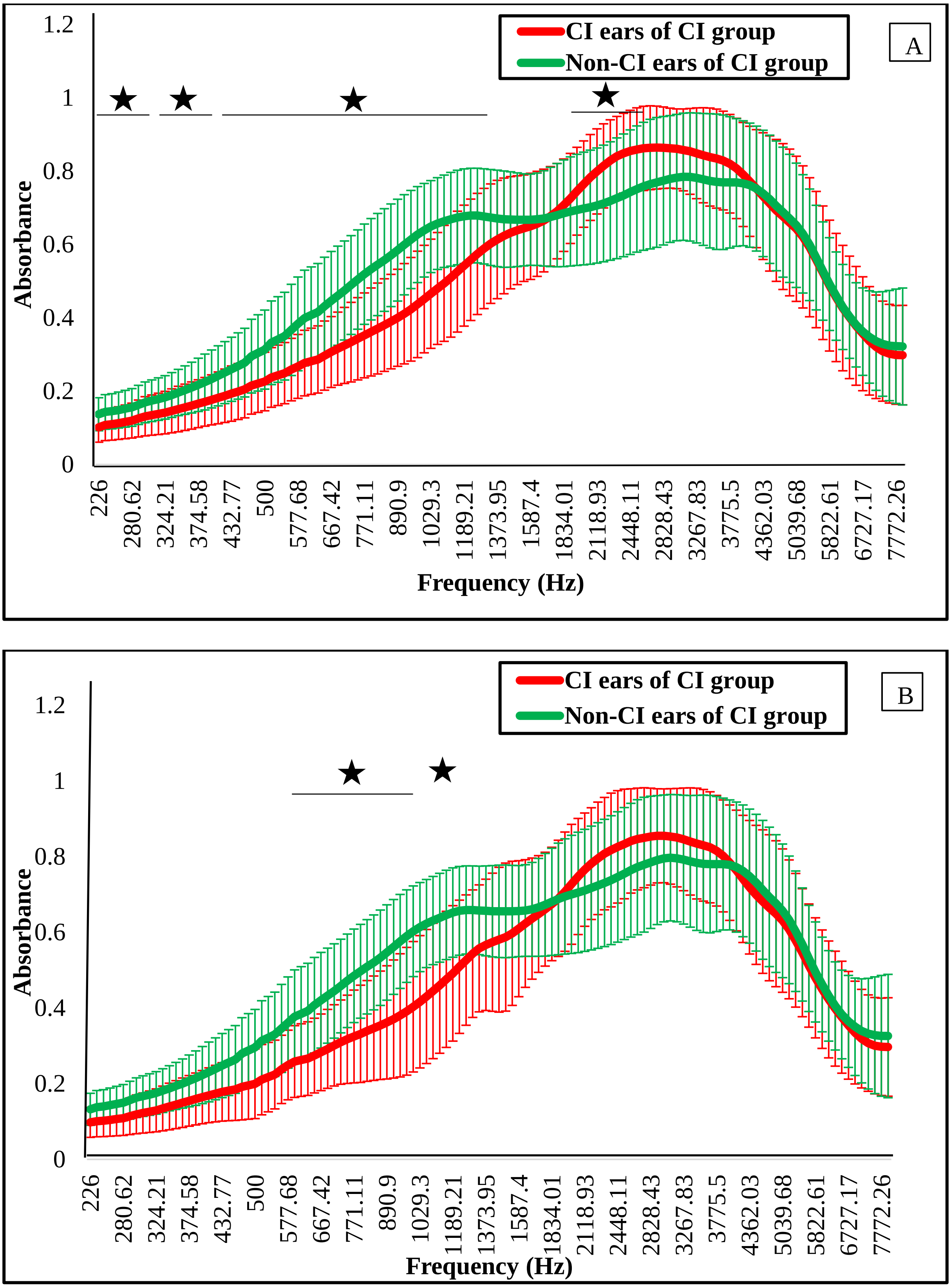


*Figure 4.2.1:* Mean and standard deviation of absorbance across frequencies in the CI ears and the non-CI ears of the CI group at (A) peak pressure and (B) ambient pressure. The star-marked comparisons have a statistically significant difference ($p < 0.05$).

Wilcoxon signed rank test was done to compare the two ears at peak pressure. The CI ears had significantly lower absorbance than the non-CI ears in the frequency range of 226-288.84 Hz, 306.12-374.58 Hz, and 396.95-1296.84 Hz ($p < 0.05$). Further, the CI ears had significantly higher absorbance than the non-CI ears in the frequency range of 2058.6-2448.11 Hz ($p < 0.05$). At ambient pressure, the CI ears showed significantly lower absorbance than the non-CI ears in the frequency range of 594.6-1000Hz and at a sporadic frequency of 1059.46 Hz ($p > 0.05$). At all other frequencies there was no significant difference between the ears at ambient pressure. The specific Z-values and $p$-values obtained on the Wilcoxon signed rank test are shown in Table 4.2.1.

**Table 4.2.1**

*The outcome of Wilcoxon signed rank test for pair-wise comparison of absorbance at peak pressure and ambient pressure between CI and non-CI ears of the CI group*

| Frequency (in Hz) | Peak pressure condition | | Ambient pressure condition | |
|---|---|---|---|---|
| | Z-value | *p*-value | Z-value | *p*-value |
| 226.00 | -2.09 | 0.037 | -1.49 | 0.135 |
| 250.00 | -2.01 | 0.044 | -1.49 | 0.135 |
| 257.33 | -2.05 | 0.040 | -1.45 | 0.145 |
| 264.87 | -2.01 | 0.044 | -1.53 | 0.126 |
| 272.63 | -2.01 | 0.044 | -1.60 | 0.108 |
| 280.62 | -1.99 | 0.046 | -1.60 | 0.108 |
| 288.84 | -1.97 | 0.048 | -1.60 | 0.108 |
| 297.30 | -1.93 | 0.053 | -1.55 | 0.121 |
| 306.12 | -2.09 | 0.037 | -1.49 | 0.135 |
| 314.98 | -2.16 | 0.030 | -1.49 | 0.135 |
| 324.21 | -2.16 | 0.030 | -1.49 | 0.135 |
| 333.71 | -2.2 | 0.028 | -1.49 | 0.135 |
| 343.49 | -2.16 | 0.030 | -1.45 | 0.145 |
| 353.55 | -2.16 | 0.030 | -1.49 | 0.135 |
| 363.91 | -2.09 | 0.037 | -1.43 | 0.151 |
| 374.58 | -2.01 | 0.044 | -1.45 | 0.145 |
| 385.55 | -1.94 | 0.052 | -1.44 | 0.147 |
| 396.95 | -2.05 | 0.040 | -1.45 | 0.145 |
| 408.48 | -2.05 | 0.040 | -1.51 | 0.130 |
| 420.45 | -2.31 | 0.021 | -1.56 | 0.117 |
| 432.77 | -2.33 | 0.020 | -1.60 | 0.108 |
| 445.45 | -2.42 | 0.015 | -1.68 | 0.093 |
| 458.50 | -2.5 | 0.012 | -1.79 | 0.073 |
| 471.94 | -2.65 | 0.008 | -1.79 | 0.073 |
| 485.77 | -2.68 | 0.007 | -1.75 | 0.079 |
| 500.00 | -2.68 | 0.007 | -1.75 | 0.079 |
| 514.65 | -2.59 | 0.009 | -1.75 | 0.079 |
| 529.73 | -2.61 | 0.009 | -1.79 | 0.073 |
| 545.25 | -2.61 | 0.009 | -1.79 | 0.073 |
| 561.23 | -2.68 | 0.007 | -1.86 | 0.062 |
| 577.68 | -2.72 | 0.006 | -1.86 | 0.062 |
| 594.60 | -2.87 | 0.004 | -2.09 | 0.037 |

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Table 4.2.1 continued from previous page

| Frequency (in Hz) | Peak pressure condition | | Ambient pressure condition | |
|---|---|---|---|---|
| | Z-value | *p*-value | Z-value | *p*-value |
| 612.03 | -2.91 | 0.004 | -2.16 | 0.030 |
| 629.96 | -2.94 | 0.003 | -2.24 | 0.025 |
| 648.42 | -2.89 | 0.004 | -2.20 | 0.028 |
| 667.42 | -2.83 | 0.005 | -2.24 | 0.025 |
| 686.98 | -2.83 | 0.005 | -2.31 | 0.021 |
| 707.11 | -2.83 | 0.005 | -2.27 | 0.023 |
| 727.83 | -2.91 | 0.004 | -2.33 | 0.020 |
| 749.15 | -3.06 | 0.002 | -2.24 | 0.025 |
| 771.11 | -3.06 | 0.002 | -2.20 | 0.028 |
| 793.70 | -3.17 | 0.002 | -2.20 | 0.028 |
| 816.96 | -3.21 | 0.001 | -2.35 | 0.019 |
| 840.90 | -3.09 | 0.002 | -2.27 | 0.023 |
| 865.54 | -3.15 | 0.002 | -2.12 | 0.033 |
| 890.90 | -3.21 | 0.001 | -2.24 | 0.025 |
| 917.00 | -3.21 | 0.001 | -2.24 | 0.025 |
| 943.87 | -3.28 | 0.001 | -2.24 | 0.025 |
| 971.53 | -3.28 | 0.001 | -2.12 | 0.033 |
| 1000.00 | -3.24 | 0.001 | -1.97 | 0.048 |
| 1029.30 | -3.28 | 0.001 | -1.94 | 0.052 |
| 1059.46 | -3.17 | 0.002 | -1.97 | 0.048 |
| 1090.51 | -3.17 | 0.002 | -1.79 | 0.073 |
| 1122.46 | -3.13 | 0.002 | -1.75 | 0.079 |
| 1155.35 | -3.09 | 0.002 | -1.60 | 0.108 |
| 1189.21 | -2.95 | 0.003 | -1.56 | 0.117 |
| 1224.05 | -2.95 | 0.003 | -1.43 | 0.151 |
| 1259.92 | -2.61 | 0.009 | -1.15 | 0.247 |
| 1296.84 | -2.12 | 0.033 | -0.70 | 0.478 |
| 1334.84 | -1.88 | 0.059 | -0.56 | 0.575 |
| 1373.95 | -1.75 | 0.079 | -0.52 | 0.601 |
| 1414.21 | -1.75 | 0.079 | -0.52 | 0.601 |
| 1455.65 | -1.62 | 0.104 | -0.37 | 0.709 |
| 1498.31 | -1.67 | 0.095 | -0.41 | 0.681 |
| 1542.21 | -1.41 | 0.156 | -0.18 | 0.852 |
| 1587.4 | -1.12 | 0.263 | -0.11 | 0.911 |
| 1633.92 | -0.97 | 0.332 | -0.16 | 0.867 |
| 1681.79 | -0.78 | 0.433 | -0.26 | 0.794 |
| 1731.07 | -0.78 | 0.433 | -0.41 | 0.681 |
| 1781.80 | -0.37 | 0.709 | -0.48 | 0.627 |

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Table 4.2.1 continued from previous page

| Frequency (in Hz) | Peak pressure condition | | Ambient pressure condition | |
|---|---|---|---|---|
| | Z-value | *p*-value | Z-value | *p*-value |
| 1834.01 | -0.11 | 0.911 | -0.67 | 0.502 |
| 1887.75 | -1.08 | 0.279 | -0.85 | 0.391 |
| 1943.06 | -1.56 | 0.117 | -0.89 | 0.370 |
| 2000.00 | -1.68 | 0.093 | -0.98 | 0.322 |
| 2058.60 | -2.05 | 0.040 | -1.17 | 0.240 |
| 2118.93 | -2.27 | 0.023 | -1.32 | 0.185 |
| 2181.02 | -2.35 | 0.019 | -1.43 | 0.151 |
| 2244.92 | -2.42 | 0.015 | -1.51 | 0.131 |
| 2310.71 | -2.43 | 0.015 | -1.60 | 0.108 |
| 2378.41 | -2.22 | 0.026 | -1.23 | 0.218 |
| 2448.11 | -2.09 | 0.037 | -1.08 | 0.279 |
| 2519.84 | -1.71 | 0.086 | -0.95 | 0.341 |
| 2593.68 | -1.54 | 0.121 | -1.00 | 0.313 |
| 2669.68 | -1.19 | 0.232 | -0.92 | 0.355 |
| 2747.91 | -0.89 | 0.370 | -0.97 | 0.332 |
| 2828.43 | -0.44 | 0.654 | -0.89 | 0.370 |
| 2911.31 | -0.05 | 0.955 | -0.78 | 0.433 |
| 2996.61 | -0.22 | 0.823 | -0.78 | 0.433 |
| 3084.42 | -0.44 | 0.654 | -0.70 | 0.478 |
| 3174.80 | -0.44 | 0.654 | -0.71 | 0.478 |
| 3267.83 | -0.70 | 0.478 | -0.32 | 0.744 |
| 3363.59 | -0.48 | 0.627 | -0.07 | 0.940 |
| 3462.15 | -0.57 | 0.563 | -0.22 | 0.823 |
| 3563.59 | -0.57 | 0.563 | -0.26 | 0.794 |
| 3668.02 | -0.33 | 0.737 | -0.38 | 0.702 |
| 3775.50 | -0.37 | 0.709 | -0.48 | 0.627 |
| 3886.13 | -0.48 | 0.627 | -0.59 | 0.550 |
| 4000.00 | -0.44 | 0.654 | -0.61 | 0.538 |
| 4117.21 | -0.42 | 0.668 | -0.74 | 0.455 |
| 4237.85 | -0.70 | 0.478 | -1.12 | 0.263 |
| 4362.03 | -0.84 | 0.401 | -1.19 | 0.232 |
| 4489.85 | -0.98 | 0.322 | -1.23 | 0.218 |
| 4621.41 | -1.00 | 0.313 | -1.13 | 0.255 |
| 4756.83 | -0.93 | 0.351 | -1.06 | 0.287 |
| 4896.21 | -0.95 | 0.341 | -1.08 | 0.279 |
| 5039.68 | -1.00 | 0.313 | -1.15 | 0.247 |
| 5187.36 | -0.97 | 0.332 | -1.23 | 0.218 |
| 5339.36 | -1.02 | 0.305 | -1.30 | 0.191 |

Table continued on next page

Table 4.2.1 continued from previous page

| Frequency (in Hz) | Peak pressure condition | | Ambient pressure condition | |
|---|---|---|---|---|
| | Z-value | *p*-value | Z-value | *p*-value |
| 5495.81 | -1.10 | 0.271 | -1.41 | 0.156 |
| 5656.85 | -1.12 | 0.263 | -1.49 | 0.135 |
| 5822.61 | -1.08 | 0.279 | -1.53 | 0.126 |
| 5993.23 | -0.97 | 0.332 | -1.41 | 0.156 |
| 6168.84 | -0.93 | 0.351 | -1.34 | 0.179 |
| 6349.60 | -0.88 | 0.376 | -1.19 | 0.232 |
| 6535.66 | -0.82 | 0.411 | -0.97 | 0.332 |
| 6727.17 | -0.85 | 0.391 | -0.98 | 0.322 |
| 6924.29 | -0.82 | 0.411 | -1.00 | 0.313 |
| 7127.19 | -0.63 | 0.526 | -1.00 | 0.313 |
| 7336.03 | -0.52 | 0.601 | -0.89 | 0.370 |
| 7550.99 | -0.59 | 0.550 | -0.85 | 0.390 |
| 7772.26 | -0.59 | 0.550 | -0.89 | 0.370 |
| 8000.00 | -0.48 | 0.629 | -0.93 | 0.351 |

In addition to the group-wise comparison, the individual data were also analyzed to obtain the proportion of ears with an abnormal absorbance. Figure 4.2.2 and Figure 4.2.3 show the abnormal absorbance at various frequencies in CI and non-CI ears of the CI group at peak pressure and ambient pressure, respectively. Figure 4.2.4 and Figure 4.2.5 show the individual absorbance curves across frequencies when compared against the mean absorbance curve and standard deviation of the NH group at peak pressure and ambient pressure, respectively.

