EFFECT OF NOISE-INDUCED HEARING LOSS ON PERCEPTUAL AND CLINICAL CORRELATES: A ICF FRAMEWORK

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A Dissertation Submitted in Part Fulfilment for the Degree of
Master of Science in Audiology
University of Mysore, Mysuru.

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SEPTEMBER – 2021

CERTIFICATE

This is to certify that this dissertation entitled **“Effect of Noise-Induced Hearing Loss On Perceptual and Clinical Correlates: A ICF Framework”** is the bonafide work submitted in part fulfilment for the degree of Master of Science (Audiology) of the student with Registration Number: **19AUD024**. 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.

Mysuru,
September, 2021

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This is to certify that this Master's dissertation entitled **"Effect of Noise-Induced Hearing Loss On Perceptual and Clinical Correlates: A ICF Framework"** is the result of my own study under the guidance of Dr Sreeraj Konadath., (Guide) and Dr Nisha KV., (Co-Guide) 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.

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September, 2021

DEDICATED TO MY APPA,
AMMA & INDIVIUALS WITH
NOISE INDUCED HEARING LOSS

ACKNOWLEDGEMENT

‘என்ன தவம் செய்தேனோ நான்’

23 வயசு பையன வேலைக்கு போனு துறத்தாம, இன்னும் கைக்குழந்தைய போல பாத்துகிட்டு, சாப்பாடு ஊட்டி விட்டு, எது கேட்டாலும் இல்லனு சொல்லாம வாங்கி கொடுத்து, இது வரைக்கும் நல்ல வழியில கூப்பிட்டு போன ***என் அப்பா, அம்மா*** *கிடைக்க நான் என்ன தவம் செய்தனு தெரியல..!! அவங்கள எனக்கு கொடுத்த கடவுளுக்கு நன்றி..!!*

என்னோடு, எங்கும் எதிலும் எப்போதும், என் நண்பனாய்! என் ஆசானாய்! என் துணையாய்! என் எல்லாமுமாக இருந்த ***என் தாய் தந்தைக்கு*** *என் இதயம் கனிந்த நன்றிகள்..!!*

I would like to extend my sincere and deep sense of gratitude towards my guides ***Dr Sreeraj Konadath*** *and* ***Dr Nisha KV****, for their constant support, encouragement, patient listening, guidance and for being super cool guides. Thank you so much, Sir and Ma’am, for all your patience throughout this dissertation, and I am very fortunate to have you both as my guides.*

I never wanted to pursue post-graduation, even wanted to drop out from undergraduate, but Today, I am not the same person anymore, and I am super proud of myself for pursuing post-graduation. And it’s all because of you, my dear friend ***Kirthana Madhavan****;* I couldn’t have done it without you. You are a good friend, teacher, moreover, the best person I ever met. I thank you from the bottom of my heart for everything.. Thank you!!

A special thanks to my junior ***Anusha MN*** *for motivating me to prepare for the entrance exam. Your help means a lot to me*

Yaazhini, Sriranjani *and* ***Subhiksha****, I cannot begin to express my gratitude for your valuable time and effort for my data collection. Words can't explain how thankful I am; I might say I owe you people one*

Sahana, Gowthami, Jeyasree *and* ***Chinnarasu****, thanks a million people!! For the coding work, I truly appreciate you all*

I would love to thank my juniors who transcribed my data (1st Msc – ***Madhuriya, Nethra*** *Intern* ***– Sai shruthi, Rohini,*** *3rd Bsc –* ***Chandan, Gunasekar, Hani sulthana, Sahaja, Rashmi, Pooja, Pallavi, Meghna, Ganavi, Chandana, Subhiksha, Chaitanya,*** *2nd Bsc –* ***Sreenivas, Manjunath, Chandana, Varshini, Spoorthi, Aishwarya, Ruchitha, Shilpa, Thejeswini, Thejeswini, Mayuri, Varsha, Kavya ,*** *1st Bsc –* ***Hema, Prassana, Vidya, Prakrati, Deepthi, Geetha, Rashmi, Aashika, Ramya, Chinmayi, Aishwarya, Manjunath, Dinesh****) and also who helped me in data entry and pdf conversion (****Shyam, Rejils, Dhruvan, Jeeva, Viswajith, Triston, Nikki, Parvathy, Malavika, Akila****) Thanks a ton for helping out!!!!*

Janani and Sivadharani Thanks a bunch for your transcription work!

