# IMMITTANCE MEASUREMENTS IN INDIVIDUALS WITH MENIERE'S DISEASE: A RETROSPECTIVE STUDY

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## CERTIFICATE

This is to certify that this dissertation entitled **'Immittance Measurements in Individuals with Meniere's Disease: A Retrospective Study'** is the bonafide work submitted as a part for the fulfilment for the degree of Master of Science (Audiology) of the student Registration Number: 20AUD034. This has been carried out under the guidance of the faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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## CERTIFICATE

This is to certify that this master's dissertation entitled **'Immittance Measurements in Individuals with Meniere's Disease: A Retrospective Study'** has been prepared under my supervision and guidance. It is also being 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 **'Immittance Measurements in Individuals with Meniere's Disease: A retrospective'** 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, Mysore. This has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru

August 2022

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*Dedicated to my husband*
*and my family*

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**कर्मण्येवाधिकारस्ते मा फलेषु कदाचन ।**
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## ABSTRACT

The main purpose of this study was to investigate the differences in immittance findings between individuals with Meniere's disease (MD) and those without MD by comparing tympanometric measures between individuals with MD, and individuals with cochlear hearing loss and normal hearing counterparts. A retrospective study design was conducted and the medical records of 282 individuals were reviewed and immittance findings from the case files were tabulated. The between-group comparison and within-group comparison were done using non-parametric statistics for tympanogram type, static acoustic admittance, tympanometric peak pressure, and ear canal volume of all the individuals. The results of this study indicates a significant difference in the tympanometric findings in individuals with MD compared to their normal-hearing counterparts ($p < 0.005$). However, the results are not significantly different between the two pathological groups ($p > 0.005$). There were no significant difference in the findings of the two subgroups of the MD with and without aural fullness ($p > 0.05$). Therefore, the traditional tympanometric measurements were able to distinguish between MD and normal ears and the results indicate that traditional tympanometry potentially could be a useful as simple non-invasive clinical tools for MD.

**Keywords:** Meniere's disease, aural fullness, traditional tympanometry, standard immittance measurement.

# CHAPTER 1

# INTRODUCTION

Meniere's disease (MD) is a chronic inner ear disorder affecting hearing and balance. The four distinctive symptoms of Meniere's disease are episodic vertigo, fluctuating hearing loss, low-frequency tinnitus, and aural fullness, all of which occur in a unique cluster, which strongly suggests a common origin (Eliachar, Keels, & Wolfson¸1973; Enander & Stahle, 1967; Meyerhoff, Paparella, & Gudbrandsson, 1981; Stahle, 1976; Thomas & Harrison, 1971).

The foremost vestibular symptom in Meniere's disease is reported to be episodic vertigo (Haid, Watermeier, Wolf, & Berg, 1995) with the duration of each episode ranging from 20 minutes to hours, and rarely to two days (Friberg, Stahle, & Svedberg, 1983; Paparella, 1991, Paperella, 1994). These are often associated with vegetative symptoms like nausea and vomiting. The other symptoms, in addition to nausea and vomiting - include drop attacks, gait difficulty (Pyykkö, Ishizaki, Kaasinen, & Aalto, 1994) and reduced tolerance to loud sounds (Büki, Jünger, & Avan, 2012; Kitajima, Watanabe, & Suzuki, 2011). Nearly 25% of patients with Meniere's disease also exhibit Eustachian tube dysfunction (Kitajima et al., 2011).

The incidence and prevalence of Meniere's disease are estimated to be 15-50 and 21.4-220 per 100,000 populations respectively (Friedrichs & Thornton, 2001; Green, Blum, & Harner, 1991; Shojaku et al., 1995; Wladislavosky-Waserman, Facer, Mokri, & Kurland, 1984). The hearing loss usually starts unilaterally and eventually shows a bilateral involvement in approximately 30-40% of these individuals (Friedrichs & D. Thornton, 2001; Green et al., 1991). Large variation in the prevalence and incidence report might be due to the complex nature of the diseases

selected in each study. It may also have a contribution from the variability in the geographical regions of the population in which those studies were conducted. The mean age of onset for Meniere's diseases is the middle-age, which ranges between 40 to 55 years (Havia & Kentala, 2004; Thomas & Harrison, 1971).

The aetiology of Meniere's disease is a matter of debate; however, the popular belief suggests a multifactorial origin with probable interactions of various proportions between genetics, anatomy, autoimmunity, and environmental factors contributing to the onset and the severity of the disease (Lopez-Escamez et al., 2015). Histopathological studies of the temporal bone have confirmed a strong association between Meniere's disease and the evidence of endolymphatic hydrops (Miehe et al., 2022). The pathophysiology of Meniere's disease is primarily believed to be the excessive secretion/resorption of the endolymph in the membranous labyrinth. The characteristic features of episodic vertigo and other aural symptoms can be easily explained by the acute swelling of the membranous labyrinth within vestibular and cochlear ducts (Harcourt, Barraclough, & Bronstein, 2014)

Several physiological/electrophysiological tests can be used in the diagnostic battery Meniere's disease. These includes electrocohleography (EcochG), glycerol test, CHAMP (Cochlear Hydrops Analysis by Masking Paradigm), caloric tests and cervical Vestibular Evoked Myogenic Potential (cVEMP), multifrequency tympanometry and wideband tympanometry.

**Need for the study**

The cause of aural fullness in MD is not well understood. Further, there is a lack of information regarding its prevalence and the severity affecting individuals with Meniere's disease. A group of authors in a recent study found a significant association

between the degeneration of trigeminal ganglion and the presence of aural fullness, and hence believed that the trigeminal degeneration is the likely cause of aural fullness in persons with Meniere's disease (Sevilla, Goody, Baguley, & Kasbekar, 2019). However, the aural fullness is also associated with several other pathologies such as otitis media, temporomandibular joint problems and Eustachian tube dysfunction, all of which are middle ear disorders (Gersdorff, 1980; Riga et al., 2010; Sugasawa et al., 2013). Whether or not the changes to middle ear characteristics is the reason for the aural fullness even in persons with Meniere's disease has been a matter of discussion for several decades. However, sporadic studies show results favouring a middle ear cause behind the perception of aural fullness by persons affected with Meniere's disease. Dayal (1971) reported significant improvement in aural fullness after the grommet insertion in the affected ears of individuals with Meniere's disease. Considering that a grommet insertion only helps release pressure from the middle ear, while not making any alterations to the inner ear or other cranial nerve ganglions, it appears that the middle ear might be the reason behind the aural fullness in these individuals. Immittance evaluation is a set of tests used to assess the middle ear function. In case, the above postulate of a middle ear involvement in Meniere's disease has the potential to explain the feeling of aural fullness in the diseased ears of individuals with Meniere's disease, it should show up on the immittance evaluation. However, there are very few investigations on immittance evaluation in MD.

A study showed a slight difference in the middle ear pressure in the ears with Meniere's disease than the controls (Bell, Tyrrell, & Phoenix, 2017). This view receives further support from studies using multifrequency and multicomponent tympanometry (Gersdorff, 1980; Sugasawa et al., 2013; Yasui et al., 2012). They found a slightly altered resonance frequency of the middle ear and increased width of

the conductance tympanogram at 2 kHz in the affected ears of individuals with Meniere's disease than the controls. Even the wideband tympanometry at peak pressure showed significantly lower absorbance in the frequency interval of 2000-4000 Hz in the group of individuals with Meniere's disease than the control group (Miehe et al., 2022). However, these are sporadic studies, several of which were done on a small group of participants. Further, while all of them had healthy individuals in the control group, none had a control group of participants with cochlear hearing loss, the type evidenced in Meniere's disease. Having a control group with cochlear hearing loss, other than Meniere's disease, could yield a better-controlled outcome, as it would help rule out the effects of sensory hearing loss on the outcomes.

**Aim of the study**

To investigate the differences in immittance findings between individuals with Meniere's disease and those without Meniere's disease.

**Objectives of the study**

1. To profile the standard immittance characteristics in individuals with Meniere's disease.

2. To compare the standard immittance measurement among the group of individuals with Meniere's disease, a group of individuals with cochlear hearing loss and a group of individuals with normal hearing sensitivity.

3. To compare the immittance results between individuals with Meniere's disease with and without aural fullness.

# CHAPTER-2

# REVIEW OF LITERATURE

Meniere's disease (MD) was first described by Prosper Meniere in 1861, as a disorder of the inner ear causing vertigo. MD is an incredibly complex, multifactorial disease of the inner ear that causes spontaneous episodes of vertigo, fluctuating hearing loss, tinnitus and aural fullness.

The epidemiological studies examining the prevalence of MD are variable, possibly reflecting different diagnostic criteria, methodologies, and populations surveyed. In old studies, the incidence and prevalence of MD are estimated to be 15-20 and 21.4-220 per 100,000 populations respectively (Shojaku et al., 1995; Wladislavosky-Waseman et al, 1984). Approximately 0.27% of 500,000 participants in the United Kingdom were estimated to have MD, based on cross-sectional data collected from the biobank from 2006-2010. In India, the prevalence of MD is 0.61% of all the patients tested for hearing impairment as found in the tertiary care hospital in Mumbai (Penwal & Valame, 2021). It is more prevalent among patients who are older, white, and female (Alexander & Harris, 2010; Tyrrell et al., 2014; Wladislavosky-Waserman et al., 1984). MD often occurs in the middle age group of 38 and 50 years (Stahle, Friberg, & Svedberg, 1991; Tokumasu et al., 1996). Numerous studies have reported that both sexes are equally affected by the condition (Katsarkas, 1996; Oosterveld, 1979). Despite this, some authors have claimed that women are slightly more likely to contract the disease than men (Lee, Paparella, Margolis,1995; Stahle et al., 1991).

Since the 1930s, histopathological research studies have been conducted to delve deeper into the causes of the debilitating symptoms that patients with MD. A

characteristic feature often observed in MD is endolymphatic hydrops (EH)- an excessive secretion/resorption of endolymph in the inner ear. A disruption in fluid homeostasis could explain the accumulation of endolymph. Several studies assessing the distribution of EH in specimens obtained after death from patients with MD revealed the universal involvement of structures of the inferior parts of the inner ear (the saccule and the cochlea), with less-frequent involvement of the superior sections (the utricle and the semicircular canals) (Okuno & Sando, 1987). Anatomical variations of the temporal bone include exaggerated narrowing of the isthmus of the endolymphatic duct as a histopathological feature more commonly observed in the temporal bone of patients with MD (Ikeda & Sando, 1984), changes in the anatomy and positioning of the vestibular aqueduct, endolymphatic duct and sac, and the lateral (sigmoid) sinus, as well as pneumatization (i.e., the presence of air-filled spaces) of the petrous bone. These factors potentially predispose to MD (Paparella & Djalilian, 2002).