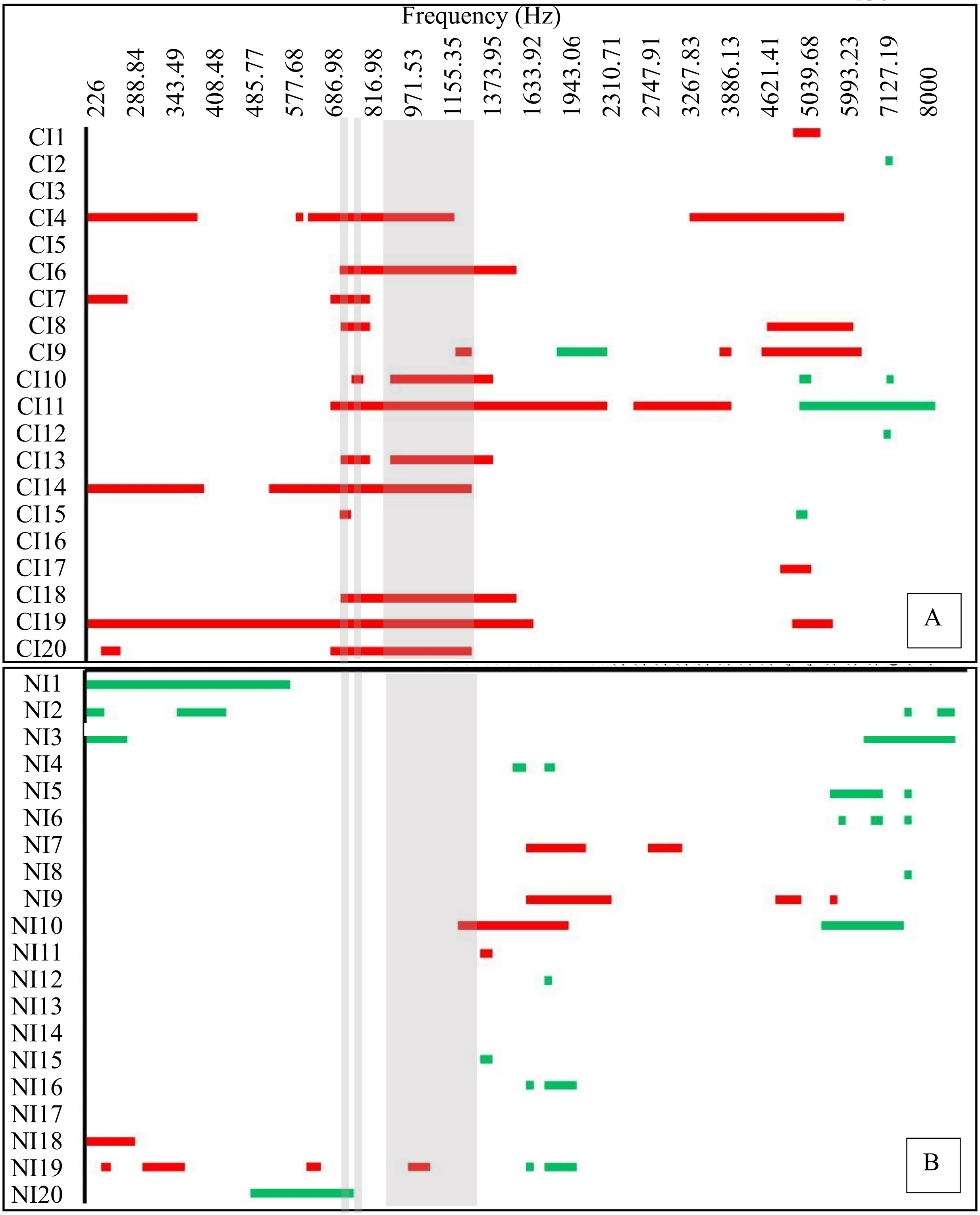



*Figure 4.2.2:* Abnormal absorbance across frequencies at peak pressure in (A) CI ears of the CI group and (B) non-CI ears of the CI group. The digits on the Y-axis represent participant number and prefix of ‘CI’ and ‘NI’ indicates CI and non-CI ears of the CI group, respectively. The red-colour lines represent significantly lower absorbance and green-colour lines indicate significantly higher absorbance. The grey shaded regions indicate statistically significant difference in proportions of abnormal results.

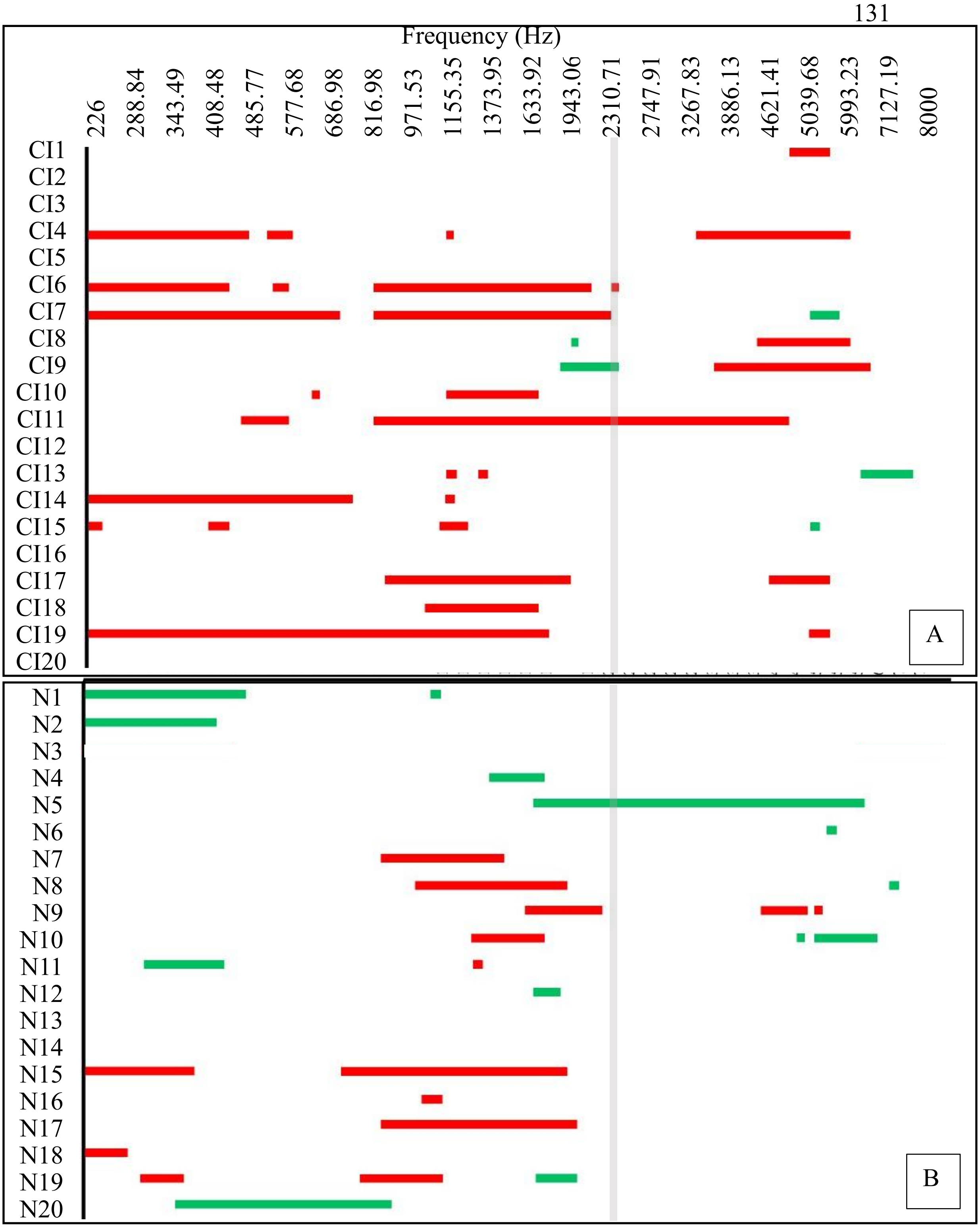



*Figure 4.2.3:* Abnormal absorbance across frequencies at ambient pressure in (A) CI ears of the CI group and (B) non-CI ears of the CI group. The digits on the Y-axis represent participant number and prefix of 'CI' and 'NI' indicates CI and non-CI ears of the CI group, respectively. The red-colour lines represent significantly lower absorbance and green-colour lines indicate significantly higher absorbance. The grey shaded regions indicate statistically significant difference in proportions of abnormal results.

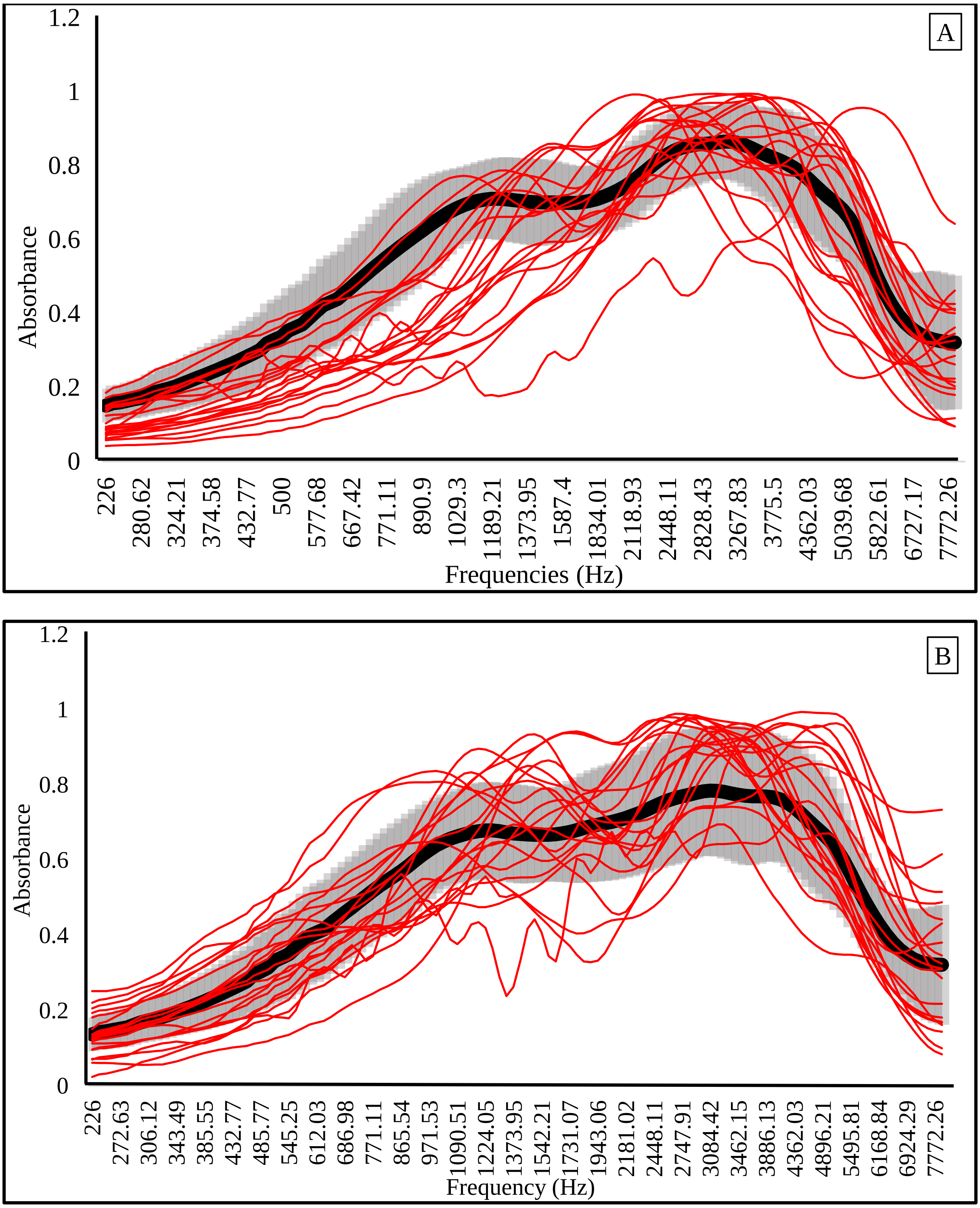



*Figure 4.2.4:* Absorbance curves at peak pressure in (A) CI ears of the CI group, and (B) non-CI ears of the CI group. The thin red lines represent absorbance curve of each participant in his/her respective group. In each panel, the thick black line represents the mean absorbance values and the gray shaded region covers 2 standard deviations of absorbance found in the matched ears of the NH group (normative data).