Thank you, ***Apoorva Prathiba****, for teaching me Kannada. I appreciate it more than you will ever know. I am thankful to my juniors* ***Harshitha*** *and* ***Chandana S****, for the same.*

My sincere thanks to ***Dr M. Pushpavathi****, Director, AIISH, Mysuru, for providing me with a platform to carry out this study.*

I would also like to thank all the lecturers and faculties of the Department of Audiology, AIISH, Mysuru for helping and guiding me throughout my Post Graduation.

And I would also like to thank all ***my teachers, seniors*** *and* ***juniors*** *from MERF-ISH, Chennai, for building a strong foundation in me that made me what am I today.*

I would like to thank all my subjects who participated in my study for dedicating their precious time and co-operating for the data collection.

I would like to thank my batchmates, ***Renovators 2.0****, for making these PG days memorable.*

I would like to extend a big thanks to all who have helped me directly or indirectly and made this dissertation a success.

ABSTRACT

Noise exposure and its hazardous effects on the auditory system in general and overall health, in particular, has shown an alarming increase in the past decade. The overall impact of noise exposure can be understood only through systematic profiling of its auditory and non-auditory effects. The conventional audiological test battery assesses only the former and largely ignores the effects of the latter. Using the International classification for functioning disability and health (ICF) core set for noise exposure-related, we aimed to profile the overall impact of noise exposure and correlate them with conventional auditory measures. The study sample included 45 adults with hazardous levels of noise exposure. The data was collected from all the participants using two open-ended questions: Problem effects (PQ) and life-effects (LEQ). A content analysis approach was used to link the responses to ICF categories. There were 155 responses related to PQ and 156 for LEQ, with activity limitation and body function being the most affected domains in PQ and LEQ, respectively. The functions most commonly affected under each domain is discussed. No correlations were found between the ICF-based responses and demographic/audiological measures, signifying the need for profiling the heterogeneity of noise effects in the target population using internationally established tools like ICF. Based on the affected domains in the ICF, a questionnaire for assessing the overall noise impact in the participants exposed to industrial noise is documented.

Abbreviations. ICF: International classification for functioning disability and health; Problem effects question (PQ) and life-effects question (LEQ)

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Chapter I

INTRODUCTION

Hearing loss caused by exposure to very intense sounds or unacceptable levels of sound for long periods is called Noise-induced hearing loss (Rabinowitz, 2000). People of all ages, including older people, young adults, teens and children, can develop noise-induced hearing loss. Noise can result in permanent sensorineural hearing loss when there is an impulse noise at a very high level of around 130-140 dB, or a high level of exposures equal to an average SPL of 85 dB(A) or higher for eight hours (Occupational Safety and Health Administration, 2013). In India, 39% of industrial workers (Ranga et al., 2014) and 22.9 % of Air Force Personnel (Nair & Kashyap, 2009) have noise-induced hearing loss (NIHL). Around the world, 16% of the disabling hearing loss in the adult population is attributed to occupational noise, ranging from 7 to 21% in the various sub-regions (Nelson et al., 2005). According to the world report on the hearing, over 1.5 billion people currently experience some degree of hearing loss, which could reach 2.5 billion by 2050. Also, 1.1 billion young population are at risk of permanent hearing loss from listening to music at loud volumes over prolonged periods (World Health Organization., 2021).

Exposure to loud impulsive noise could disrupt the microstructures of the cochlea and can result in permanent loss of the hair cells and other sensory cells (Roberto & Zito, 1988). The gradually growing sensory damage by noise generally occurs first to hair cells associated with the perception of frequencies, those most critical for speech discrimination (Mirza et al., 2018). The higher frequencies (3 - 6 kHz) are more affected than the lower frequencies (0.5 - 2 kHz); among the higher frequencies, the 4 kHz frequency is the most severely affected (Kirchner et al., 2012). High-intensity noise exposure can cause severe to profound sensorineural hearing loss in some individuals. In many cases, noise exposure also results in the perception of tinnitus (Henderson et al., 2011). Any degree of NIHL may attenuate high-frequency speech and other environmental sounds and may result in speech understanding difficulty, especially in environments with background noise, many different voices, or room reverberation (Baxter, 1996).