Despite extensive research, the cause of EH and the relationship between EH and MD remains unknown. Recent evidence suggests that EH has a causal relationship with MD, but that it requires additional co-factors to become symptomatic. EH can be either symptomatic or asymptomatic, whereas MD is always accompanied by symptoms. MD can be unilateral or bilateral in nature. A unilateral MD is defined as MD with symptoms in only one ear and bilateral MD involves both the ears in pathophysiology. The hearing loss usually starts unilaterally and eventually shows a bilateral involvement in approximately 30-40% of these individuals (Friedrichs & Thornton, 2001; Green et al., 1991). Further, unilateral MD does not rule out the possibility of asymptomatic EH in the other ear. Given that MD is a heterogeneous disorder, diagnosis is complicated; the reason for the variability in symptomatology is

unknown, and the relationship between EH and clinical symptoms of MD requires further investigation.

### 2.1 Etiology and Clinical symptoms

MD can be considered idiopathic due to no acceptable justification of its causes. It can arise from genetic factors, infection, trauma, inflammatory and immunologic dysfunctions and vasculopathy (Paparella & Sajjadi,1999). Patients with MD have symptoms of both peripheral vestibular as well as cochlear disorders. Rauch (2010) reported high variability in the symptoms of MD. These symptoms were shown to occur in a cluster or sporadically. Typically, symptoms occurring due to cochlear involvement include hearing loss, tinnitus and aural fullness and vestibular system involvement causes vertigo. The following sections go over the symptoms of MD in depth.

*Vertigo*

Vertigo is considered to be the most striking and traumatic symptom of MD among its four characteristic features (Meyerhoff et al., 1981). Vertigo associated with MD can be characterised as the episodic and true spinning sensation that peaks within a few minutes, persists as a severe symptom for several minutes to a few hours, and then gradually returns to normal over a few hours (Baloh, 1995), although it is considered as the mild form on the severity scale (Meyerhoff et al., 1981). Disturbance in the inner ear fluid often leads to abnormal excitability and disruption of the sensory input from the affected ear. There are two theories for the cause of vertigo attack i.e, rupture theory and non-rupture theory. Rupture theory believes that a rupture of the Reissner's membrane results in leakage of high-potassium endolymph into perilymph, which can depolarize and activate auditory nerve fibres into pathological firing

(Kingma & Wit 2010, Schuknecht, 1976). However, according to non-rupture theory, water or substance movements within the endolymphatic space may cause vertigo attacks in MD patients.

Single vertigo episodes can last anywhere from 20 minutes to 24 hours (Alford, 1972; AAO-HNS, 1995) and are accompanied by nausea or vomiting (Alford, 1972). The number of vertigo spells is higher in the early stages of MD and can exceed 30 per year in one-third of MD patients (Haye & Quist- Hanssen, 1976). Friberg et al., (1984) reported that the mean number of attacks per year remained 6-11/year up to 20 years after the disease's onset and then drops to 3-4/year.

*Hearing loss*

The basilar membrane is wider and softer at the apex of the cochlea than at the base. As a result, in EH, membrane distension begins at the apex, which is responsible for the low-frequency hearing seen in the early stages of the disease. Hearing loss at high then mid frequencies occurs as the disease progresses, indicating the progression of disease within the cochlea. The disease worsens over time until it reaches an asymptotic level. Other symptoms include sensitivity to loud noises, auditory pressure, and diplacusis (Lee et al., 1995).

A 20-year longitudinal study of 34 patients with MD revealed that 47% of patients had bilateral involvement showed over the course of the study (Friberg et al., 1983). Salvinelli et al., (1999) followed 49 patients with MD for an average of 7 years (range = 5-12 years) after the onset of MD and found that while 23 (46%) of them had bilateral symptoms, the diagnostic criteria classified only 7 (14.3%) of them as having true bilateral involvement (symptomatic MD). As a result, it should be noted that the

diagnostic criterion used across studies limits the precise prediction of bilateral involvement in MD patients.

Recruitment is also found to be often associated with hearing loss due to MD. People with hearing loss due to MD usually perceive loud sounds as extremely loud and even painful. This is thought to result from the damage to the hair cells in the cochlea (McNeill, McMahon, Newall, & Kalantzis, 2008).

*Tinnitus*

Tinnitus in MD patients is mostly low frequency, but high pitch tinnitus is also mentioned in the literature (Vernon, Johnson, & Schleuning, 1980; Kolbe et al., 2000). Most patients describe tinnitus as a roaring, buzzing, ringing, or popping sound that can be heard continuously during and immediately after the vertigo attack (Stouffer & Tyler 1990). The majority of the studies reported tinnitus as the most distressing symptom of MD during the early stages of life (Hagnebo et al., 1997). Tinnitus is commonly rated as severe by patients with MD, and the loudness increases with the disease (Kolbe et al., 2000; Stouffer & Tyler, 1990), but also diminish like other symptoms according to the progression of the disease (Vernon et al., 1980).

Kentala (1996) investigated the prevalence of tinnitus in six major diseases that cause vertigo and discovered that tinnitus is more common in patients with MD than in the other five conditions. An investigation on 564 people suffering from tinnitus due to a variety of conditions discovered that the severity of tinnitus was greater in people with MD than in people with other conditions (Stouffer & Tyler, 1990).

*Aural fullness*

Aural fullness is considered a minor complaint of MD because it is usually less debilitating than other symptoms- vertigo, tinnitus, and hearing loss. Although the

precise mechanism of aural fullness is unknown, it is commonly associated with middle ear problems such as otitis media, Eustachian tube dysfunction, and temporomandibular joint dysfunction (Riga et al., 2010). Several studies have found that aural fullness may be caused by associated degeneration in the trigeminal ganglion (Sevilla et al., 2019). The discovery of nociceptive fibres in the mammalian cochlea may point to an alternative mechanism. Levo, Kentala, Rasku, & Pyykkő, (2013) found that salt restriction, can be used to alleviate aural fullness, only relaxation produces statistically results. The symptom of aural fullness can be extremely bothersome in older patients during active MD and even in remission.

The prevalence and significance of aural fullness associated with MD are unknown. Because the severity of other symptoms –hearing loss, vertigo and tinnitus- makes aural fullness ignorable during the course of medicinal treatment. Others suggest that the aural fullness may be psychological in nature. Few studies on aural fullness in MD have been conducted, possibly due to the perceived mildness of this complaint in comparison to the other disease.

### 2.2 Diagnostic tools for Meniere's disease

The diagnosis of MD has always been a source of argument. There is no single test that is definitive for the diagnosis. A search of the vast literature shows that several tests can distinguish individual with MD from those without this disease. Several subjective and objective test can be used for the diagnosis of the MD.

#### 2.2.1 Subjective assessment of individuals with MD

In common practice, a subjective assessment test battery given by the American Academy of Otolaryngology-Head and Neck Surgery Committee on Hearing and Equilibrium Criteria (AAO-HNS CHE) is used for the diagnosis of MD. For

diagnostic purposes, this subjective assessment method can be used on its own or in combination with an instrumental approach, such as ECochG and CHAMP measures.

*AAO-HNS Criteria*

In 1972, the first standard for MD diagnosis was established by the AAO-HNS using a designation system to categorize various forms of patient presentations. These guidelines were revised many times and made to reflect the advancement in the knowledge gained from the research on MD. The new AAO-HNS diagnostic consensus statement, 2020 and the revisions include two categories: definite MD and probable MD. Definite MD has two or more spontaneous attacks of vertigo lasting 20 minutes to 12 hours each, audiometrically documented low to mid-frequency sensorineural hearing loss in the affected ear on at least one occasion before, during, or after one of the episodes of vertigo, and fluctuating aural symptoms (tinnitus and aural fullness) in the affected ear. Whereas the probable MD will be considered when at least two episodes of vertigo or dizziness lasting 20 minutes to 24 hours, as well as fluctuating aural symptoms in the affected ear. Other causes must be ruled out by additional tests before the disease can be classified.

*Pure Tone Audiometry*

Meniere's disease has been reported to be associated with sensorineural hearing loss of different configurations based on the stage of the disease. The most common pattern is the rising pattern with hearing loss maximal in the low frequencies. This is seen in the early stages of the disease (Enander & Stahle ,1967; Klockhoff & Lindblom, 1961). Further, MD has also been reported to present with flat hearing loss (Kotimäki, Sorri, & Muhli, 2001; Savastano et al., 2006) and occasionally slightly slopping hearing loss in the later stages of the disease (Kotimaki, 2003). Hence, the

configuration of hearing loss cannot specifically be used for confirmation of a diagnosis of MD.

*Speech Audiometry*

The characteristic finding in severe MD is that of worsening of the discrimination scores with increasing speech level of the speech stimuli (Paparella, 1995). The discrimination difficulty is attributed to the distortion produced in the cochlea. However, such findings have also been reported in certain other pathologies like acoustic neuromas and other retrocochlear lesions (Meyer & Mishler, 1985) and thus do not offer any diagnostic ground for MD.

### 2.2.2 Objective assessment in individuals with MD

Several physiological/electrophysiological tests can be used in the diagnostic battery of Meniere's disease. These include EcochG, glycerol test, CHAMP, caloric tests and cVEMP, multifrequency tympanometry and wideband tympanometry. As this study focuses on the importance of tympanometric findings in individuals with MD, the details of the tympanometric findings in the individuals with MD are discussed in detail below:

*Role of Standard immittance testing*

Few studies explored the findings of standard immittance testing (acoustic reflex threshold and tympanometry) results in individuals with MD. Brookes, Morrison, & Richard, (1985) studied oto-admittance changes following glycerol dehydration in MD, that acoustic immittance measurements were shown to have higher sensitivity with regard to prediction of reversible and irreversible EH, but the results are not statistically significant.

Kitajima et al., (2011), reported that the tympanometry configuration is “A” type in most cases of MD. The study hypothesized that the EH in MD could be associated with Eustachian tube dysfunction and immittance testing was not sensitive in diagnosis. However, the results of this study were not significant. Park et al., (2009) pointed out the importance of tympanometry in detecting the admittance changes in the middle ear in individuals with MD for the detection of abnormal middle ear ventilation and for placement of a ventilation tube. Bell et al., (2017) reported the findings of traditional tympanometry and found a slight difference in the middle ear pressure (-45 daPa) in the MD group compared to the control group.

*Role of multi-frequency tympanometry*

Bianchedi, Croce, Neri, & Moretti, (1996) carried out multifrequency tympanometry in subjects with MD. The author tested 15 MD patients and 10 normal hearing subjects using multifrequency tympanometry. The subjects in both groups were tested with 220 Hz and 678 Hz probe tones in order to find out the resonance frequency. The presence of a camel hump pattern obtained with 678 Hz indicated an elastic tympano-ossicular system (low point middle ear resonance). The results indicated that in MD carriers 21 ears (70%) had a resonance frequency higher and 6 ears (20%) had lower than 678Hz and 3 patterns were not classifiable. In the normal hearing group, 23 ears (57.5%) had a resonance frequency lower than 678Hz, in 13 ears (32.5%) it was higher, and further patterns were not classifiable.