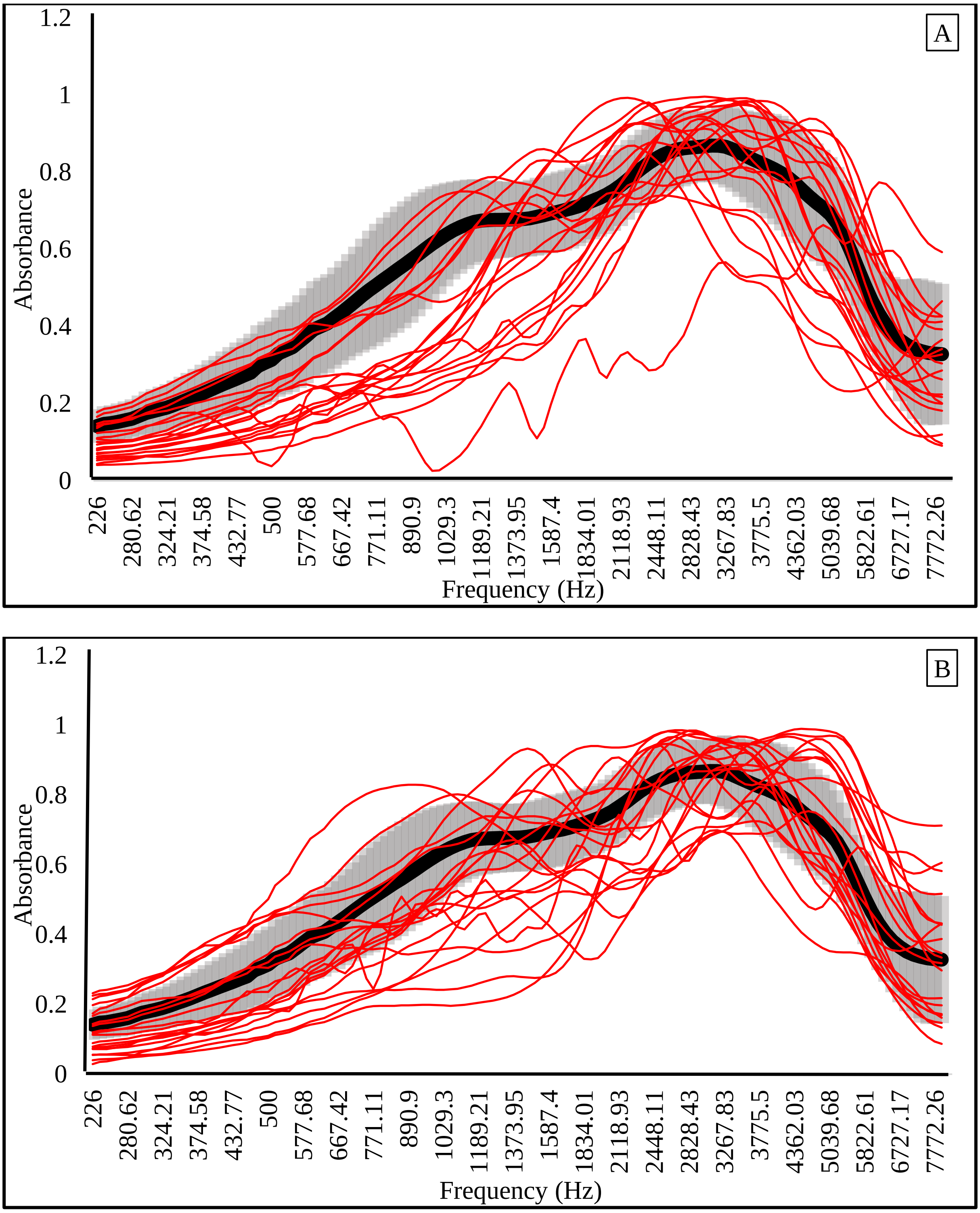



*Figure 4.2.5:* Absorbance curves at ambient pressure in (A) CI ears of the CI group, and (B) non-CI ears of the CI group. The thin red lines represent absorbance curve of each participant in his/her respective group. In each panel, the thick black line represents the mean absorbance values and the gray shaded region covers 2 standard deviations of absorbance found in the matched ears of the NH group (normative data).

In the present study, the individual participants data were also analyzed to find the proportion of ears with abnormal absorbance at each frequency. These proportions were compared between the CI and the non-CI ears using McNemar test. The dichotomy of data is one of the main presumptions when administering the McNemar test (McNemar, 1947; Eliasziw & Donner, 1991; Fagerland, Lyderson, & Laake, 2013). The McNemar test cannot be used if all subjects have only "normal" absorbance values or all subjects have only "abnormal" absorbance values at any given frequency. The results in the present study revealed significant difference in the proportion of abnormal absorbance between the CI ears and non-CI ears at 707.11 Hz and 727.83 Hz, and in the frequency range of 816.96-1189 Hz ($p < 0.05$) at peak pressure.  At the ambient pressure, a significant difference was evidenced only at a sporadic frequency of 2310.71 Hz ($p < 0.05$). The measures of association could not be computed for some of the frequencies due to non-dichotomous data. Table 4.2.2 shows the results of McNemar test for CI ears and non-CI ears of the CI group at peak and ambient pressure conditions.

**Table 4.2.2.**

*The result of McNemar test for comparison of the proportion of ears with abnormal absorbance at peak and ambient pressure between the CI ears and non-CI ear of the CI group*

| Frequency (in Hz) | Peak pressure condition | | Ambient pressure condition | |
|---|---|---|---|---|
| | $\chi^2$ (1) | *p*-value | $\chi^2$ (1) | *p*-value |
| 226.00 | 0.39 | 1.000 | 0.84 | 1.000 |
| 250.00 | 0.39 | 1.000 | 0.35 | 0.727 |
| 257.33 | 0.00 | 1.000 | 0.00 | 0.508 |
| 264.87 | 0.00 | 1.000 | 0.07 | 0.727 |
| 272.63 | 0.13 | 0.687 | 0.07 | 0.727 |
| 280.62 | 0.39 | 1.000 | 0.31 | 1.000 |
| 288.84 | 0.93 | 1.000 | 0.80 | 1.000 |
| 297.30 | 0.93 | 1.000 | 0.80 | 1.000 |
| 306.12 | 0.93 | 1.000 | 0.80 | 1.000 |
| 314.98 | 0.93 | 1.000 | 0.80 | 1.000 |
| 324.21 | 0.93 | 1.000 | 0.80 | 1.000 |
| 333.71 | 0.93 | 1.000 | 0.07 | 0.727 |
| 343.49 | 0.93 | 1.000 | 0.07 | 0.727 |
| 353.55 | 2.13 | 1.000 | 0.07 | 0.727 |
| 363.91 | 2.13 | 1.000 | 0.00 | 0.508 |
| 374.58 | 2.13 | 1.000 | 0.00 | 0.508 |
| 385.55 | 3.95 | 1.000 | 0.00 | 0.508 |
| 396.95 | 0.05 | 1.000 | 0.35 | 0.727 |
| 408.48 | # | # | 0.35 | 0.727 |
| 420.45 | # | # | 0.35 | 0.727 |
| 432.77 | # | # | 0.00 | 1.000 |
| 445.45 | # | # | 0.00 | 1.000 |
| 458.50 | # | # | 0.00 | 1.000 |
| 471.94 | # | # | 0.07 | 1.000 |
| 485.77 | # | # | 0.07 | 1.000 |
| 500.00 | # | # | 0.13 | 0.687 |
| 514.65 | # | # | 0.01 | 0.453 |
| 529.73 | # | # | 0.01 | 0.453 |
| 545.25 | 9.47 | 1.000 | 0.01 | 0.453 |
| 561.23 | 9.47 | 1.000 | 0.39 | 1.000 |
| 577.68 | 2.13 | 1.000 | 0.93 | 1.000 |
| 594.60 | 3.95 | 1.000 | 0.39 | 1.000 |
| 612.03 | 3.95 | 1.000 | 0.39 | 1.000 |
| 629.96 | 3.95 | 1.000 | 0.39 | 1.000 |
| 648.42 | 8.88 | 0.500 | 0.93 | 1.000 |
| 667.42 | 8.88 | 0.500 | 0.93 | 1.000 |
| 686.98 | 0.00 | 0.109 | 0.39 | 1.000 |

Table continued on next page

Table 4.2.2 continued from previous page

| Frequency (in Hz) | Peak pressure condition | | Ambient pressure condition | |
|---|---|---|---|---|
| | $\chi^2$ (1) | *p*-value | $\chi^2$ (1) | *p*-value |
| 707.11 | 0.39 | 0.039 | 0.24 | 1.000 |
| 727.83 | 0.19 | 0.021 | 0.24 | 1.000 |
| 749.15 | 0.39 | 0.039 | 0.11 | 1.000 |
| 771.11 | 0.66 | 0.070 | 0.39 | 1.000 |
| 793.70 | 4.12 | 0.063 | 0.55 | 0.687 |
| 816.96 | 1.28 | 0.031 | 0.74 | 0.453 |
| 840.90 | 1.28 | 0.031 | 0.13 | 0.687 |
| 865.54 | 1.28 | 0.008 | 0.13 | 0.687 |
| 890.90 | 1.28 | 0.008 | 0.74 | 0.375 |
| 917.00 | 1.28 | 0.008 | 0.74 | 0.375 |
| 943.87 | 1.28 | 0.008 | 0.74 | 0.375 |
| 971.53 | 1.28 | 0.008 | 0.42 | 0.219 |
| 1000.00 | 1.28 | 0.008 | 6.55 | 0.125 |
| 1029.30 | 2.71 | 0.016 | 6.55 | 0.125 |
| 1059.46 | 2.71 | 0.016 | 1.68 | 0.070 |
| 1090.51 | 3.52 | 0.016 | 1.25 | 0.070 |
| 1122.46 | 2.71 | 0.008 | 2.55 | 0.219 |
| 1155.35 | 2.71 | 0.016 | 2.55 | 0.219 |
| 1189.21 | 2.71 | 0.016 | 0.20 | 0.289 |
| 1224.05 | 6.66 | 0.250 | 2.54 | 0.687 |
| 1259.92 | 3.15 | 0.125 | 2.54 | 0.687 |
| 1296.84 | 3.15 | 0.125 | 1.83 | 0.687 |
| 1334.84 | 0.26 | 0.375 | 1.83 | 0.687 |
| 1373.95 | 0.26 | 0.375 | 0.84 | 1.000 |
| 1414.21 | 0.26 | 0.375 | 0.84 | 1.000 |
| 1455.65 | 0.18 | 0.625 | 0.84 | 1.000 |
| 1498.31 | 0.11 | 1.000 | 0.01 | 1.000 |
| 1542.21 | 0.39 | 1.000 | 0.01 | 1.000 |
| 1587.40 | 0.42 | 0.219 | 0.01 | 1.000 |
| 1633.92 | 0.35 | 0.219 | 0.00 | 1.000 |
| 1681.79 | 0.35 | 0.219 | 0.07 | 1.000 |
| 1731.07 | 1.25 | 0.625 | 0.80 | 1.000 |
| 1781.80 | 1.25 | 0.625 | 2.85 | 1.000 |
| 1834.01 | 1.25 | 0.625 | 0.00 | 1.000 |
| 1887.75 | 0.74 | 0.375 | 0.49 | 0.453 |
| 1943.06 | 0.74 | 0.375 | 2.55 | 0.219 |
| 2000.00 | 2.13 | 1.000 | 8.23 | 0.250 |
| 2058.60 | 2.13 | 1.000 | 10.5 | 0.500 |
| 2118.93 | 2.13 | 1.000 | 3.51 | 0.375 |
| 2181.02 | 0.18 | 0.625 | 4.12 | 0.063 |
| 2244.92 | # | # | 2.45 | 0.063 |
| 2310.71 | # | # | 1.95 | 0.031 |
| 2378.41 | 0.11 | 1.000 | 2.45 | 0.063 |

Table continued on next page

Table 4.2.2 continued from previous page

| Frequency (in Hz) | Peak pressure condition | | Ambient pressure condition | |
|---|---|---|---|---|
| | $\chi^2$ (1) | *p*-value | $\chi^2$ (1) | *p*-value |
| 2448.11 | 0.11 | 1.000 | 3.45 | 0.063 |
| 2519.84 | 0.11 | 1.000 | 4.45 | 0.063 |
| 2593.68 | 0.11 | 1.000 | 0.18 | 0.625 |
| 2669.68 | 0.05 | 1.000 | 0.26 | 0.375 |
| 2747.91 | 0.11 | 1.000 | 0.26 | 0.375 |
| 2828.43 | 0.11 | 1.000 | 0.18 | 0.625 |
| 2911.31 | 0.11 | 1.000 | 0.26 | 0.375 |
| 2996.61 | 0.24 | 1.000 | 0.55 | 0.687 |
| 3084.42 | 0.11 | 1.000 | 0.24 | 1.000 |
| 3174.80 | 0.11 | 1.000 | 0.11 | 1.000 |
| 3267.83 | # | # | # | # |
| 3363.59 | # | # | 5.96 | 0.500 |
| 3462.15 | # | # | 5.96 | 0.500 |
| 3563.59 | # | # | 5.96 | 0.500 |
| 3668.02 | # | # | 5.96 | 0.500 |
| 3775.50 | 0.05 | 1.000 | 5.96 | 0.500 |
| 3886.13 | 0.05 | 1.000 | 4.21 | 0.250 |
| 4000.00 | 9.47 | 9.474 | 4.21 | 0.250 |
| 4117.21 | 5.96 | 0.500 | 6.66 | 0.250 |
| 4237.85 | 5.96 | 0.500 | 6.66 | 0.250 |
| 4362.03 | 4.21 | 0.250 | 2.26 | 0.375 |
| 4489.85 | 0.39 | 1.000 | 3.26 | 0.625 |
| 4621.41 | 0.72 | 1.000 | 0.31 | 1.000 |
| 4756.83 | 0.13 | 1.000 | 0.13 | 1.000 |
| 4896.21 | 0.13 | 1.000 | 0.83 | 0.727 |
| 5039.68 | 0.58 | 1.000 | 0.83 | 0.727 |
| 5187.36 | 1.26 | 1.000 | 0.65 | 0.727 |
| 5339.36 | 0.00 | 1.000 | 0.08 | 1.000 |
| 5495.81 | 0.00 | 1.000 | 0.07 | 1.000 |
| 5656.85 | 1.25 | 1.000 | 0.39 | 1.000 |
| 5822.61 | 1.25 | 1.000 | 0.55 | 0.687 |
| 5993.23 | 0.88 | 1.000 | 0.55 | 0.687 |
| 6168.84 | 0.39 | 1.000 | 0.39 | 1.000 |
| 6349.60 | 0.11 | 1.000 | 0.11 | 1.000 |
| 6535.66 | 0.11 | 1.000 | 0.18 | 0.625 |
| 6727.17 | 0.18 | 0.625 | 0.18 | 0.625 |
| 6924.29 | 0.95 | 0.952 | 0.11 | 1.000 |
| 7127.19 | 0.05 | 1.000 | 0.11 | 1.000 |
| 7336.03 | 0.05 | 1.000 | 0.05 | 1.000 |
| 7550.99 | 0.05 | 1.000 | 0.05 | 1.000 |
| 7772.26 | 0.05 | 1.000 | # | # |
| 8000.00 | 0.05 | 1.000 | # | # |