Noise can adversely affect other non-auditory systems such as cardiovascular (Babisch, 2003), neuroendocrine (Ising et al., 1999), and psychological (Passchier-Vermeer & Passchier, 2000). Along with the hearing loss, exposure to loud noise also results in non-auditory effects like increased stress, high blood pressure (Basner et al., 2014), annoyance, sleeping, and mental health problems (Eggermont, 2014; Smith, 1991). Noise annoyance can result from noise interfering with daily activities, feelings, thoughts, sleep accompanied by negative responses, such as anger, displeasure, exhaustion, and stress-related symptoms (Öhrström et al., 2006). Also, it can cause annoyance, aggression, reduce helping behaviour, influence judgement and subsequently lead to several psychological perturbations that can severely affect the quality of one’s life and their family members. It has been reported that noise may negatively impact interpersonal relationships (Kryter, 1972).

The regular hearing test battery, which includes tests of hearing sensitivity (air and bone conduction pure tone audiometry, Uncomfortable Loudness Level (UCL), speech perception scores), focuses only on the specific functions like auditory effects of the noise exposure such as the configuration of hearing, type and degree of hearing loss. High-frequency audiometry is shown to be more sensitive to detect noise-induced hearing loss than conventional pure tone audiometry (Mehrparvar et al., 2011), while the use of otoacoustic emissions in test batteries adds to the high sensitivity (79 - 95%)

of NIHL detection (Attias et al., 2001), especially in the early stages of the disorder (Job et al., 2009). In addition, supra-threshold tests like speech perception and temporal summation in noise can provide insights into the deleterious effects of noise exposure on other functional aspects of audition (Fulbright et al., 2017). Although the inclusion of these tests aids in understanding the auditory effects of noise exposure, they fail to portray the overall deleterious effects of noise due to their insensitivity to test the other non-auditory manifestations of the disorder. Although the non-auditory effects of noise have multi-faceted ramifications on the overall health status of the worker, the general awareness of the hazardous effects of noise on hearing and other body systems is limited from the perspective of both the employer and employee (Rus et al., 2008). In reference to this, the Audiologists need to profile the non-auditory effects of noise and correlate those findings with auditory measures to understand the overall impact of noise on the worker's health.

The overall impact of noise exposure can be assessed with the help of the International classification of functioning, disability and health (ICF) theoretical framework given by the World Health Organization (WHO) in (2001). ICF integrates the social model (wherein disability is viewed as consequences of societal conditions) and the medical model (for which disability is considered to be connected to a person's bodily dimension, caused by a disease) into a bio-psycho-social approach. ICF is also a classification, with numerical category codes developed for use in clinical settings or research.

The classification is based on a hierarchical structure and consists of two parts: (A) Functioning & Disability and (B) Contextual factors. The Functioning & Disability is further divided into (A1) Body structures (anatomical parts of the body) & Body functions (physiological functions of body systems), (A2) Activities (execution of a task or an action by an individual) & Participation (involvement in a life situation). Likewise, the Contextual factors are further divided into (B1) Environmental factors (the physical, social, and attitudinal environment), and (B2) Personal factors (the particular background of an individual's life and living) (World Health Organisation, 2001). Each component is composed of various domains and, within each domain, categories, which are the units of classification. The classification is easily understandable, with more than 1500 categories. An individual’s health and health-related conditions can be documented by selecting the appropriate category code or codes (Numeric codes) which specify the extent or the magnitude of the functioning or disability in that category, or the extent to which an environmental factor is a facilitator or barrier (World Health Organisation, 2001).