Hence, it can be concluded that in MD, the tympanometric patterns for the 678 Hz probe tone indicated the presence of a more rigid tympano-ossicular system. Franco-Vidal et al., (2005) carried out a study to assess the qualitative and quantitative aspects of multifrequency tympanogram in individuals with MD. Forty MD patients,

26 females and 14 males, and 24 normal-hearing adults participated in the study. The diagnosis of MD was based on the criteria of AAO-HNS guidelines. They were all classified as having definite MD. Out of these, 8 had bilateral whereas 24 had unilateral MD. For each ear, the admittance tympanogram at 226 Hz was performed. A resonance frequency (RF) determination was done using frequency sweep and tympanograms for admittance (Y), conductance (G), and susceptance (B), at RF and 2 kHz was done. Qualitative assessment was done firstly using Vanhuyse model and secondly by classifying tympanogram patterns by comparison with letter forms according to the number and direction of maximum peaks (M, W, N, V). Quantitative assessment was done using four criteria for tympanograms: amplitude, width, peak pressure value, and +200 daPa value. The results of this study revealed that the resonance frequency was decreased in individuals with MD. Moreover, the conductance tympanogram only showed a pattern that was constant. Width of the conductance tympanogram was increased at 2 kHz in ears with MD compared to that of normals. Hence, using conductance width at 2 kHz with a threshold of 235 daPa differentiated patients with MD from normal hearing ears. It was concluded that the width of conductance at 2 kHz seemed to be a sensitive diagnostic test in MD. Hence the use of various aspects of tympanometric findings that reveal typical findings in individuals with MD can aid in streamlining the diagnosis.

*Role of wide band tympanometry*

In recent years, several studies have attempted to identify MD by using wideband tympanometry (WBT). However, there are limited studies in this area. There is no consensus on how to use WBT to diagnose MD. Reduction in resonance frequency and absorbance are characteristic of MD and can identify MD.

Miehe et al., (2022) did the retrospective analysis using 116 patients diagnosed with MD and details of wideband tympanometry were extracted from the files of the individuals. Mean energy absorbance curves with 95% confidence intervals were computed in the frequency range of 226-8000 Hz in the MD group and normal hearing group. MD group showed a statistically significant lower absorbance at tympanometric peak pressure compared to the control group ($p < 0.01$) within a frequency range of 2000-4000 Hz. Demir et al., (2020) supports the findings of the above study and found significant lower absorbance in low frequencies and low resonance frequency in the individuals with MD.

However, one study has evaluated the effects of acute MD attacks on WBT findings (Cetin, Gurkan, Kirkim, & Guneri, 2019). Thirty subjects with definite MD with unilateral low tone SNHL and aural fullness and a control group were taken for the study. The resonance frequency, mean absorbance value, mean low- and high-frequency absorbance values and double peak width at 2 kHz of conductance tympanometry (2-kHz PW) were assessed. This study found no significant effect on the 2 kHz PW in individuals with acute episodes of MD. Thus, this study concluded that wide band tympanometry seems to be ineffective as a diagnostic tool during the acute episodes of MD. Hence, wide band tympanometry has a potential for future use in MD, but utility of this test is still controversial. However, further large sample sizes, and multi-center studies are needed (Meng, Zhu, Yue, & Han, 2022).

# CHAPTER 3

# METHODS

## 3.1 Study design

This study involved a retrospective standard group comparison research design. Both within and across groups comparisons were done.

## 3.2 Participants

The participants were divided into three groups for Standard group comparison; two of them were based on the Pathophysiology of the deficit and one control group. The first group comprised 90 individuals with clinically diagnosed Meniere's disease. They were in the age range of 18-60 years (mean age = 43.13 ± 10.13; 56 males & 34 females) with minimal to profound degree of hearing loss based on the four frequency average (500Hz, 1kHz, 2kHz & 4kHz). Hereafter, this group will be termed as Meniere's disease group, abbreviated as the MD group. This group was further divided into Meniere's disease with aural fullness (n = 37, mean age = 44.50 ± 9.10; 19 males & 18 females) and Meniere's disease without aural fullness (n = 53, mean age = 42.09 ± 10.20; 37 males & 16 females) for sub-group comparison.

The second group consisted of 102 individuals with cochlear hearing loss in the age range of 18-60 years (mean age = 34.42 ± 9.11, 64 males & 38 females). Hereafter this group will be termed as Cochlear hearing loss group, abbreviated as the CHL group. Like the MD group, the CHL group consisted of individuals with hearing loss ranging from minimal to severe degree of hearing loss.

The third group had 90 individuals with normal hearing sensitivity, age ranging from 17-49 years (mean age = 30.57 ± 7.53; 59 males & 31 females). They had no history of middle ear pathology or complaint related to hearing or balance disorders. Hereafter, the group will be termed a Normal hearing group, abbreviated as NH group.

### 3.3 Participant selection criteria

In the MD group, all participants had the classical triad symptoms of Meniere's disease (hearing loss, episodic vertigo and tinnitus) in the case history. The clinical diagnosis of definite Meniere's disease was based on the guidelines from the American Association of Otolaryngology-Head and Neck Surgery (AAO-HNS), given in the year 1995 and reports from the experienced ENT doctor and audiologist.

In the CHL group, the participants had a cochlear hearing loss with absent oto-acoustic emissions (SNR <3dB) and the presence of acoustic reflex thresholds below 60dBSL (with respect to the PTA of the respective frequency).

In the NH group, all participants had normal hearing sensitivity with no other medical history which can impact hearing. Results within the normal range in audiological tests ensured a normal auditory system. The tests included were pure-tone audiometry, speech audiometry and immittance evaluation. They had hearing thresholds within 15 dB HL at all octave frequencies from 250 Hz to 8000 Hz. The Speech Recognition Threshold (SRT) were within 12dB of four frequency pure tone average threshold and the Speech Identification Scores (SIS) were >90%. In the immittance evaluation, the acoustic reflexes were present within 70-100dBHL at 500Hz, 1kHz, and 2kHz and tympanogram types were A, As or Ad types.
The subject selection criteria also included normal vestibular function, which was

ascertained through no complaint/history of vertigo, motion sickness and balance issues for the CHL group and NH group. Individuals with a history or complaint of aural fullness and tinnitus were also excluded from the NH group. Individuals with any history of middle ear pathology or abnormal otoscopic findings were excluded from all the groups.

### 3.4 Test Environment

All audiological test rooms in the Department of Audiology are well-illuminated, electrically shielded and sound-treated with ambient noise levels within the permissible limits (ANSI S3.1, 1999, R2013). Therefore, all audiological tests were administered in well illuminated, electrically shielded, sound-treated rooms. The pure tone and speech audiometry tests were administered in two-room setups whereas immittance measurements were carried out in single-room set-ups.

### 3.5 Instrumentation

The standard protocol of Audiological testing in the Department of Audiology, AIISH, Mysore was followed for all the individuals. Calibrated diagnostic immittance meters were used to obtain tympanograms and acoustic reflex thresholds and calibrated diagnostic audiometers were used for pure-tone and speech audiometric tests.

### 3.6 Procedure

*Scrutiny of case files for the MD group*

The data collection for profiling individuals with Meniere's Disease was done retrospectively. The Case files were obtained from the medical records section after

receiving general details from the Vertigo Clinic, ENT Department, AIISH, Mysore. Table 3.1 shows the search criteria for case files for the MD group. Figure 3.1 shows a flow chart depicting the selection process and provides the details on the number of non-selections and the reasons for the same.

Table 3.1 *Search criteria used to extract case files for the MD group.*

| **Parameters** | | **Eligibility criteria** |
|---|---|---|
| **Date** | From | November 2010 |
| | To | December 2019 |
| **Age** | Minimum | 18 years |
| | Maximum | 60 years |
| **Gender** | | All |
| **Language** | | All |
| **Audiological findings** | | Minimal to Profound sensorineural hearing loss |

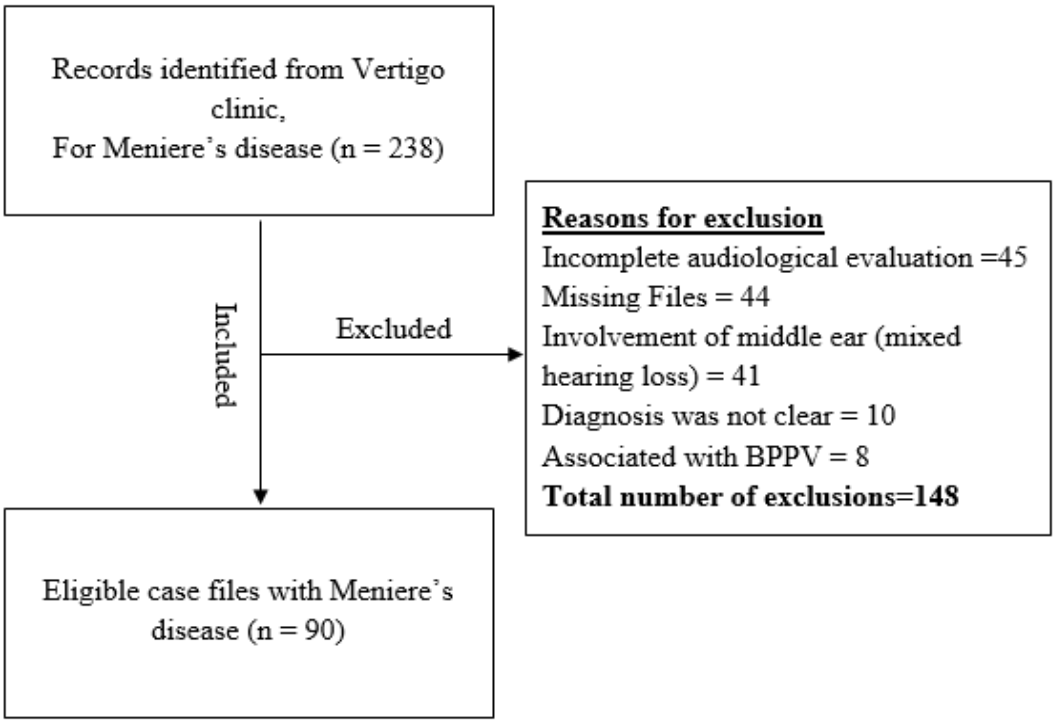


*Figure 3.1.* Flow chart for selection process to MD group

*Scrutiny of case files for cochlear hearing loss and normal hearing group:*

The database of the AIISH Client Database Management Software (CDMS) was searched to obtain information on persons diagnosed as having "Sensorineural hearing loss" and "Normal hearing sensitivity". The settings used in the search criteria for CHL and NH groups are delineated in Table 3.2.