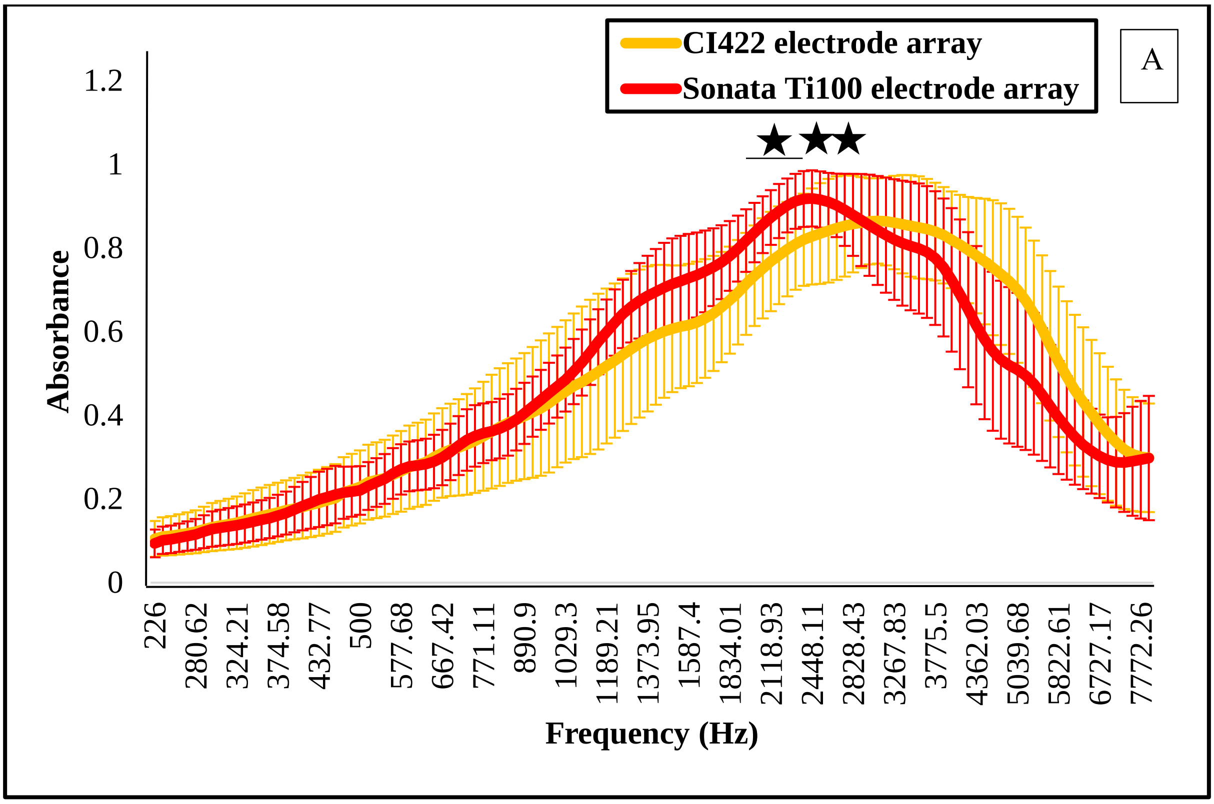
*Note.* '#'- McNemar test could not be performed due non-dichotomous data

### 4.2.3 Comparison of resonance frequency of middle ear between CI ear and non-CI ear within the CI group

The comparison between the ears within the CI group was done using Wilcoxon signed rank test. The results showed no significant differences in resonance frequency of middle ear between the ears [$Z = 0.299$, $p = 0.765$].

## 4.3 Comparison of WBA at peak and ambient pressure conditions and resonance frequency between the two electrode types

The participants in the CI group had either of the two electrode types: CI422 electrode array or Sonata Ti100 electrode array. The mean and standard deviation of absorbance across frequencies in the CI ears with CI422 electrode array and the CI ears with Sonata Ti100 electrode array at peak and ambient pressure conditions are shown in Figure 4.3.1.



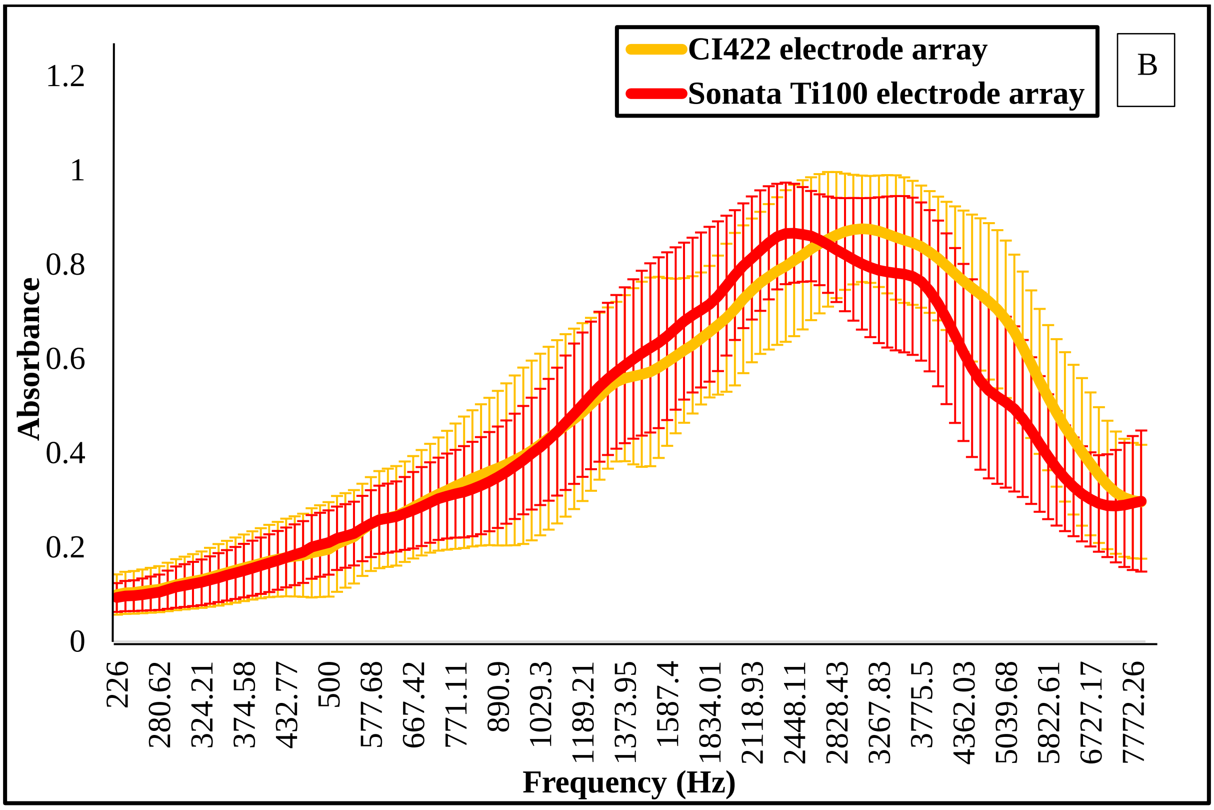




*Figure 4.3.1:* Mean and standard deviation of absorbance across frequencies at (A) peak pressure and (B) ambient pressure in group of children implanted with CI422 electrode array and Sonata Ti100 electrode array.

The comparison of absorbance between the two electrode types was done using Mann-Whitney *U* test. The results showed no significant difference in absorbance between the two electrode types at peak and ambient pressure ($p > 0.05$), except for a narrow range of frequencies at peak pressure ($p < 0.05$). The CI422 electrode array produced significantly lower absorbance values than the Sonata Ti100 electrode array in the frequency range of 2000-2244.92 Hz and at sporadic frequencies of 2378.4 Hz and 2519.84 Hz ($p < 0.05$) at peak pressure alone. The specific Z-values and *p*-values obtained from the Mann-Whitney *U* Test for peak and ambient pressure are shown in Table 4.3.1.

For the comparison of resonance frequency of middle ear between the two electrode types, the Mann-Whitney *U* Test was done. The results showed no significant difference in resonance frequency of middle ear between the two electrode types [Z = 0.082, p = 0.934].

**Table 4.3.1.**

*The outcome of Mann-Whitney U test for pair-wise comparison of absorbance at peak and ambient pressure between CI422 and Sonata Ti100 electrode arrays*

| Frequency (in Hz) | Peak pressure condition | | Ambient pressure condition | |
|---|---|---|---|---|
| | Z-value | *p*-value | Z-value | *p*-value |
| 226.00 | -0.45 | 0.650 | -0.25 | 0.805 |
| 250.00 | -0.16 | 0.869 | -0.25 | 0.805 |
| 257.33 | -0.08 | 0.934 | -0.21 | 0.837 |
| 264.87 | -0.08 | 0.934 | -0.16 | 0.869 |
| 272.63 | -0.08 | 0.934 | -0.16 | 0.869 |
| 280.62 | -0.12 | 0.902 | -0.16 | 0.869 |
| 288.84 | -0.12 | 0.902 | -0.08 | 0.934 |
| 297.30 | -0.12 | 0.902 | -0.04 | 0.967 |
| 306.12 | -0.12 | 0.902 | 0.00 | 1.000 |
| 314.98 | -0.04 | 0.967 | 0.00 | 1.000 |
| 324.21 | -0.12 | 0.902 | 0.00 | 1.000 |
| 333.71 | -0.08 | 0.934 | 0.00 | 1.000 |
| 343.49 | -0.12 | 0.901 | 0.00 | 1.000 |
| 353.55 | 0.00 | 1.000 | 0.00 | 1.000 |
| 363.91 | -0.08 | 0.934 | -0.04 | 0.967 |
| 374.58 | -0.08 | 0.934 | -0.08 | 0.934 |
| 385.55 | -0.08 | 0.934 | -0.17 | 0.869 |
| 396.95 | -0.08 | 0.934 | -0.16 | 0.869 |
| 408.48 | -0.08 | 0.934 | -0.25 | 0.805 |
| 420.45 | -0.08 | 0.934 | -0.25 | 0.805 |
| 432.77 | -0.21 | 0.837 | -0.25 | 0.805 |
| 445.45 | -0.16 | 0.869 | -0.41 | 0.680 |
| 458.50 | -0.25 | 0.805 | -0.41 | 0.680 |
| 471.94 | -0.08 | 0.934 | -0.41 | 0.680 |
| 485.77 | -0.08 | 0.934 | -0.41 | 0.680 |
| 500.00 | -0.16 | 0.869 | -0.33 | 0.741 |
| 514.65 | -0.08 | 0.934 | -0.25 | 0.805 |
| 529.73 | 0.00 | 1.000 | -0.16 | 0.869 |
| 545.25 | -0.08 | 0.934 | -0.16 | 0.869 |
| 561.23 | -0.25 | 0.805 | 0.00 | 1.000 |
| 577.68 | -0.33 | 0.741 | -0.08 | 0.934 |
| 594.60 | -0.17 | 0.869 | -0.08 | 0.934 |
| 612.03 | -0.08 | 0.934 | 0.00 | 1.000 |
| 629.96 | -0.08 | 0.934 | 0.00 | 1.000 |
| 648.42 | -0.17 | 0.869 | -0.17 | 0.869 |

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Table 4.3.1 continued from previous page

| Frequency (in Hz) | Peak pressure condition | | Ambient pressure condition | |
|---|---|---|---|---|
| | Z-value | *p*-value | Z-value | *p*-value |
| 667.42 | -0.25 | 0.805 | 0.00 | 1.000 |
| 686.98 | -0.16 | 0.869 | -0.17 | 0.869 |
| 707.11 | -0.08 | 0.934 | -0.25 | 0.805 |
| 727.83 | -0.21 | 0.837 | -0.25 | 0.805 |
| 749.15 | -0.16 | 0.869 | -0.12 | 0.901 |
| 771.11 | -0.21 | 0.837 | -0.08 | 0.934 |
| 793.70 | -0.16 | 0.869 | -0.21 | 0.837 |
| 816.96 | -0.08 | 0.934 | -0.25 | 0.804 |
| 840.90 | -0.21 | 0.837 | -0.25 | 0.805 |
| 865.54 | -0.49 | 0.621 | -0.17 | 0.869 |
| 890.90 | -0.62 | 0.536 | 0.00 | 1.000 |
| 917.00 | -0.74 | 0.458 | -0.04 | 0.967 |
| 943.87 | -0.66 | 0.509 | -0.08 | 0.934 |
| 971.53 | -0.66 | 0.509 | -0.08 | 0.934 |
| 1000.00 | -0.66 | 0.509 | -0.08 | 0.934 |
| 1029.30 | -0.74 | 0.458 | 0.00 | 1.000 |
| 1059.46 | -0.78 | 0.433 | -0.04 | 0.967 |
| 1090.51 | -0.82 | 0.409 | -0.08 | 0.934 |
| 1122.46 | -0.91 | 0.364 | 0.00 | 1.000 |
| 1155.35 | -0.82 | 0.409 | -0.08 | 0.934 |
| 1189.21 | -0.82 | 0.409 | -0.16 | 0.869 |
| 1224.05 | -0.91 | 0.364 | -0.16 | 0.869 |
| 1259.92 | -0.82 | 0.409 | -0.17 | 0.869 |
| 1296.84 | -0.91 | 0.364 | -0.21 | 0.837 |
| 1334.84 | -0.91 | 0.364 | -0.08 | 0.934 |
| 1373.95 | -0.99 | 0.322 | -0.08 | 0.934 |
| 1414.21 | -1.07 | 0.283 | -0.25 | 0.805 |
| 1455.65 | -1.07 | 0.284 | -0.29 | 0.773 |
| 1498.31 | -1.24 | 0.216 | -0.49 | 0.621 |
| 1542.21 | -1.53 | 0.127 | -0.49 | 0.621 |
| 1587.40 | -1.65 | 0.099 | -0.58 | 0.564 |
| 1633.92 | -1.65 | 0.099 | -0.66 | 0.509 |
| 1681.79 | -1.73 | 0.083 | -0.74 | 0.458 |
| 1731.07 | -1.77 | 0.076 | -0.82 | 0.409 |
| 1781.80 | -1.90 | 0.058 | -0.91 | 0.364 |
| 1834.01 | -1.81 | 0.070 | -0.82 | 0.409 |
| 1887.75 | -1.90 | 0.058 | -0.91 | 0.364 |
| 1943.06 | -1.90 | 0.058 | -0.95 | 0.343 |
| 2000.00 | -2.06 | 0.039 | -0.91 | 0.364 |