Table 3.2: *Search criteria used to extract the case file from AIISH CDMS for CHL group and NH group.*

| Parameters | | Eligibility criteria |
|---|---|---|
| **Date** | From | January 2016 |
| | To | December 2019 |
| **Age** | Minimum | 16 |
| | Maximum | 60 |
| **Gender** | | All |
| **Language** | | All |
| **Audiological findings** | For CHL group | Bilateral minimal to severe sensorineural hearing loss |
| | For NH group | Bilateral normal hearing sensitivity |

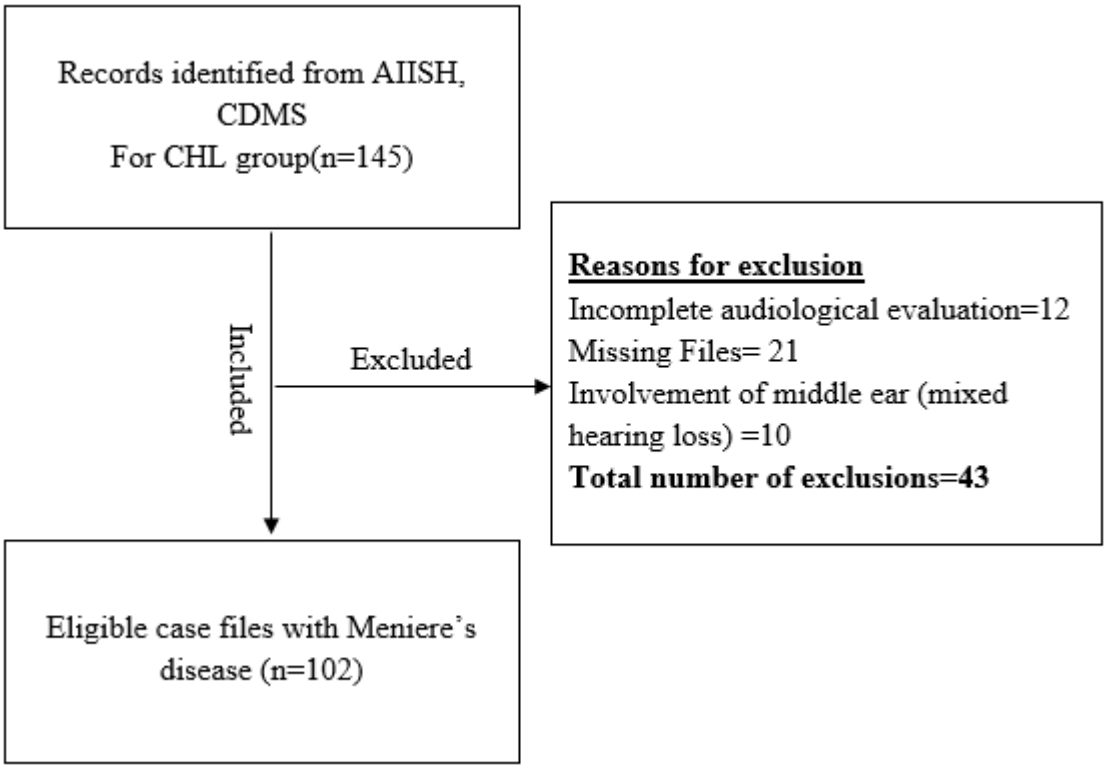


*Figure 3.2:* Flow chart for selection process to CHL group.

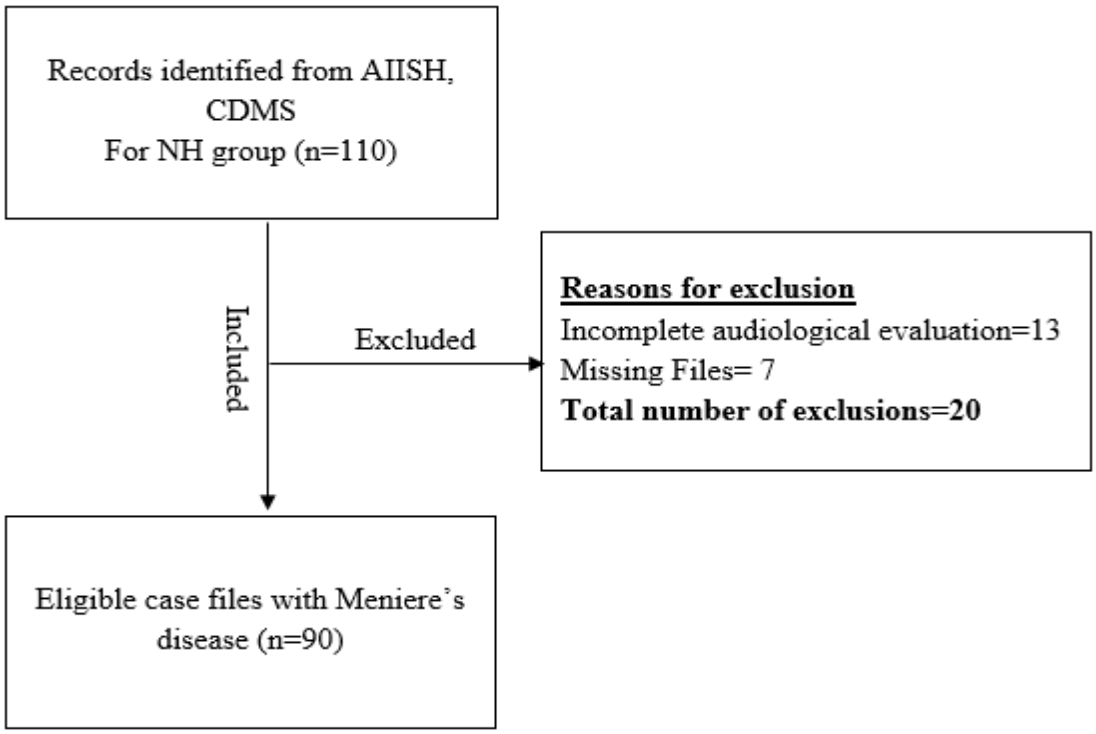

*Figure 3.3:* Flow chart for selection process to NH group.

The case files of all three groups were analysed individually and data were extracted for individuals falling within the inclusion and exclusion criteria. From each case file, information extracted and tabulated were: comprehensive case history, pure tone thresholds, and immittance findings. Detailed results of immittance findings (type of tympanogram, static acoustic admittance, tympanometric peak pressure and ear canal volume) were tabulated.

**Ethical guidelines**

The study used a retrospective research design. All the participants were tested using standard procedures that are ethically acceptable all over the world. Hence, the study adhered to the ethical guidelines for the use of human subjects.

**Statistical analysis:**

The raw score of the retrospectively collected data was subjected to statistical analysis using IBM Statistical Package Social Sciences, Version 25.0 (SPSS Inc, Chicago). Smiths statistical package was used for equality of test for proportions. To profile the audiological test measures of all three groups, descriptive statistics were used (mean, median, SD and Inter-quartile range) for all measures.

The Shapiro-Wilk's test of normality was administered. The data was found to be not normally distributed ($p < 0.05$). Hence, non-parametric tests were used for the analysis. This involved a Kruskal Wallis test for overall comparison and a Mann-Whitney U test for pairwise comparison between the groups. The McNemar test and Wilcoxon signed-rank test were used for the within-group comparisons.

# CHAPTER-4

# RESULTS

This study was carried out to identify the differences in standard immittance findings between individuals with Meniere's disease and those without Meniere's disease. In addition, it looked at identifying differences in the immittance findings in Meniere's disease individuals with and without aural fullness. To achieve these aims, the participants were divided into three groups, identified as the MD group, CHL group and NH group. For comparisons between the groups, the symptomatic ear of individuals with Meniere's disease was compared with the right ear of the CHL group and NH group. Similarly, the unaffected ears of the individuals with Meniere's disease were compared with the left ears of the individuals in the CHL and NH groups. In the within-group comparison, the symptomatic ears of the MD group were compared with their asymptomatic ears.

## 4.1. Case history

The information from the semi-structured case history was derived from the case files. The following section discusses the findings of primary (otological) complaints, associated complaints and medical history.

### 4.1.1 Otological complaints

*Tinnitus*

Among the MD group, 24 participants reported bilateral tinnitus, while others had unilateral tinnitus (29 right ears; 37 left ears). In the CHL group, 26 participants had

bilateral tinnitus, and 10 had unilateral tinnitus. In the NH group, no participant had tinnitus. The distribution of tinnitus in all three groups is shown in Figure 4.1.1.

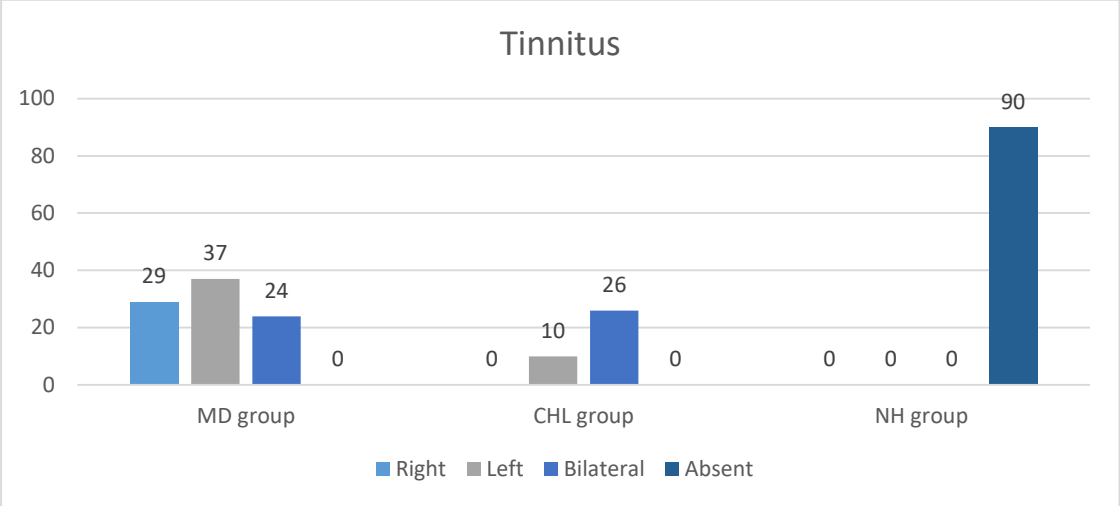


*Figure 4.1.1*: Tinnitus distribution among the groups.

*Aural fullness*

In the MD group, bilateral aural fullness was reported by 15 participants and unilateral aural fullness (in the symptomatic ear) by 22 participants, fifty-three participants in this group did not have a complaint or history of aural fullness. Participants with aural fullness were not included in the CHL and NH groups, because of the subject selection criteria. The distribution of aural fullness in the MD group is shown in Figure 4.1.2.

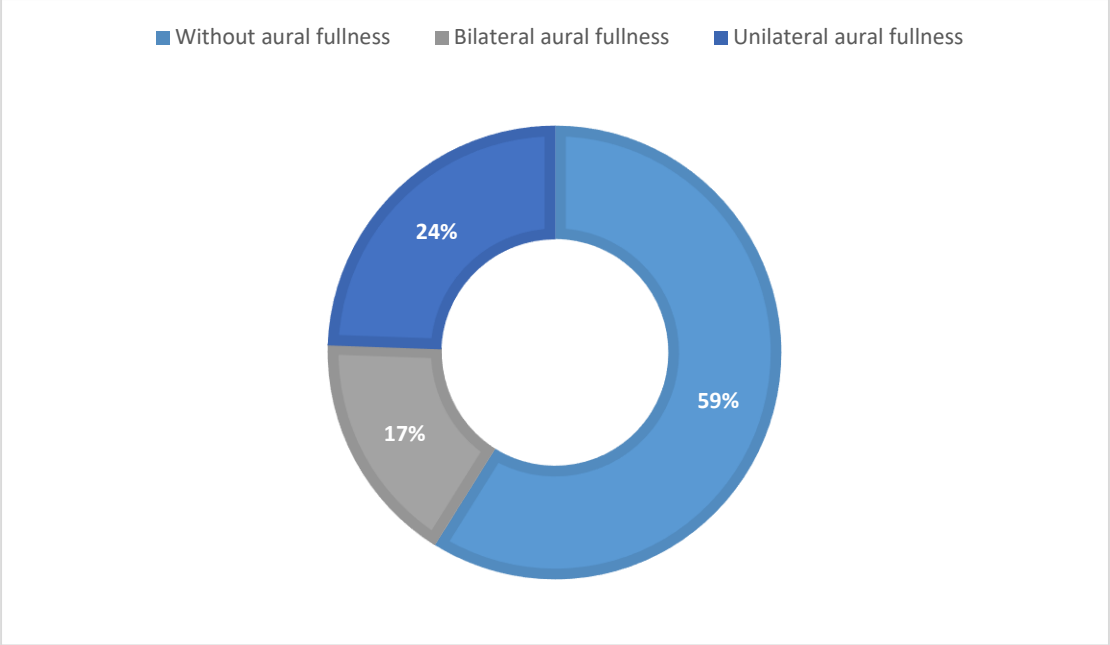


*Figure 4.1.2* The distribution of aural fullness in the MD group.

*Hearing loss*

The MD group consisted of 22 participants with bilateral hearing loss and 65 participants with unilateral hearing loss. Furthermore, 27 ears had minimal hearing loss, 17 had mild hearing loss, 19 had moderate hearing loss, 22 had moderately severe hearing loss, 4 had severe hearing loss and 1 had profound hearing loss. In the CHL group, all participants had bilateral hearing loss. Among them, 5 ears had minimal hearing loss, 25 had mild hearing loss, 49 had moderate hearing loss, and 23 had moderately severe hearing loss. Figures 4.1.3 and 4.1.4 depict the distribution of hearing loss and the frequency distribution of the degree of hearing loss, respectively.

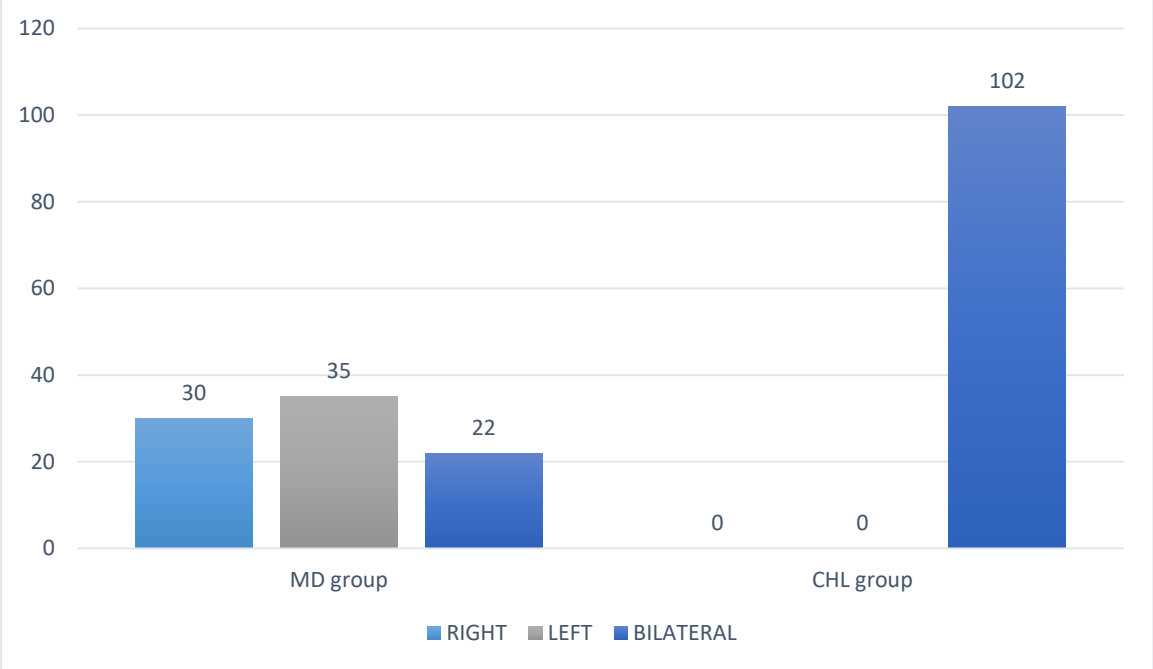


*Figure 4.1.3*: Distribution of hearing loss in MD and CHL groups.

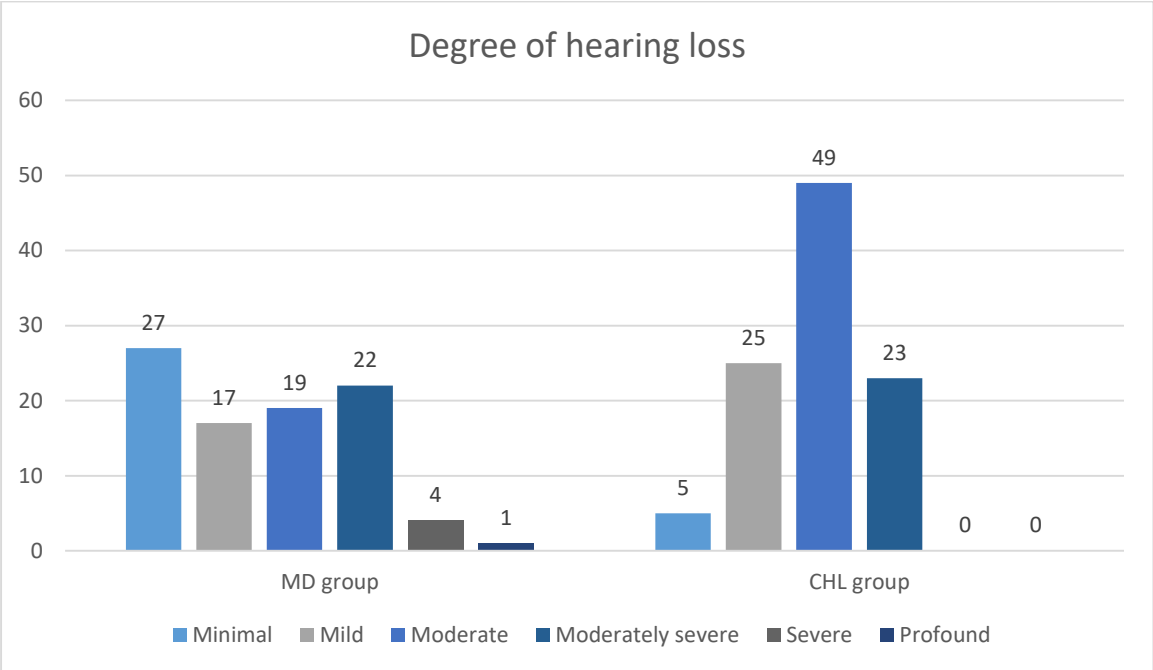


*Figure 4.1.4*: Distribution of degree of hearing loss in MD and CHL groups.

### 4.1.2 Other complaints

Medical history, associated history and family history of illness of participants were recorded. In the MD group, 13 participants had hypertension,7 had diabetes, 2 had hypothyroidism and 1 had a head injury. In the CHL group, 2 participants had hypertension and 3 had hypothyroidism. In the normal-hearing group, 9 participants had a history of ear pain, 4 had foreign body, and 6 had itching. No associated problems and family history of illness were reported by any participant in all three groups.

## 4.2 Group comparisons of standard immittance measures

All participants underwent standard immittance testing and the type of tympanogram, tympanometric peak pressure, static admittance and ear canal volume were recorded. The between-groups comparison of each parameter is discussed in the sub-sections below.

### 4.2.1 Tympanogram type

The tympanogram type was recorded from the case files of all the participants. It can be noticed from Figure 4.2.1 that 92.2% (n = 83) of the NH group individuals had A-type tympanogram. In the CHL and MD groups, 76.5 % (n = 78) and 66.70 % (n = 60) respectively had A-type tympanogram.

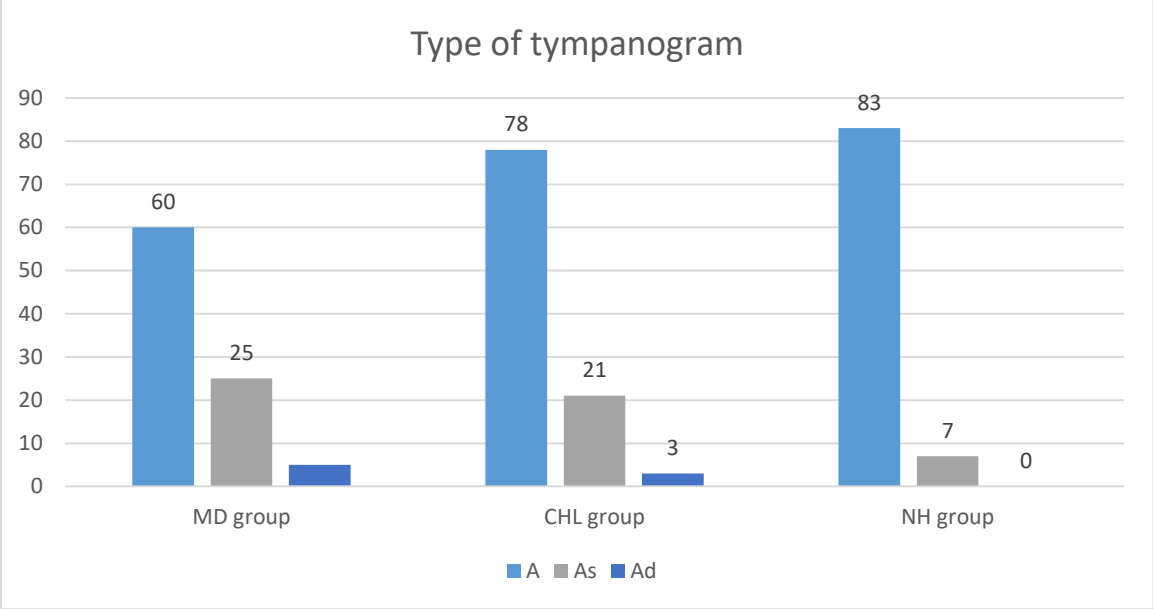


*Figure:4.2.1*: Distribution of tympanogram types in various groups of the study.