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Table 4.3.1 continued from previous page

| Frequency (in Hz) | Peak pressure condition | | Ambient pressure condition | |
|---|---|---|---|---|
| | Z-value | *p*-value | Z-value | *p*-value |
| 2058.60 | -2.06 | 0.039 | -0.82 | 0.409 |
| 2118.93 | -2.19 | 0.029 | -0.82 | 0.409 |
| 2181.02 | -2.23 | 0.026 | -0.82 | 0.409 |
| 2244.92 | -2.19 | 0.029 | -0.78 | 0.433 |
| 2310.71 | -1.90 | 0.058 | -0.99 | 0.322 |
| 2378.41 | -1.98 | 0.048 | -0.78 | 0.433 |
| 2448.11 | -1.86 | 0.063 | -0.74 | 0.458 |
| 2519.84 | -1.98 | 0.048 | -0.74 | 0.458 |
| 2593.68 | -1.40 | 0.161 | -0.08 | 0.934 |
| 2669.68 | -1.15 | 0.248 | -0.08 | 0.934 |
| 2747.91 | -0.41 | 0.680 | -0.54 | 0.592 |
| 2828.43 | -0.33 | 0.741 | -0.74 | 0.458 |
| 2911.31 | -0.25 | 0.805 | -0.82 | 0.409 |
| 2996.61 | 0.00 | 1.000 | -0.74 | 0.458 |
| 3084.42 | -0.08 | 0.934 | -0.82 | 0.409 |
| 3174.80 | -0.37 | 0.710 | -0.82 | 0.409 |
| 3267.83 | -0.49 | 0.621 | -0.66 | 0.509 |
| 3363.59 | -0.66 | 0.509 | -0.87 | 0.386 |
| 3462.15 | -0.74 | 0.458 | -0.91 | 0.364 |
| 3563.59 | -0.70 | 0.483 | -0.82 | 0.409 |
| 3668.02 | -0.82 | 0.409 | -0.78 | 0.433 |
| 3775.50 | -0.82 | 0.409 | -0.82 | 0.409 |
| 3886.13 | -0.91 | 0.364 | -0.91 | 0.364 |
| 4000.00 | -1.11 | 0.265 | -0.91 | 0.364 |
| 4117.21 | -1.32 | 0.187 | -1.24 | 0.216 |
| 4237.85 | -1.48 | 0.138 | -1.32 | 0.187 |
| 4362.03 | -1.65 | 0.099 | -1.40 | 0.161 |
| 4489.85 | -1.81 | 0.070 | -1.73 | 0.083 |
| 4621.41 | -1.81 | 0.070 | -1.90 | 0.058 |
| 4756.83 | -1.81 | 0.070 | -1.81 | 0.070 |
| 4896.21 | -1.81 | 0.070 | -1.81 | 0.070 |
| 5039.68 | -1.69 | 0.091 | -1.57 | 0.117 |
| 5187.36 | -1.61 | 0.108 | -1.61 | 0.108 |
| 5339.36 | -1.65 | 0.099 | -1.53 | 0.127 |
| 5495.81 | -1.57 | 0.117 | -1.48 | 0.138 |
| 5656.85 | -1.40 | 0.161 | -1.53 | 0.127 |
| 5822.61 | -1.40 | 0.161 | -1.65 | 0.099 |
| 5993.23 | -1.48 | 0.138 | -1.48 | 0.138 |
| 6168.84 | -1.65 | 0.099 | -1.57 | 0.117 |

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Table 4.3.1 continued from previous page

| Frequency (in Hz) | Peak pressure condition | | Ambient pressure condition | |
|---|---|---|---|---|
| | Z-value | *p*-value | Z-value | *p*-value |
| 6349.60 | -1.57 | 0.117 | -1.48 | 0.138 |
| 6535.66 | -1.32 | 0.187 | -1.28 | 0.201 |
| 6727.17 | -0.91 | 0.364 | -0.91 | 0.364 |
| 6924.29 | -0.70 | 0.483 | -0.74 | 0.458 |
| 7127.19 | -0.29 | 0.773 | -0.45 | 0.650 |
| 7336.03 | -0.08 | 0.934 | -0.12 | 0.901 |
| 7550.99 | -0.25 | 0.805 | -0.25 | 0.804 |
| 7772.26 | -0.33 | 0.741 | -0.25 | 0.805 |
| 8000.00 | -0.33 | 0.741 | -0.25 | 0.805 |

In addition to the group-wise comparison, the individual data were also analyzed to obtain the proportion of ears with an abnormal absorbance at different frequencies. Figure 4.3.2 and Figure 4.3.3 show the abnormal absorbance at various frequencies in each individual with CI422 electrode and Sonata Ti100 electrode at peak and ambient pressure, respectively. Figure 4.3.4 and Figure 4.3.5 show the individual absorbance curves across frequencies when compared against the mean absorbance curve and standard deviation of the NH group at peak and ambient pressure conditions, respectively.

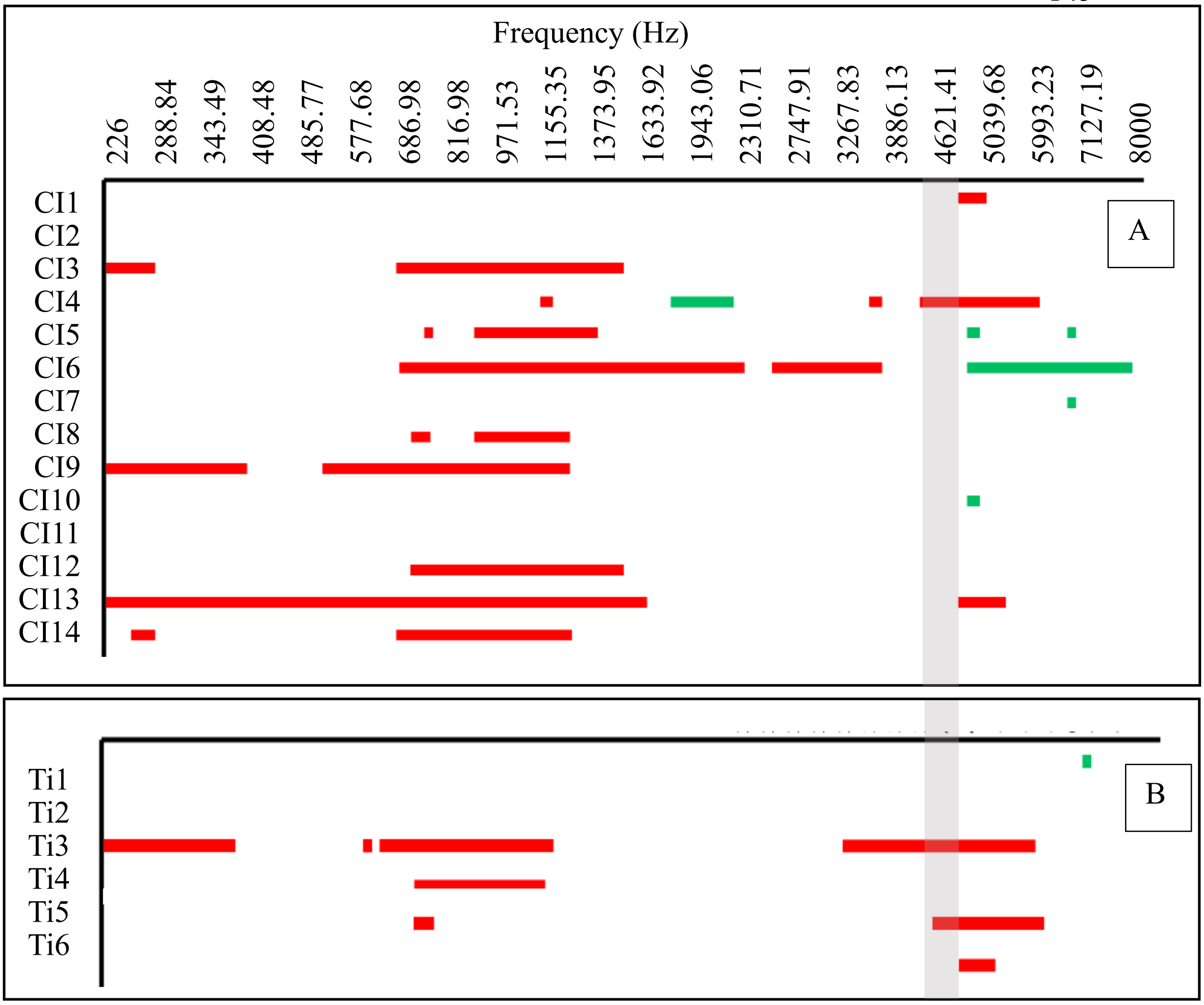


*Figure 4.3.2:* Abnormal absorbance across frequencies at peak pressure in (A) ears with CI422 electrodes and (B) ears with Sonata Ti100. The digits on the Y-axis represent participant number and prefix of 'CI' and 'Ti' indicates ears with CI422 and Sonata Ti100 electrodes, respectively. The red-colour lines represent significantly lower absorbance and green-colour lines indicate significantly higher absorbance. The grey shaded regions indicate statistically significant difference in proportions of abnormal results.

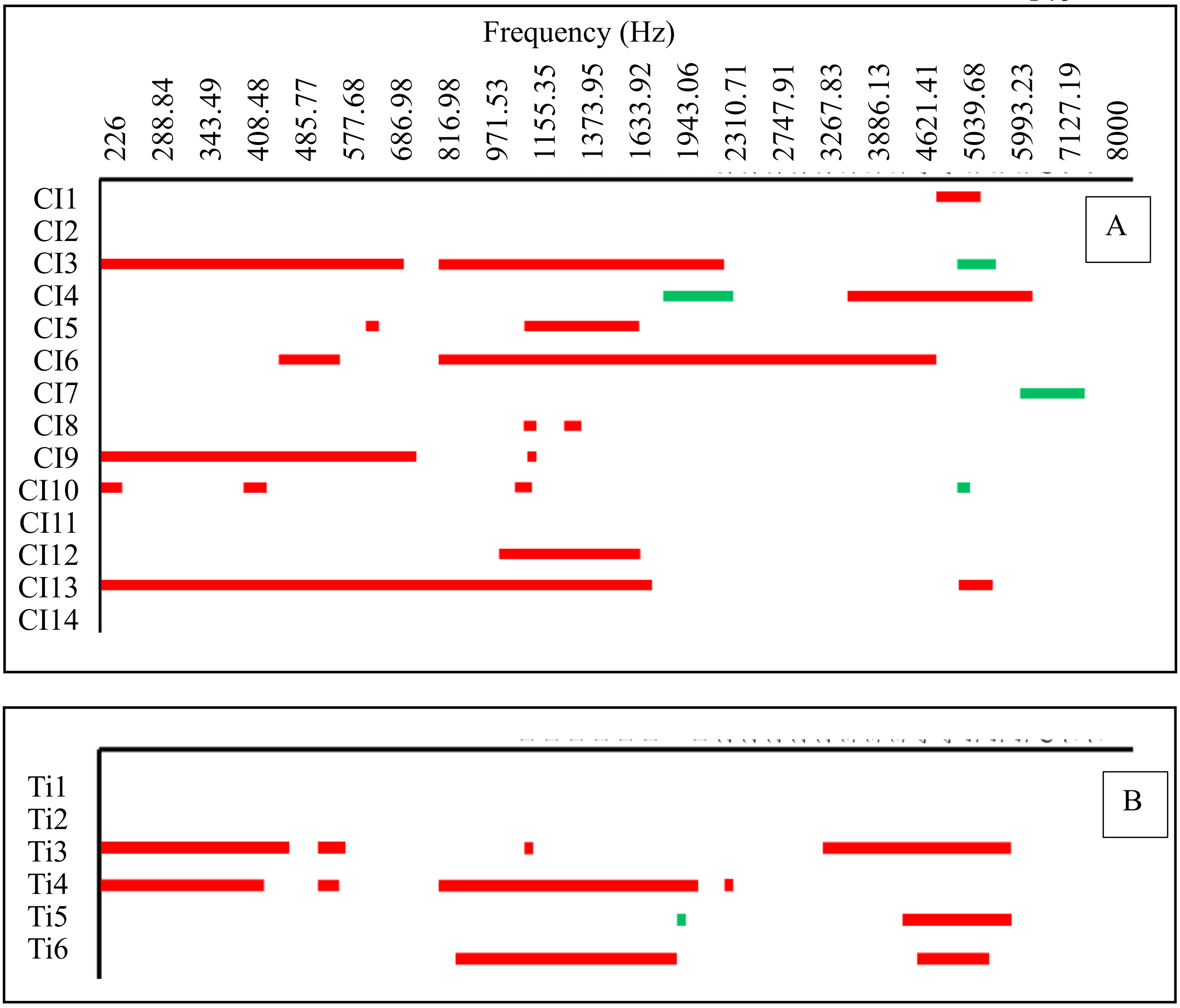


*Figure 4.3.3:* Abnormal absorbance across frequencies in the ambient pressure in (A) ears with CI422 electrodes and (B) ears with Sonata Ti100. The digits on the y-axis represent participant number and prefix of 'CI' and 'Ti' indicates ears with CI422 and Sonata Ti100 electrodes, respectively. The red-colour lines represent significantly lower absorbance and green-colour lines indicate significantly higher absorbance. The grey shaded regions indicate statistically significant difference in proportions of abnormal results.

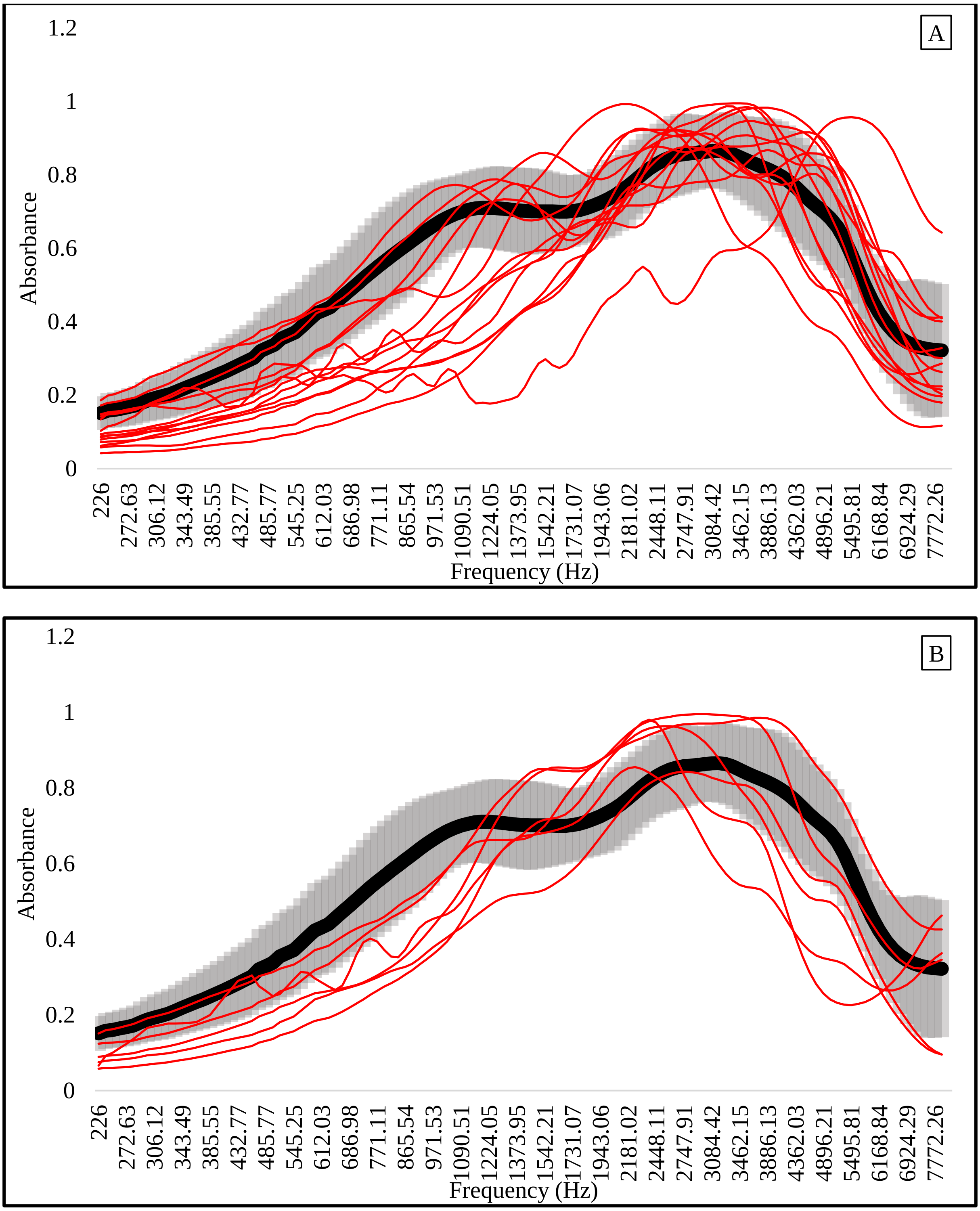


*Figure 4.3.4:* Absorbance curves at peak pressure in (A) ears with CI422 electrodes, and (B) ears with Sonata Ti100 electrodes. The thin red lines represent absorbance curve of each participant in his/her respective group. In each panel, the thick black line represents the mean absorbance and the gray shaded region covers 2 standard deviations of absorbance found in the ears of the NH group (normative data).

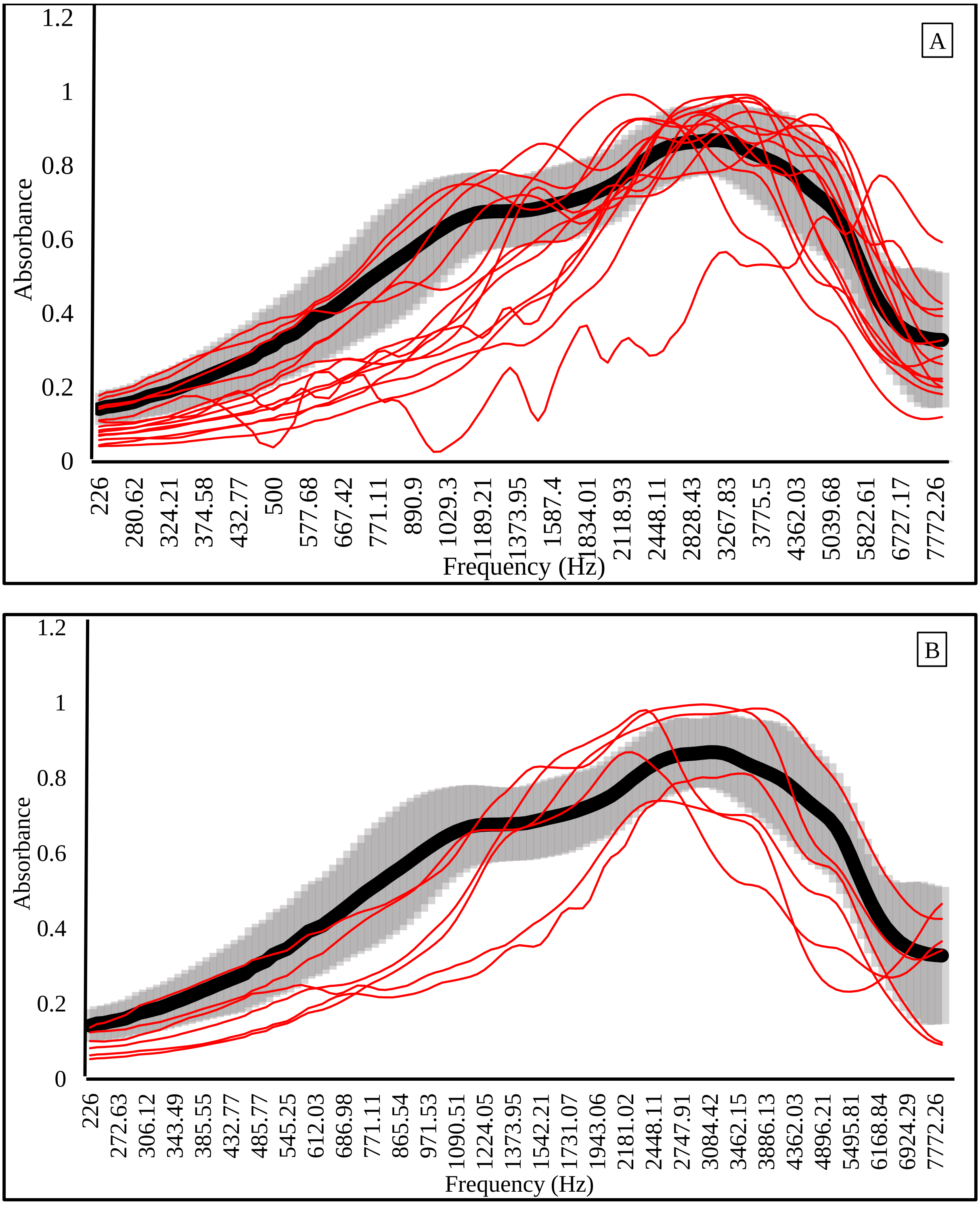


*Figure 4.3.5:* Absorbance curves at ambient pressure in (A) ears with CI422 electrodes, and (B) ears with Sonata Ti100 electrodes. The thin red lines represent absorbance curve of each participant in his/her respective group. In each panel, the thick black line represents the mean absorbance and the gray shaded region covers 2 standard deviations of absorbance found in the ears of the NH group (normative data).

At peak pressure and ambient pressure, the proportion of individuals with an abnormal absorbance was compared between the two electrode types using the Equality of test for proportions. The results showed a significant difference in proportion of abnormal absorbance at peak pressure for 4362.03 Hz and 4489.85 Hz frequencies ($p < 0.05$). In case of ambient pressure, there was no significant difference in proportion of ears with abnormal absorbance. The specific Z-values and *p*-values for the comparisons are shown in Table 4.3.2.

**Table 4.3.2.**

*The results of Equality of test for proportions for comparison of the proportion of ears with abnormal absorbance across frequencies between CI422 and Sonata Ti100 electrodes at peak and ambient pressure*

| Frequency (in Hz) | Peak pressure condition | | Ambient pressure condition | |
|---|---|---|---|---|
| | Z-value | *p*-value | Z-value | *p*-value |
| 226.00 | 0.24 | 0.807 | 0.21 | 0.831 |
| 250.00 | 0.24 | 0.807 | 0.21 | 0.831 |
| 257.33 | 0.56 | 0.573 | 0.56 | 0.573 |
| 264.87 | 0.56 | 0.573 | 0.56 | 0.573 |
| 272.63 | 0.56 | 0.573 | 0.56 | 0.573 |
| 280.62 | 0.24 | 0.807 | 0.56 | 0.573 |
| 288.84 | 0.13 | 0.891 | 0.56 | 0.573 |
| 297.30 | 0.13 | 0.891 | 0.56 | 0.573 |
| 306.12 | 0.13 | 0.891 | 0.56 | 0.573 |
| 314.98 | 0.13 | 0.891 | 0.56 | 0.573 |
| 324.21 | 0.13 | 0.891 | 0.56 | 0.573 |
| 333.71 | 0.13 | 0.891 | 0.56 | 0.573 |
| 343.49 | 0.13 | 0.891 | 0.56 | 0.573 |
| 353.55 | 0.13 | 0.891 | 0.56 | 0.573 |
| 363.91 | 0.13 | 0.891 | 0.56 | 0.573 |
| 374.58 | 0.13 | 0.891 | 0.56 | 0.573 |
| 385.55 | 0.97 | 0.329 | 0.56 | 0.573 |
| 396.95 | 0.67 | 0.501 | 0.21 | 0.831 |
| 408.48 | 0.67 | 0.501 | 0.21 | 0.831 |
| 420.45 | 0.67 | 0.501 | 0.21 | 0.831 |
| 432.77 | 0.67 | 0.501 | 0.24 | 0.807 |
| 445.45 | 0.67 | 0.501 | 0.56 | 0.573 |
| 458.50 | 0.67 | 0.501 | 0.56 | 0.573 |
| 471.94 | 0.67 | 0.501 | 1.46 | 0.143 |
| 485.77 | 0.67 | 0.501 | 1.46 | 0.143 |
| 500.00 | 0.97 | 0.329 | 0.56 | 0.573 |
| 514.65 | 0.97 | 0.329 | 0.21 | 0.831 |
| 529.73 | 0.97 | 0.329 | 0.21 | 0.831 |
| 545.25 | 0.97 | 0.329 | 0.21 | 0.831 |
| 561.23 | 0.97 | 0.329 | 0.24 | 0.807 |
| 577.68 | 0.13 | 0.891 | 1.22 | 0.218 |
| 594.60 | 0.97 | 0.329 | 1.46 | 0.143 |
| 612.03 | 0.13 | 0.891 | 1.46 | 0.143 |
| 629.96 | 0.13 | 0.891 | 1.46 | 0.143 |
| 648.42 | 0.56 | 0.573 | 1.22 | 0.218 |
| 667.42 | 0.85 | 0.394 | 1.22 | 0.218 |
| 686.98 | 0.29 | 0.768 | 1.22 | 0.218 |

Table continued on next page

Table 4.3.2 continued from previous page

| Frequency (in Hz) | Peak pressure condition | | Ambient pressure condition | |
|---|---|---|---|---|
| | Z-value | *p*-value | Z-value | *p*-value |
| 707.11 | 0.29 | 0.768 | 0.97 | 0.329 |
| 727.83 | 0.59 | 0.550 | 0.97 | 0.329 |
| 749.15 | 0.29 | 0.768 | 0.67 | 0.501 |
| 771.11 | 0.00 | 1.000 | 1.22 | 0.218 |
| 793.70 | 0.39 | 0.690 | 0.24 | 0.804 |
| 816.96 | 0.39 | 0.690 | 0.56 | 0.573 |
| 840.90 | 0.39 | 0.690 | 0.56 | 0.573 |
| 865.54 | 0.97 | 0.329 | 0.56 | 0.573 |
| 890.90 | 0.97 | 0.329 | 0.56 | 0.573 |
| 917.00 | 0.97 | 0.329 | 0.56 | 0.573 |
| 943.87 | 0.97 | 0.329 | 0.56 | 0.573 |
| 971.53 | 0.97 | 0.329 | 0.21 | 0.831 |
| 1000.00 | 0.97 | 0.329 | 0.10 | 0.918 |
| 1029.30 | 0.97 | 0.329 | 0.10 | 0.918 |
| 1059.46 | 0.97 | 0.329 | 0.29 | 0.768 |
| 1090.51 | 1.27 | 0.202 | 0.97 | 0.329 |
| 1122.46 | 1.27 | 0.202 | 0.39 | 0.690 |
| 1155.35 | 1.66 | 0.095 | 0.39 | 0.690 |
| 1189.21 | 1.66 | 0.095 | 0.39 | 0.690 |
| 1224.05 | 1.69 | 0.091 | 0.39 | 0.690 |
| 1259.92 | 1.69 | 0.091 | 0.39 | 0.690 |
| 1296.84 | 1.69 | 0.091 | 0.10 | 0.918 |
| 1334.84 | 1.46 | 0.143 | 0.10 | 0.918 |
| 1373.95 | 1.46 | 0.143 | 0.10 | 0.918 |
| 1414.21 | 1.46 | 0.143 | 0.10 | 0.918 |
| 1455.65 | 1.22 | 0.218 | 0.10 | 0.918 |
| 1498.31 | 0.97 | 0.329 | 0.10 | 0.918 |
| 1542.21 | 0.97 | 0.329 | 0.10 | 0.918 |
| 1587.40 | 0.97 | 0.329 | 0.10 | 0.918 |
| 1633.92 | 0.67 | 0.501 | 0.56 | 0.573 |
| 1681.79 | 0.67 | 0.501 | 0.97 | 0.329 |
| 1731.07 | 0.97 | 0.329 | 0.56 | 0.573 |
| 1781.80 | 0.97 | 0.329 | 1.27 | 0.201 |
| 1834.01 | 0.97 | 0.329 | 0.24 | 0.807 |
| 1887.75 | 0.97 | 0.329 | 0.24 | 0.807 |
| 1943.06 | 0.97 | 0.329 | 0.24 | 0.807 |
| 2000.00 | 0.97 | 0.329 | 1.22 | 0.218 |
| 2058.60 | 0.97 | 0.329 | 1.22 | 0.218 |
| 2118.93 | 0.67 | 0.501 | 0.24 | 0.807 |
| 2181.02 | 0.67 | 0.501 | 0.97 | 0.329 |
| 2244.92 | # | # | 0.67 | 0.501 |
| 2310.71 | # | # | 0.67 | 0.501 |
| 2378.41 | 0.67 | 0.501 | 0.67 | 0.501 |