Equality of test for proportions was used for the between-group comparisons of tympanogram type. The results revealed a significant difference between the MD and NH groups for all the tympanogram types as well as for the CHL and NH group ($p$<0.05). Further, there was no significant difference in the MD and CHL groups ($p$>0.05) in any of the tympanogram type results. Table 4.2.1 shows the outcomes of the equality of test for proportions for between-group comparisons of tympanogram type.

Table 4.2.1. *Equality of test for proportions for tympanogram type among groups.*

| Comparisons | A -type | | As -type | | Ad-type | |
|---|---|---|---|---|---|---|
| | Z-value | *p*-value | Z-value | *p*-value | Z-value | *p*-value |
| MD and NH group | 4.24 | <0.001 | 3.50 | <0.001 | 2.26 | 0.02 |
| CHL and NH group | 2.96 | 0.003 | 2.50 | 0.01 | 0.16 | 0.10 |
| MD and CHL group | 1.50 | 0.13 | 1.16 | 0.24 | 0.90 | 0.36 |

### 4.2.2 Tympanometric peak pressure

The tympanometric peak pressure was analysed in all groups. The mean, median, standard deviation and interquartile range of tympanometric peak pressure were calculated. Table 4.2.2 shows that the median tympanometric pressure was lesser in the MD and CHL groups than NH group.

Table 4.2.2. *Mean, median, standard deviation, range and interquartile range of Tympanometric peak pressure in MD group, CHL group and NH group.*

| | Tympanometric peak pressure | | | | | | |
|---|---|---|---|---|---|---|---|
| Group | Mean | SD | Median | IQR | | Range | |
| | | | | Min. | Max. | Min. | Max. |
| MD group | 6.42 | 26.30 | 15.00 | 0.37 | 21.25 | -95.0 | 55.0 |
| CHL group | 10.22 | 24.80 | 15.00 | 15.0 | 25.0 | -95.0 | 60.0 |
| NH group | 17.61 | 19.46 | 20.00 | 15.0 | 25.0 | -50.0 | 87.0 |

Note: "SD" = standard deviation, IQR = interquartile range, min.= minimum, and max.= maximum.

A Kruskal-Wallis test was carried out to investigate the statistical significance of the above-mentioned observations for tympanometric peak pressure. The results revealed a significant group difference for tympanometric peak pressure [$\chi^2$ (2) = 11.489, $p$ = 0.003]. This necessitated further pair-wise comparison between the three groups in order to find out the specific pairs of groups that were significantly different from each other.

Mann-Whitney U test was done for pair-wise comparison of tympanometric peak pressure between the groups. The results revealed a significant difference between the

MD and NH groups [Z = -3.279, $p$ = 0.001], as well as between the CHL and NH groups [Z = -2.427, $p$ = 0.015]. However, there was no significant difference between the MD group and the CHL group [Z = -0.946, $p$ = 0.344] for tympanometric peak pressure. Figure 4.2.2 is shows the pair-wise comparison of tympanometric peak pressure.

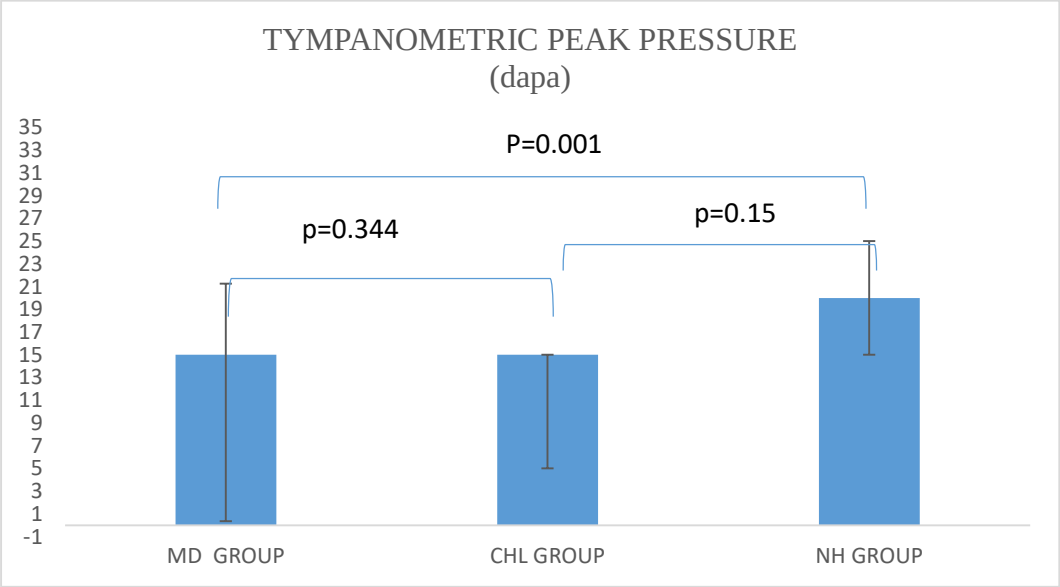


*Figure 4.2.2: Median and IQR of tympanometric peak pressure and outcomes of Mann-Whitney U tests for groups.*

### 4.2.3 Static acoustic admittance

The static acoustic admittance was analysed in all the groups. The mean, median, standard deviation and range were calculated and are shown in Table 4.2.3. It can be noticed from the table that the largest mean static acoustic admittance values corresponded to the NH group whereas the smallest mean value of static acoustic admittance corresponded to the CHL group.

Table 4.2.3 *Mean, median, standard deviation, interquartile range and range of static acoustic admittance in MD group, CHL group and NH group*.

| Group | Static acoustic admittance | | | | | | |
|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | IQR | | Range | |
| | | | | Min. | Max. | Min. | Max. |
| MD group | 0.76 | 0.63 | 0.60 | 0.40 | 0.60 | 0.00 | 3.60 |
| CHL group | 0.73 | 0.51 | 0.60 | 0.40 | 0.90 | 0.20 | 3.50 |
| NH group | 0.81 | 0.32 | 0.70 | 0.50 | 1.00 | 0.20 | 1.60 |

Note: "SD" = standard deviation, IQR = interquartile range, min.= minimum, and max.= maximum.

Kruskal-Wallis test was done to investigate the statistical significance of the above-mentioned observations for static acoustic admittance. The results revealed a significant group difference for static acoustic admittance [$\chi^2(2) = 12.317$, $p = 0.002$].

Mann-Whitney U test was done to find out the specific pairs of groups that were significantly different from each other. The results revealed a significant difference between the MD and NH groups [Z = -3.084, $p = 0.002$] and the CHL and NH groups [Z = -3.084, $p = 0.002$]. However, there was no significant difference between the MD group and the CHL group [Z = -0.383, $p = 0.701$] for static acoustic admittance. Figure 4.2.3 shows the pair-wise comparison of the static acoustic admittance.

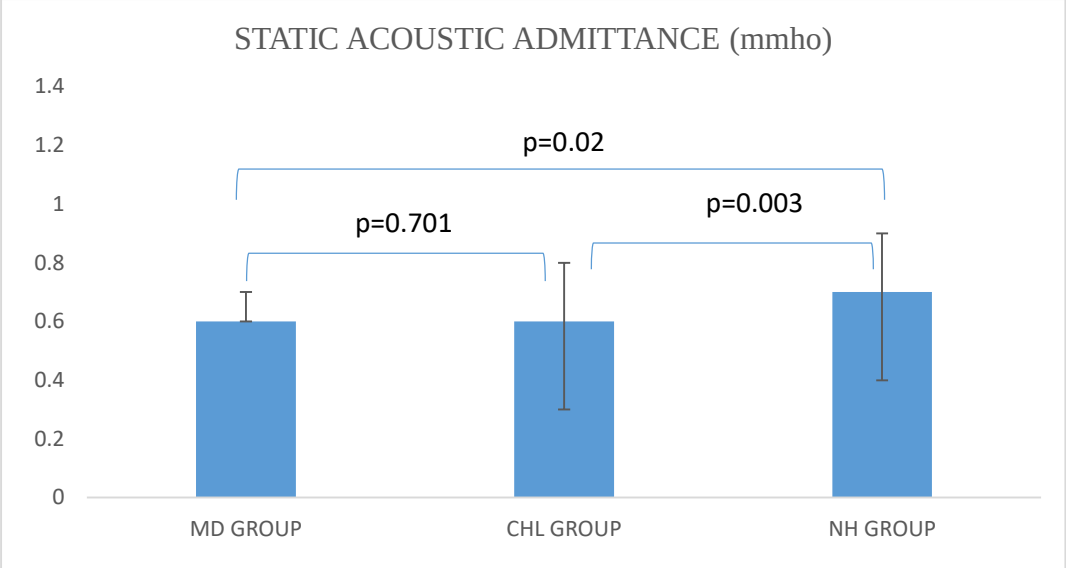


Figure 4.2.3: *Median and IQR of static acoustic admittance and the outcome of Mann-Whitney U tests for groups.*

### 4.2.4 Ear canal volume

The ear canal volume was analysed in all three groups. The mean, median, standard deviation, interquartile range and range of tympanometric peak pressure were calculated and are shown in Table 4.2.4.

Table 4.2.4 *Mean, median, SD, IQR and range of ear canal volume in MD group, CHL group and NH group.*

| | Ear canal volume | | | | | | |
|---|---|---|---|---|---|---|---|
| Group | Mean | SD | Median | IQR | | Range | |
| | | | | Min | Max | Min | Max |
| MD group | 1.32 | 0.49 | 1.30 | 1.00 | 1.50 | 0.00 | 4.10 |
| CHL group | 1.30 | 0.32 | 1.22 | 1.1 | 1.5 | 0.70 | 2.50 |
| NH group | 1.27 | 0.35 | 1.30 | 1.00 | 1.5 | 0.00 | 2.10 |

Note: “SD” = standard deviation, IQR = interquartile range, min.= minimum, and max.= maximum.

A Kruskal-Wallis test revealed no significant group difference in ear canal volume [$\chi^2(2) = 0.005$, $p = 0.997$]. Figure 4.2.4 shows the box-plot for ear canal volume in all three groups.