Table continued on next page

Table 4.3.2 continued from previous page

| Frequency (in Hz) | Peak pressure condition | | Ambient pressure condition | |
|---|---|---|---|---|
| | Z-value | *p*-value | Z-value | *p*-value |
| 2448.11 | 0.67 | 0.501 | 0.67 | 0.501 |
| 2519.84 | 0.67 | 0.501 | 0.67 | 0.501 |
| 2593.68 | 0.67 | 0.501 | 0.67 | 0.501 |
| 2669.68 | 0.67 | 0.501 | 0.67 | 0.501 |
| 2747.91 | 0.67 | 0.501 | 0.67 | 0.501 |
| 2828.43 | 0.67 | 0.501 | 0.67 | 0.501 |
| 2911.31 | 0.67 | 0.501 | 0.67 | 0.501 |
| 2996.61 | 0.65 | 0.515 | 0.65 | 0.515 |
| 3084.42 | 0.65 | 0.515 | 0.65 | 0.515 |
| 3174.80 | 0.65 | 0.515 | 0.65 | 0.515 |
| 3267.83 | 0.65 | 0.515 | 0.13 | 0.891 |
| 3363.59 | 0.13 | 0.891 | 0.13 | 0.891 |
| 3462.15 | 0.13 | 0.891 | 0.13 | 0.891 |
| 3563.59 | 0.13 | 0.891 | 0.13 | 0.891 |
| 3668.02 | 1.56 | 0.117 | 0.13 | 0.891 |
| 3775.50 | 1.56 | 0.117 | 0.13 | 0.891 |
| 3886.13 | 1.56 | 0.117 | 0.97 | 0.329 |
| 4000.00 | 0.65 | 0.515 | 0.97 | 0.329 |
| 4117.21 | 1.50 | 0.132 | 1.69 | 0.091 |
| 4237.85 | 1.50 | 0.132 | 1.69 | 0.091 |
| 4362.03 | 2.19 | 0.028 | 1.27 | 0.201 |
| 4489.85 | 2.19 | 0.028 | 1.69 | 0.091 |
| 4621.41 | 1.27 | 0.201 | 1.69 | 0.091 |
| 4756.83 | 0.29 | 0.768 | 0.59 | 0.550 |
| 4896.21 | 0.29 | 0.768 | 0.59 | 0.550 |
| 5039.68 | 0.92 | 0.350 | 0.59 | 0.550 |
| 5187.36 | 0.21 | 0.831 | 0.92 | 0.357 |
| 5339.36 | 0.56 | 0.573 | 1.27 | 0.201 |
| 5495.81 | 0.56 | 0.573 | 0.97 | 0.329 |
| 5656.85 | 0.97 | 0.329 | 1.50 | 0.132 |
| 5822.61 | 0.97 | 0.329 | 0.65 | 0.515 |
| 5993.23 | 0.13 | 0.891 | 0.97 | 0.329 |
| 6168.84 | 0.97 | 0.329 | 0.97 | 0.329 |
| 6349.60 | 0.67 | 0.501 | 0.67 | 0.501 |
| 6535.66 | 0.67 | 0.501 | 0.67 | 0.501 |
| 6727.17 | 0.67 | 0.501 | 0.67 | 0.501 |
| 6924.29 | 0.24 | 0.807 | 0.67 | 0.501 |
| 7127.19 | 0.67 | 0.501 | 0.67 | 0.501 |
| 7336.03 | 0.67 | 0.501 | 0.67 | 0.501 |
| 7550.99 | 0.67 | 0.501 | 0.67 | 0.501 |
| 7772.26 | 0.67 | 0.501 | # | # |
| 8000.00 | 0.67 | 0.501 | # | # |

*Note*. '#'- equality of test for proportions could not be performed due no success in either of the group

# Chapter V

# Discussion

The present study aimed to compare the findings of WBT at peak and ambient pressure in normal-hearing children and those with sensorineural hearing loss with or without CI. Additionally, the present study also aimed to compare the findings of WBT between the implant and non-implant ears of children with a unilateral cochlear implant. A final aim of the present study was to compare the WBT findings between the electrode types. To fulfill these aims, WBT was performed on 60 children, of which 40 children had congenital hearing impairment of sensorineural type, and 20 had normal hearing. Among the 40 children with sensorineural hearing loss, 20 received unilateral CI, whereas the remaining 20 were bilateral hearing aid users. The absorbance at peak and ambient pressure conditions were compared within and between the groups. Further, the resonance frequency values were also compared within and between the groups.

## 5.1 Comparison of WBA between the CI group and SNHL group

CI ears of the CI group and the CI-matched ears of the SNHL group were compared to investigate the effect of cochlear implantation on the wide-band absorbance. At peak pressure, the CI ears showed significantly lower absorbance at low frequencies below 750 Hz and significantly higher absorbance in the frequency range of about 1800-3600 Hz in comparison to the SNHL ears. In ambient pressure condition, the differences between the two groups of ears followed a similar pattern, although in a slightly narrower range of frequencies than the peak pressure condition. There are no studies of direct comparison between CI group and SNHL group. However, a few studies have compared, the pre-implant WBT to post-implant WBT. Since, implantation is done mostly in cases of sensorineural hearing loss, it may not be completely out of place to equate the pre-implant middle ear status to the middle ear status in an independent SNHL group. Using this consideration, the findings of the present the study are similar to some of the studies reported previously (Saoji et al., 2020; Racca et al., 2022). Saoji et al. (2020) compared the wide-band absorbance before and after implantation in 5 unilateral CI recipients and reported significantly reduced absorbance in the frequency range of 600-1100 Hz. While they did not report about the increased absorbance in the mid-frequency to high-frequency region, the increased absorbance in the mid-to-high frequencies could be visualized in 3 out of the 5 CI ears in the individual data provided in their study. Therefore, the findings of the present study are similar to their findings. The findings of the present study almost completely mirrored those of by Racca et al. (2022).

The findings of the present study show dissonance with those of Saki et al. (2022) who reported significantly reduced post-implantation absorbance in the frequency range 1260-3175 Hz and also 5040-8000 Hz with no change in the low frequency range. The different age group of the participants in the two studies could be one of the reasons of this dissonance. Saki et al. (2022) performed WBT on infants younger than 24 months of age, whereas the individuals in the current study had mean age of 5.2 years (age range 3 - 6 years). Given that maturational changes are seen in WBT findings from birth to 12 years of age (Aithal et al., 2017; Hunter et al., 2016), the age disparities between the two investigations may have led to the contradictory findings. Since the middle ear characteristics of children <24 months could be quite different from those in the 3-6 years age bracket, the way implantation could affect the characteristics of middle ear may be different. This might explain the differences of the present study’s findings from those of Saki et al. (2022).

The observed changes in absorbance following cochlear implantation raise important questions regarding the underlying mechanisms. It has been reported that after CI surgery, the middle characteristics are affected. However, it is not apparent whether, how, or to what extent CI surgery affects the sound conduction process.

The changes in absorbance after cochlear implant surgery can be influenced by various factors related to the surgery itself, and the interaction between the cochlear implant and the middle ear structures (Attias et al., 2022; Racca et al., 2022). These changes in the absorbance could be as result of factors originating from middle ear and inner ear. The probable CI surgery related factors affecting the middle ear could be (1) increased stiffness, (2) bone dust accumulation, (3) pressure changes, (4) eustachian tube function, (5) tympanic membrane mechanics, and (6) electrical stimulation.

The stiffness of middle ear may be impacted by each step of the CI procedure, such as mastoidectomy and posterior tympanotomy, as well as by post-operative conditions including fibrosis (Attias et al., 2022). Another factor reported by Wasson et al. (2018) suggested that the bone dust created during mastoid drilling may enhance ossicular mass which could be additional cause for the changes in middle ear properties after CI.

Also, cochlear implantation surgery could induce transient pressure changes within the middle ear cavity (Hartl et al., 2018). These pressure fluctuations might affect the middle ear's acoustic properties and consequently impact absorbance. Other than these factors, cochlear implantation surgery might influence Eustachian tube function and middle ear pressure regulation. These changes in pressure dynamics could affect the middle ear's compliance and contribute to absorbance alterations.

These long-term changes might contribute to gradual alterations in absorbance. Furthermore, due to surgery there could be changes in tympanic membrane properties. The presence of a cochlear implant could influence the movement and vibration of the tympanic membrane (Chan et al., 2005). This change in tympanic membrane function could impact the transfer of sound energy into the middle ear, leading to changes in absorbance.

Additionally, the cochlear implant mechanism of working includes electrical stimulation, which further generates neural impulses. This electrical stimulation delivered by the cochlear implant directly activates auditory nerve fibers within the cochlea that could induce neural responses that affect the mechanical properties of the middle ear structures by way of altering the stapedial reflex and the tensor tympani reflex (Rattay, 1999). After cochlear implant surgery, the auditory system undergoes a period of adaptation to the new sensory input provided by the implant. This adaptation could lead to changes in the neural processing of auditory information, potentially influencing the mechanical responses of the middle ear (Glennon et al., 2020). The interplay of various factors mentioned above makes this an intricate and multifaceted phenomenon that requires further investigation for a complete understanding.

There are also factors related to the inner ear that might affect the absorbance after a CI surgery. These effects include (1) cochleostomy, (2) electrode insertion, (3) changes in fluid dynamics, (4) scar tissue formation, and (5) fibrosis. First, cochleostomy could act as a third window and have an impact on absorption and stiffness (Attias et al., 2022). The third window effect due to this cochleostomy may have caused higher absorbance in the mid-to-high frequencies in the present study. The introduction of the facial recess, the cochlear implant electrode array, the positioning and sealing of the electrode at the round window or cochleostomy, are some additional potential factors that could affect ossicular chain mobility as a result of implantation.

Another probable reason for changes in absorbance after cochlear implant surgery might be the electrode insertion effects. The surgical procedure for cochlear implantation involves the insertion of an electrode array into the cochlea. This insertion might mechanically impact the delicate structures of the middle ear, leading to alterations in the compliance and impedance of the middle ear system. Also, the alterations to the middle ear mechanics by the presence of the cochlear implant electrode array within the cochlea can potentially affect the transmission of sound waves through the cochlea and middle ear structures. This altered transmission might result in changes in the resonant frequencies, stiffness, and damping characteristics of the middle ear. The presence of electrodes in the inner ear might have potentials effects on increasing the inner ear stiffness, similar to otosclerotic ears, in which condition the low frequency absorbance is also reported to be reduced (Shahnaz et al., 2009). Also, the presence of a cochlear implant electrode array might influence the fluid dynamics within the cochlea, affecting the movement of perilymph and endolymph (Andersen et al., 2012). Changes in fluid dynamics can indirectly impact the mechanical properties of the middle ear system.

Scar tissue formation around the electrode array or within the middle ear could introduce changes in tissue compliance and stiffness, leading to alterations in absorbance characteristics (Choi & Oghalai et al., 2005). Other effects could include the development of fibrous tissue after surgery, which could limit basal intrascalar fluid circulation and increased impedance at the oval window, indirectly increasing ossicular chain stiffness and lowering middle ear absorption (Saoji et al., 2020).

The duration after cochlear implant surgery could have a significant impact on absorbance at different time points. The healing and adaptation processes that occur in the post-operative period can influence how the middle ear absorbance characteristics change over time. Immediate post-operative effects, healing processes, electrode-related interactions, and long-term adaptation of the auditory system all play roles in shaping the absorbance patterns at different stages after surgery.

In a study by Racca et al. (2022), the absorbance change in CI ears and non-CI ears at various time points were investigated. They reported dramatic change in absorbance up until three or six months after surgery, at which point it stabilised. With this study, it is clear that post-implantation time is a crucial aspect to take into account. In order to find whether or not post-implantation duration may have played a role in the present study, we divided the CI group by implant age with two different boundaries separating the sub-groups (1) at 3 months (2) at 6 months. The results revealed no significant difference in absorbance in CI ears of children with implant age less than or more than 3 or 6 months for the data of present study. This analysis explains why the study's findings were unaffected by variations in implant ages and proves that the differences in implant age was not the reason behind the findings of the present study. Further research is needed to comprehensively understand the intricate relationship between post-operative duration and absorbance changes.

The comparison of the non-CI ears of the CI group with the non-CI matched ears of the SNHL group showed significantly lower absorbance in a narrow frequency range 2828.43-3084.42 Hz at peak pressure in the non-CI ears of the CI group than the CI-matched ears of the SNHL group, similar to previous studies (Saoji et al., 2020). However, contrary to the findings of present study, Saki et al. (2022) reported no significant difference in the non-CI ears after unilateral CI surgery. Again, the age variations between the included participants in the two studies could be the cause of this discrepancy. For ambient pressure conditions, there was no significant difference between the non-CI ears of CI group and CI-matched ears of the SNHL group, unlike in the study by Racca et al. (2022) the authors reported significant changes in the non-CI ears till one month of implantation after which there were no further changes. The present study included most of the participants of more than 1 month of implant age, and hence, probably the differences in the present study from Racca et al. (2022).

The change in the non-CI ears of the CI group could have occurred due to the hard bone drilling during surgery, as the whole skulls vibrates. Cochlear implant involves extreme drilling of the mastoid on one side in a unilateral CI case. However, the effects could be equitable on the contralateral side due to equal energy transfer from one side mastoid to the other side mastoid caused by virtually no interaural attenuation between them (Studebaker 1967; Silman & Silverman 1991). This might have an effect on the bone in the contralateral ear. Similar results were shown for other surgeries involving unilateral mastoidectomy (Latheef et al., 2018).

### 5.1.2 Comparison of WBA at peak and ambient pressure condition between the CI group and NH group

CI ears of the CI group and CI-matched ears of NH were compared to investigate the effect of surgery on the findings of WBT. The CI ears of the cochlear implant group showed significantly lower absorbance values compared to the CI-matched ears of the NH group at low frequencies from 226 Hz to 1259.92 Hz at peak pressure. At ambient pressure, CI ears of the CI group showed significantly lower absorbance than the CI-matched ears of the NH group in the frequency range of 226 Hz to 1296.84 Hz. The previous studies in this regard also reported a reduction in the low frequency absorbance in the implant ear (Merchant et al., 2020; Scheperle & Hajicek, 2021). However, these studies also reported higher absorbance in the CI ear than normal hearing ears in the region around 2000 Hz, which is contrary to the finding of no significant difference in this region in the present study. This could be due to the differences in the age groups of the individuals included between the studies. While the participants in the present study were children, those in the published studies were adults (Merchant et al., 2020; Scheperle & Hajicek, 2021; Attias et al., 2022). There might be a different age and CI effect interaction in the two age groups, leading to the difference in findings in the 2000 Hz region between the studies.