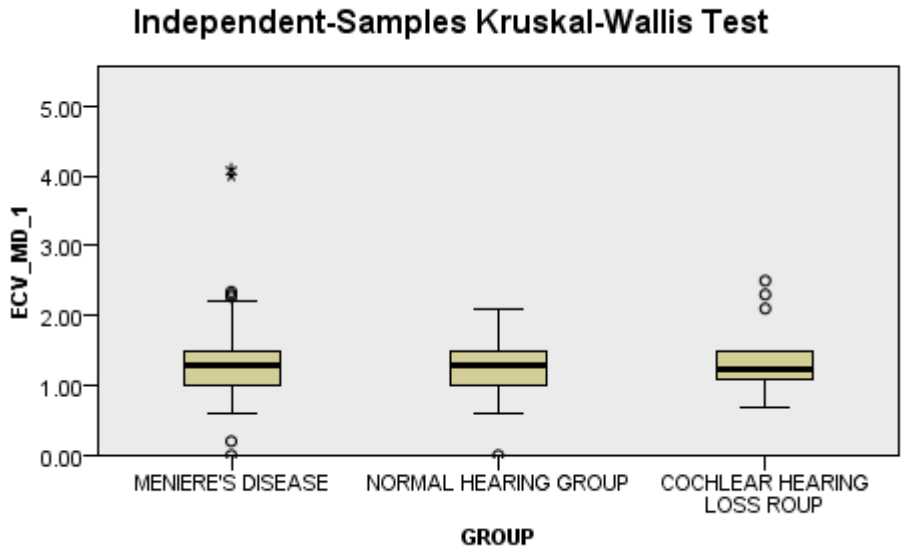


*Figure 4.2.4:* Box-plot of ear canal volume in all the three groups.

### 4.3 Comparison of standard immittance measures under the MD group

#### 4.3.1 Comparison of sub-groups: MD with aural fullness and MD without aural fullness group

The MD group was divided into two subgroups (with and without aural fullness) for further comparisons. The tympanogram type, tympanometric peak pressure, static acoustic admittance and ear canal volume were recorded. The distribution of tympanogram types in the two subgroups is given in Figure 4.3.1

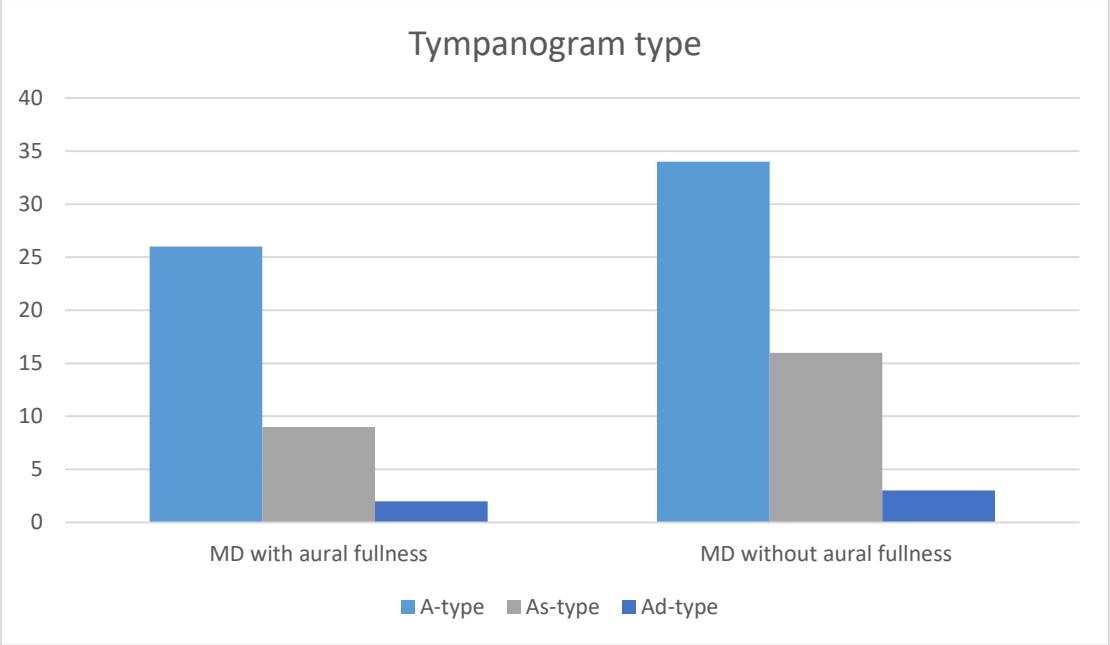


*Figure 4.3.1:* Distribution of tympanogram type among the two subgroups of MD.

Equality of test for proportions was used for the subgroup comparisons of tympanogram type. The results revealed no significant difference between the MD with and without aural fullness for the A-type tympanogram [ Z= 0.60, $p$ = 0.54], As-type tympanogram [Z= 0.61, $p$ = 0.54] and Ad-type tympanogram [Z= 0.05, $p$ = 0.95].

The mean, median, standard deviation and range of tympanometric peak pressure, static acoustic admittance and ear canal volume were calculated and are shown in Table 4.3.1. The mean of tympanometric peak pressure was 0.21 for the aural fullness group and 10.76 in without aural fullness group. The mean value of static acoustic admittance is slightly higher in with aural fullness group than the group without aural fullness.

Table 4.3.1 Mean, median, standard deviation, range and IQR *of standard immittance measures in MD group with aural fullness and without aural fullness.*

| Standard immittance measures | MD group | Mean | SD | Median | IQR | | Range | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Min. | Max. | Min. | Max. |
| Tympanometric peak pressure | AF | 0.21 | 32.54 | 15.00 | -19.50 | 20.00 | -95.00 | 45.00 |
| | WAF | 10.76 | 20.10 | 15.00 | 5.00 | 25.00 | -45.00 | 55.00 |
| Static acoustic admittance | AF | 0.80 | 0.59 | 0.60 | 0.40 | 0.95 | 0.20 | 3.30 |
| | WAF | 0.74 | 0.67 | 0.50 | 0.40 | 0.95 | 0.00 | 3.60 |
| Ear canal volume | AF | 1.49 | 0.72 | 1.30 | 1.05 | 1.65 | 0.80 | 4.10 |
| | WAF | 1.25 | 0.41 | 1.30 | 1.00 | 1.50 | 0.00 | 2.30 |

Note: AF = aural fullness, WAF = without aural fullness, SD = standard deviation and IQR = interquartile range, min. = minimum, and max = maximum.

Further, non-parametric statistical analysis was done using the Mann-Whitney U test in order to investigate the statistical significance of the above mentioned observations for standard immittance measures. The results revealed there was no significant group difference in tympanometric peak pressure [Z= -0.97, *p* =0.32], static acoustic admittance [Z= -0.99, *p* =0.31] and ear canal volume [Z= -1.06, *p* =0.28] for the individuals with MD between with and without aural fullness.

### 4.3.2 Within-group comparison of the MD group

The within-group comparison of the individuals in the MD group with unilateral pathology was done between symptomatic and asymptomatic ears. The tympanometric type, tympanometric peak pressure, static acoustic admittance and ear canal volume were recorded for both ears of the MD group. The distribution of tympanogram types within the MD group between two ears is given in Figure 4.3.2.

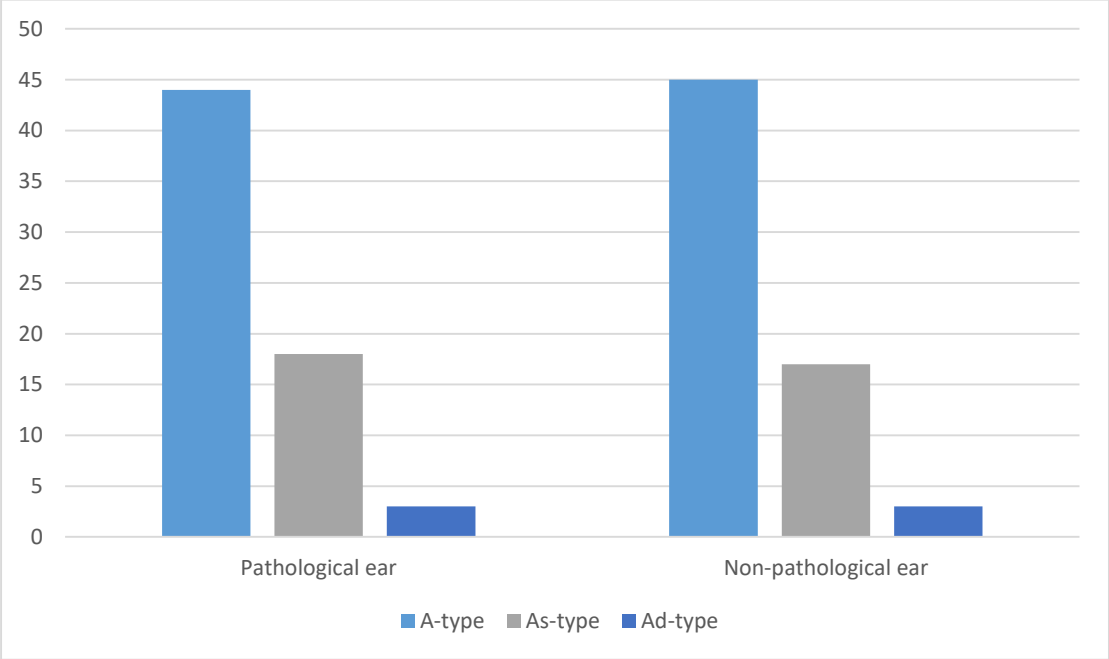


*Figure 4.3.2:* Distribution of tympanogram type of symptomatic ears and asymptomatic ears of MD group

In order to investigate the statistical significance of tympanogram type within MD group between ears was done using McNemar test. The results revealed that there was no significant difference between the ears within the MD group ($p > 0.05$).

The mean, median, standard deviation and range of tympanometric peak pressure, static acoustic admittance and ear canal volume were calculated and are shown in Table 4.3.2.

Table 4.3.2: *Mean, median, standard deviation, range and IQR of standard immittance measures in the MD group for symptomatic ear and asymtomatic ear.*

| Standard immittance measures | MD group | Mean | SD | Median | IQR | | Range | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Min. | Max. | Min. | Max. |
| Tympanometric peak pressure | SE | 6.02 | 27.32 | 15.00 | 0.25 | 22.50 | -95.00 | 45.00 |
| | AE | 11.97 | 31.17 | 20.00 | 10.00 | 25.00 | -80.00 | 55.00 |
| Static acoustic admittance | SE | 0.73 | 0.62 | 0.60 | 0.40 | 0.90 | 0.20 | 3.60 |
| | AE | 0.80 | 0.84 | 0.60 | 0.40 | 0.90 | 0.10 | 5.00 |
| Ear canal volume | SE | 1.30 | 0.48 | 1.30 | 1.00 | 1.50 | 0.20 | 4.00 |
| | AE | 1.33 | 0.36 | 1.20 | 1.10 | 1.60 | 0.60 | 2.20 |

Note: SE= symptomatic ear, AE= asymptomatic ear, AF = aural fullness, WAF = without aural fullness, SD = standard deviation and IQR = interquartile range, min. = minimum, and max= maximum

In order to examine the statistical significance of the above-mentioned observations from descriptive statistics, a Wilcoxon signed-rank test was done to investigate the difference in the symptomatic and asymptomatic ears. The results revealed no significant difference within the group for these measurements ($p > 0.05$). Table 4.3.3 displays the outcome of the Wilcoxon signed-rank test for standard immittance measures of the MD group.

Table 4.3.3. *Wilcoxon signed-rank test for standard immittance testing between symptomatic and asymptomatic ears of MD*

| | **Tympanometric peak pressure** | **Standard acoustic admittance** | **Ear canal volume** |
|---|---|---|---|
| Z | -2.143 | -.817 | -1.385 |
| *p*-value | 0.062 | 0.414 | 0.166 |

Overall, the results indicate that there was no significant difference between the MD and CHL group for all the standard immittance measures ($p > 0.05$). However, except for ear canal volume, the results of tympanometric peak pressure, static admittance and tympanogram type were statistically different between the MD and NH groups (($p > 0.05$) and also between the CHL and NH groups. While comparing the two subgroups, there were no statistically significant differences found for any measure of tympanometry in MD with and without aural fullness. The statistical analysis of the within-group between ears of the MD group was done. There was no significant difference found between the ears on standard immittance measures ($p > 0.05$).

# CHAPTER 5

# DISCUSSION

The present study aimed to compare the standard immittance findings in individuals with and without MD. Medical records of 282 individuals were reviewed retrospectively, with 90 participants being identified in the MD group, 102 participants in the CHL group, and 90 individuals in the NH (control) group. The findings of comparison between groups and within groups has been discussed below.

## 5.1 Comparing the findings of standard immittance measurements between the groups

*Tympanogram type*

In the present study, a significantly higher proportion of As-type tympanogram was seen in the MD group and CHL group compared to the NH group; however, there was no significant difference in the proportions of the As-type tympanogram between the two pathological groups i.e. MD group and the CHL group. This suggests that admittance properties of the middle ear are altered not only in Meniere's disease but also in other cochlear pathologies.

Few studies have reported the findings of traditional tympanometry in individuals with MD. A study done by Kitajima et al., (2011), reported A-type tympanograms in most cases with Meniere's disease. No study has reported the finding of significantly higher proportion of As-type tympanogram in the MD group than the normal controls. The possible reason for altered middle ear admittance in individuals with MD compared to their normal-hearing counterparts could be a build-up of excessive endolymph within the inner ear which probably exerts pressure on the stapes footplate, which can cause a cascading effect of pressure transmission via the

ossicular chain to the tympanic membrane, altering the admittance properties of the middle ear. This can explain the findings of As-type tympanogram in these individuals. However, the study has not found any significant difference in the MD group and CHL group in tympanogram type. This might be due to a close possibility of having early MD cases in the CHL group as some of them has a complaint of tinnitus in the CHL group. Nonetheless, this is at best a speculation, especially considering the retrospective nature of the data in the present study.

*Static acoustic admittance*

The study obtained a significantly low static acoustic admittance in the MD and CHL groups compared to the NH group. However, there was no significant difference in the static acoustic admittance findings of MD and CHL groups. Very few studies have reported the findings of traditional tympanometric findings in individuals with MD. The findings of the traditional tympanometry correlate with multi-frequency and multicomponent tympanometry, revealing a reduced resonance frequency and increased width of conductance tympanogram at 2kHz in individuals with MD (Franco-Vidal et al., 2005) which explains altered admittance properties of the middle ear in individuals with MD.

The explanation for having low static acoustic admittance in the MD group compared to the NH group is again due to the pressure effect of the inner ear on the ossicular chain of the middle ear, thus altering the admittance properties of the middle ear.

*Tympanometric peak pressure*

In the present study, the tympanometric peak pressure in the MD group as well as in the CHL group was lower than the NH group; nonetheless, there was no significant difference group difference. Bell et al., (2017) reported a slight difference in the middle ear pressure (-45 daPa) findings in the individuals with MD compared to the

control group. Many authors have reported Eustachian tube dysfunction in individuals with MD in nearly 25% of the cases (Kitajima et al., 2011) and thus usefulness of traditional tympanometry in detecting abnormal middle ear ventilation in individuals with MD. Therefore, the altered tympanometric peak pressure in the subjects with MD can be due to the associated sub-clinical Eustachian tube dysfunction in some individuals with MD. This finding is further supported by a recent study (Tanno et al., 2020). However, this hypothesis does not explain the altered tympanometric peak pressure in the CHL group. The probable reason could be a possibility of undiagnosed endolymphatic hydrops in a few participants in the CHL group as tinnitus was evidenced in some of them.

*Ear canal volume*

The ear canal volumes were within the normal range in all three groups. This is attributed to a lack of change in the anatomical structure of the ear canal of the individuals. None of the groups had any such deformity, and none of these are known to be associated with changes in the ear canal volume.

**5.2 Comparing the immittance results between the individuals with MD with and without aural fullness.**

The MD group was divided into two sub-groups- with and without aural fullness. The results of comparison between them revealed no significant difference in the standard immittance findings. There is a dearth of literature on this topic. A possible reason for the lack of significant difference in the two subgroups can be that aural fullness is not properly documented and left unreported in many cases as other symptoms are more troublesome to the patient. Given that the data was of a retrospective type, further details could not be obtained. Care full examination in a controlled environment is needed to rule out the difference in the two subgroups of MD.

### 5.3 Comparing the immittance results between the symptomatic ears and asymptomatic ears in the MD group.

For this kind of a comparison, only the unilateral MD cases were taken. There was no significant difference between the symptomatic ears and asymptomatic ears for tympanogram type, static acoustic admittance, tympanometric peak pressure and ear canal volume. However, both the ears of MD were significantly different from the NH group. Some authors have reported abnormal findings in the clinical exams of the asymptomatic ear in individuals with MD. Endolymphatic hydrops may be evidenced in the electrocochleography of asymptomatic ears in 15.0-35.0 % of patients with unilateral MD (Conlon & Gibson,1999; Moffat et al., 1992). Histopathological confirmation of endolymphatic hydrops of the asymptomatic ear was found in 11.1% of the cases by Fraysse et al., (1989). Ribeiro et al., (2005) reported that 15 % of the individuals with MD had an absence of absolute latency of p13 in the asymptomatic ears. These findings indicated that electrophysiological exams could identify occult endolymphatic hydrops in ears that were apparently asymptomatic in patients with MD. Therefore, occult MD in the asymptomatic ear can be a possible reason for the abnormal findings in traditional tympanometry in this study. However, there is a dearth of research on the physiological test findings in the asymptomatic ears of individuals with MD. Research in this area can help us in early prediction of MD in the asymptomatic ear and thus can help in the planning treatment plan.

# CHAPTER 6
# SUMMARY AND CONCLUSIONS

Meniere's disease (MD) is a chronic inner ear disorder characterized by episodic vertigo, fluctuating hearing loss, tinnitus, and aural fullness. Endolymphatic hydrops, the most well-accepted physiological finding in Meniere's disease, can explain episodic vertigo, fluctuating hearing loss and tinnitus. While a reverse pressure theory from the inner ear to the middle ear can also explain the perception of aural fullness, it remains a less explained feature. There is dearth of literature investigating aural fullness in MD potentially because of the perceived mildness of this complaint. Although the underlying mechanism of the aural fullness can involve any part of the peripheral auditory system, it is more often associated with changes in the middle ear characteristics. The standard immittance evaluation is the most widely used diagnostic test for the assessment of the mechanical properties of the middle ear system. If the reverse pressure theory was true, it should show up on the immittance test. Hence, the current study aimed to compare the standard immittance characteristics of individuals with MD and those without MD.

In order to fulfil the aim, a retrospective analysis was executed and medical records of 282 individuals were reviewed, with 90 participants in the MD group, 102 participants in the CHL group and 90 individuals in the normal-hearing group for between-group comparison. MD group was further divided into MD with aural fullness (n = 37) and MD without aural fullness (n = 53) for the subgroup comparison. The within-group comparison was done in unilateral MD individuals between the symptomatic ears and asymptomatic ears. Further, detailed results of standard immittance findings (type of tympanogram, standard acoustic admittance and ear canal volume) were tabulated.

The raw scores of the collected data and descriptive statistics were used to profile the measures of immittance testing. The data were non-normally distributed; hence non-parametric statistical analyses were used. The Kruskal-Wallis test was used for the overall comparison and the Mann-Whitney U test was used for the pairwise comparison between the groups and subgroups. The McNemar test and Wilcoxon signed-rank test were used for the within-group comparisons. All statistical analyses, except the equality of test for proportions, were done using the SPSS software version 25. The equality of tests for proportions was done using smith's statistical package.

The results indicate that there was no significant difference between the MD and CHL group for all the standard immittance measures ($p > 0.05$). However, except for ear canal volume, the results of tympanogram type, static admittance, and tympanometric peak pressure were statistically different between the MD and NH groups ($p < 0.05$) and also between the CHL and NH groups ($p < 0.05$). While comparing the two subgroups, there were no statistically significant differences found for any measure of tympanometry in MD with and without aural fullness ($p > 0.05$). The statistical analysis of the within-group between ears of the MD group was done. There was no significant difference found between the ears on standard immittance measures ($p > 0.05$).

The findings suggest the altered admittance properties of the middle ear in individuals with MD compared to normal hearing counterparts. This indicates the involvement of the middle ear in the disease and can be a possible reason for aural fullness in individuals with MD. However, the results of the CHL group were also affected suggesting having some patients with early Meniere's disease in this group. The affected tympanometric findings in the asymptomatic ear of MD suggestive of

latent/occult MD in that ear which necessitates further research in objective tests to find out the progression of the disease to the other ear in the early years of the MD.

**Clinical implication of the study**

The present study helps us to understand that the standard immittance findings are altered in individuals with MD. There is enough evidence in the literature which shows that admittance properties of the middle ear are changed in the MD group through findings MFT, MCT and wideband tympanometry. Also, few studies have shown the importance of the standard immittance findings in individuals with MD as it helps to see middle ear involvement in these cases and thus helps in using a better treatment approach. Traditional tympanometry is a more comprehensive and widely used indicator that may provide valuable information in the MD cases. It can be a great physiological tool, especially to diagnose the occult MD in the unilateral cases.

**Limitations of the study and future directions**

The outcomes of the study were limited due to retrospective study design. A study in the controlled environment for the pathological group can provide insights in traditional tympanometry testing and its usefulness for the MD individuals. Further, the study did not rule out the tinnitus patients from the cochlear hearing loss group. Experimental study design using the three groups in the controlled environment with good number of participants could be considered by future studies. The findings of traditional tympanometry can also help in setting normative for the tympanometric measures in individuals with MD using newer technology such as wideband tympanometry.

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