There are two major possible reasons behind the differences in absorbance between the cochlear implanted ears and normal hearing ears- (1) a congenital sensorineural hearing loss, (2) the surgery. A study have shown differences in absorbance in ears with normal hearing and those with sensorineural hearing loss, possibly caused by the changes in SNHL ears associated with causative factors of SNHL (Attias et al., 2022). An ear that undergoes CI surgery is in most likelihood an ear with sensorineural hearing loss. Therefore, the anatomical differences and thereby the physiological changes could explain the differences in absorbance between the ears of the two groups. Additionally, these differences could be accentuated by further anatomical changes due to surgery. These include bone dust from drilling (Wasson et al., 2018), cochleostomy effects (Attias et al., 2022), and fibrous tissue development (Saoji et al., 2020). Pressure fluctuations (Hartl et al., 2018) and scar tissue formation (Choi & Oghalai el al., 2005) could also play roles. Electrode insertion might affect middle ear compliance, impedance, and fluid dynamics (Shahnaz et al., 2009; Pazen et al., 2017). Eustachian tube function and long-term tissue remodeling may also contribute, along with the changes in tympanic membrane properties (Chan et al., 2005). Furthermore, electrical stimulation by the implant could also affect neural responses and auditory system adaptation (Andersen et al., 2012; Glennon et al., 2020; Rattay, 1999). All these taken together can explain of the difference in absorbance between the CI ears and the NH ears in the present study.

Studies comparing normal hearing individuals to individuals with sensorineural hearing loss have shown lower absorbance in the sensorineural hearing loss individuals in the mid-to-high frequency region (Attias et al., 2022), probably due to higher resistance in these frequencies in individuals with sensorineural hearing loss. The cochleostomy may have resulted in reduction of this resistance allowing the mid-to-high frequency absorbance values to return to the levels found in the normal hearing children. Therefore, the third window effect due to cochleostomy may have caused revival of absorbance characteristics in the mid-to-high frequencies. In addition, the other factors such as insertion of the cochlear implant electrode array, fibrotic changes after CI surgery, and accumulation of bone dust may have caused the low-to-mid frequency absorbance reduction.

Comparison between the non-CI ears of the CI group and non-CI-matched ears of the NH group were also made at peak and ambient pressure condition, which revealed no significant difference in absorbance at peak as well as at ambient pressure condition. Lower absorbance for the contralateral non-implanted ear of a CI recipient when compared to normal hearing ears at 4000 Hz and 5000 Hz has been reported (Attias et al., 2022). Although our study does show a difference in this frequency region, it could not reach the statistical significance. Since the differences between the studies are within the high frequency region, it could again be due to the age group differences between the studies, as described above.

### 5.1.3 Comparison of WBA at peak and ambient pressure condition between the SNHL group and NH group

CI-matched ears of the SNHL group and CI-matched ears of NH group were compared to investigate the effect of sensorineural hearing loss on the findings of WBT. The CI-matched ears of the SNHL group showed significantly lower absorbance values compared to the CI-matched ears of the NH group in mid-to-high frequencies from 1000 Hz to 3563.59 Hz at peak pressure. At ambient pressure, CI-matched-ears of the SNHL group showed significantly lower absorbance than the CI-matched ears of the NH group in the frequency range of 1122.46-1224.05 Hz and 1334.84-3563.59 Hz. Therefore, with an exception for a few sporadic frequencies, there was a significant group difference between NH and SNHL group in the mid-to-high frequency region of about 1000 Hz to 3500 Hz in peak as well as ambient pressure measurements.

Comparison between the non-CI ears of the SNHL group and non-CI-matched ears of the NH group were also made at peak and ambient pressure condition. It revealed no significant difference in absorbance values at peak as well as at ambient pressure. Although the frequency range of 1000-3563.59 Hz had lower mean absorbance values in the non-CI-matched ears of SNHL group than the non-CI-matched ears of the NH group, the reduction was not significant at peak and ambient pressure. Therefore, the ears with SNHL had lower absorbance in the mid-to-high frequency region than the NH ears. This is in line with reports relating this reduction in absorbance at mid-to-high frequencies (Attias et al., 2022). Sensorineural hearing loss (SNHL) involves structural and mechanical alterations in the Organ of Corti, such as the loss of cochlear neurons and sensory cells, as well as fibrosis, particularly in the stria vascularis (Linthicum et al., 2013; Bommakanti et al., 2019; Zhang et al., 2020). It might result from an abnormal or missing tectorial membrane due to sensorineural hearing loss (Ishai et al., 2019). An additional contribution to the findings could be from the changes induced by a prolonged use of hearing aids at high gain settings. Large mechanical vibrations to the cochlear partition could have induced changes to its mechanical properties there by leading to differences in absorbance.

### 5.2 Comparison of WBA between implanted and non-implanted ears of the CI group

CI ears and non-CI ears of the CI group were compared to investigate the effect of surgery on the middle ear. The CI ears showed significantly lower absorbance values compared to the non-CI ears of the CI group in low-to-mid frequencies. The findings of the present study are similar to those of Attias et al. (2022). In a study by Orhan et al. (2020), the authors compared the effect of cochlear implantation by comparing implanted and non-implanted ears of the same individual and reported statistically reduced average absorbance ratio for implanted ears at all measured frequencies from 226 Hz to 8000 Hz.

The post-implantation differences between the ears of unilateral CI cases could be due to multiple factors that influence middle ear absorbance. These encompass surgical procedures and interactions (Attias et al., 2022; Racca et al., 2022), the accumulation of bone dust during drilling (Wasson et al., 2018), cochleostomy impacts (Attias et al., 2022), and the development of fibrous tissue (Saoji et al., 2020). Additionally, fluctuations in pressure within the middle ear (Hartl et al., 2023) and the formation of scar tissue (Choi & Oghalai el al., 2005) could contribute. The insertion of electrodes could alter middle ear compliance and impedance (Shahnaz et al., 2009; Pazen et al., 2017). Eustachian tube function and gradual tissue remodeling could also play important roles, alongside changes in tympanic membrane properties (Chan et al., 2005). Moreover, the cochlear implant's electrical stimulation triggers neural responses, possibly impacting middle ear mechanics via stapedial and tensor tympani reflexes (Rattay, 1999).

**5.3 Comparison of WBA between the two electrode types**

The results of the present study revealed no significant difference in the WBT findings between the two different electrode types, although a narrow range of frequencies around 2000 Hz showed a significantly lower absorbance for the CI422 electrode array than the Sonata Ti100 electrode array. There are no previous studies on differential effects of different electrode types. The present study had participants with only two electrode types, and there was no significant difference in absorbance between them. While the results of the present study appeared to show no effect of electrode types, it would be pre-mature to conclude the same. This is because there are several electrode types, some of which are standard, short or extra-long. Therefore, it is pertinent to expect differential amount of fluid displacement within the cochlea because of different electrode dimensions. Therefore, further studies are needed to ascertain the differences in absorbance due to different electrode types.

**5.4 Comparison of resonance frequency**

The comparison of resonance frequency among the groups showed no significant difference. The comparison of resonance frequency between the two ears of CI group also showed no significant difference. Even the comparison between the two electrode types showed no significant difference. These findings on resonance frequency are unlike those reported in the previous study by Orhan et al. (2020). They reported increased resonance frequency of middle ear in implanted ears than non-implanted ears. Therefore, there is a dissonance in the findings of resonance frequency between the studies. However, since there is only one previous study, more studies are needed to fully understand the effect of cochlear implantation on the resonance of middle ear. As of the findings of the present study, the no difference in resonance frequency despite differences in absorbance properties suggest micro changes that are possibly not large enough to alter the resonance frequency significantly.

# Chapter VI

## Summary And Conclusion

WBT is an innovative method for assessing middle ear function, offering a comprehensive view of the ear's characteristics. It simultaneously measures multiple tympanograms at various probe tone frequencies, providing insights beyond the traditional single-frequency assessments. WBT can extract absorbance data, resonance frequency, and wideband averaged tympanograms, making it valuable for diagnosing conditions like otosclerosis, middle ear effusions, and grommet presence. Additionally, it provides useful insights into the inner ear conditions such as Meniere's disease and semicircular canal dehiscence. WBT's non-invasive nature also makes it suitable for post-ear surgery evaluations. Its potential in assessing middle ear status in sensorineural hearing loss cases, particularly those with cochlear implants, is an area of ongoing research.

After cochlear implantation surgery, some rare complications like ossicular displacement have been reported, but these findings are not common enough to justify the need for WBT investigations among cochlear implant recipients. However, studies have shown that the presence of the electrode array may alter the vibration patterns of the stapes footplate, leading to changes in air-conduction thresholds, despite unchanged bone-conduction thresholds. Research on WBT findings in cochlear implant cases has been steadily growing, revealing differences in WBT patterns compared to contralateral non-implanted ears of the CI recipients (if unilaterally implanted) or normal-hearing individuals; primarily, a decrease in absorbance across varying frequency ranges has been reported. These findings vary due to small sample sizes, electrode array differences, age effect, individual variations and the control groups used for comparison. It is critical to distinguish WBT patterns associated with the implantation from those associated with the hearing loss itself because implanted ears are typically associated with severe to profound SNHL. Therefore, the present study aimed at comparing the WBT findings between the normal hearing children and those with sensorineural hearing loss with or without cochlear implantation. The study also aimed at comparing WBT findings between the implanted and non-implanted ears of individuals with unilateral cochlear implantation. The final aim of the present study was also to compare the WBT findings between the two electrode types.

Present study involved three groups of children aged 3 to 13 years. Group I comprised of 20 normal-hearing children, confirmed through routine audiological assessments. Group II consisted of children with sensorineural hearing loss who had undergone unilateral cochlear implantation, ensuring they had no obvious post-surgery middle ear complications. Group III included children with sensorineural hearing loss using bilateral hearing aids, also without middle ear pathology. WBT was performed in a controlled, sound-treated room. The study utilized an Interacoustics Titan Suite IMP440/WBT440 to obtain absorbance measurement across 122 frequencies ranging from 226 Hz to 8000 Hz. Statistical analyses were conducted using SPSS software, employing non-parametric tests for data comparison due to non-normal distribution of data for a majority of test variables.

The study found significant differences in absorbance among groups. To investigate the effect of CI surgery on middle ear, ears of children with CI were compared to children of SNHL group and children of NH group. Additionally, CI ears were also compared to the contralateral non-implanted ears to study the effect of surgery. The impact of hearing loss was examined by comparing the SNHL group with the NH group. CI ears had lower absorbance values than SNHL group in low frequency range (till 800 Hz) and higher absorbance at mid-to-high frequency range (between 1500 Hz to 3500 Hz) at peak and ambient pressure. Further, CI ears had lower absorbance than NH group in low frequency range (till 1300 Hz) at peak and ambient pressure. The comparison between the non-CI ears of CI group to other group showed no significant difference or significant difference in a very narrow range of frequencies which could be a result of high variability. Additionally, in the within group comparisons, the CI ears of the CI group when compared to non-CI ears of the CI group, showed lower absorbance in low-to-mid frequency regions (till 1500 Hz) and higher absorbance at mid-to-high frequency regions (around 2000 Hz) at peak pressure. Similar results were observed at ambient pressure. The type of electrode used in cochlear implants had limited impact on absorbance values, except for a narrow frequency range in peak pressure condition.

These differences could be accentuated by further anatomical changes due to surgery. These include bone dust from drilling (Wasson et al., 2018), cochleostomy effects (Attias et al., 2022), and fibrous tissue development (Saoji et al., 2020). Pressure fluctuations (Hartl et al., 2023) and scar tissue formation (Choi & Oghalai el al., 2005) could also play roles. Electrode insertion might affect middle ear compliance, impedance, and fluid dynamics (Shahnaz et al., 2009; Pazen et al., 2017). Eustachian tube function and long-term tissue remodeling may also contribute, along with the changes in tympanic membrane properties (Chan et al., 2005). Furthermore, electrical stimulation by the implant could also affect neural responses and auditory system adaptation (Shen et al., 2020; Waltzman and Shapiro, 1999). All these taken together can explain the findings of the difference in absorbance between the CI ears and the NH ears in the present study.

## Clinical implications of the study

This study aimed to distinguish WBT findings between normal hearing children and those with sensorineural hearing loss, potentially revealing differences in WBT results following cochlear implantation. The findings of the study indicate distinctions in post-cochlear implantation WBT compared to sensorineural hearing loss without cochlear implants, it could lead to further investigations into whether middle ear changes contribute to the absence of cVEMP (cervical vestibular evoked myogenic potentials) after cochlear implantation, offering new research opportunities in this area.

## Limitations of the study and future directions

As maturational changes may have an impact, the current study included participants of various ages and implant ages; therefore, restricted age groups may be added in future investigations. To account for individual variability, pre-implanted ears compared to post-implanted ears is even a better comparison, and future studies could consider this route for investigating the effects of cochlear implantation on middle ear characteristics.

The current research included participants with different implant age. The differences in this aspect would cause differences in the amount of changes in middle ear absorbance. However, such an evaluation was not done. Further, the variations in electrode dimensions among clients may have led to differences in absorbance, but in the present study, these distinctions did not reach statistical significance, possibly due to limited sample size. To effectively explore the impact of different electrode types, a larger and more variable sample size would be necessary to achieve sufficient statistical power.

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## Appendix A

## Informed Consent Form

**Information regarding the study:**

I, Simi Milind Wagholikar, 2nd M.Sc (Audiology) student of All India Institute of Speech and Hearing, am doing my Dissertation on the topic entitled **"Wideband Tympanometry in Children with Severe to Profound Hearing loss with and without Cochlear Implant: A Comparison Study"** under the guidance of Dr. Niraj Kumar Singh, Associate Professor in Audiology. The evaluations used in the study are meant to assess the middle ear functioning. The procedures used during the study are not harmful in any way and are approved by the governing health agencies worldwide.

Signature (Simi Milind Wagholikar)

**To be filled by the participant:**

I_____________________________________________________________,
Father/ Mother/Guardian of __________________________________________, have been explained the procedure, its benefits, and outcomes. I am also aware of the consequences (if any) and that the information disclosed will be used for publications. I am willing to participate in the study on a non-payment basis.

Left hand thumb impression/Signature