The WHO initiated the ICF core sets projects to facilitate ICF's applicability in clinical settings and research. A core set is a set of ICF categories of particular relevance for a specific diagnosis or health condition. The ICF core sets for hearing loss covers both auditory and non-auditory domains (Granberg et al., 2014). According to the ICF, the sense of hearing is considered a part of the body function (coded as b230). Using ICF core sets for noise-induced hearing loss (NIHL) can establish perceptual correlates (auditory and non-auditory effects), which gives a comprehensive understanding of the health deficits due to noise exposure as a whole. Also, establishing the links between ICF-based perceptual classification and clinical findings will add to the efficacy of diagnosis and validate the utility of ICF coding in profiling the overall health hazards of NIHL.

1.1 Need for the study

Noise is an ever-rising product of our environment (Raja et al., 2019). The high level of noise exposure will result in auditory as well as non-auditory effects on health. The relationship between noise and hearing loss has been well established (Rabinowitz, 2000). However, non-auditory effects of noise on health though known, are under-studied and under-reported. Hence understanding the deleterious effects of noise on overall health is vital for the conception and execution of appropriate remedial measures and prevention.

However, to date, there is no study in the Indian context, which disentangled the link between the non-auditory and auditory effects of noise exposure in Occupational noise workers. ICF core sets for hearing loss covers both auditory and non-auditory domains (Granberg et al., 2014). Using these ICF core sets for noise-induced hearing loss (NIHL) can establish perceptual correlations (auditory and non-auditory effects), giving a comprehensive understanding of the health deficits due to noise exposure. Also, establishing the links between ICF-based perceptual classification and clinical findings will add to the efficacy of diagnosis and validate the utility of ICF coding in profiling the overall health hazards of NIHL.

1.2 Aim of the study

The current study aims to profile the perceptual correlates of noise exposure and correlate them with conventional clinical measures.

1.3 Objectives of the study

- To document the perceptual correlates (auditory & non-auditory effects) of noise-induced hearing loss using ICF classification, specifically, for the domains: body function, body structures, activities, participation, contextual factors, environmental factors, and personal factors.
- To profile the clinical correlates of noise-induced hearing loss on pure-tone audiometry, the configuration of hearing loss, speech audiometry (Speech recognition thresholds/ speech identification scores), the symmetry of hearing loss, OAEs, reflexes, Tympanometry, and electrophysiological tests.
- To correlate the perceptual and clinical correlates of NIHL.

Chapter II

REVIEW OF LITERATURE

Noise-induced hearing loss is not a new concept; over the past 50 years, it has been discussed in different peer-reviewed articles and different medical textbooks (Thurston, 2013). The different auditory and non-auditory effects of high-intensity noise exposure have been well discussed over the past half-century (Granberg et al., 2015; Kirchner et al., 2012).

When people first became aware that high intensity or loud noise could cause permanent hearing loss, hearing is still not known precisely, but the damaging nature of loud noise and its effects on hearing arose after the invention of gunpowder; this concept most probably entered Europe from China sometime in the 13th century (Pacey, 1991). By the early 20th century, doctors were aware of hearing loss due to exposure to loud sounds for a longer period. Still, no medical professional seemed to provide recommendations regarding the prevention of noise-induced hearing loss. In the middle of the 20th century, Toynbee had undergone almost 2000 temporal bone dissections (Hawkins, 2004), and from his post-mortem findings, he stated that people exposed to loud sounds or noise had damage in the membranous labyrinth of the cochlea, which could be the reason for their hearing loss. In (1890) Habermann published the histopathological changes of the inner ear of a deaf coppersmith exposed to loud noise (Gilbert, 1922; Thurston, 2013). Almost after a century, the subsequent reports of microscopic examinations of inner ears of the person exposed to loud noise published and confirmed Habermann’s findings of cochlear damage due to noise exposure (Johansson & Arlinger, 2001).

Damage to the inner ear structures by loud noise had been discussed many times in the 19th century; even after that, otolaryngologists were not able to quantify the hearing loss in noise-exposed people because a standard method of measuring hearing loss was not available until German technologists developed an electronic audiometer in 1919 (Blume S, 1879). Before the invention of the audiometer, physicians used various methods to test hearing sensitivity, including 'how well a subject could hear a whispered command or a pocket watch' (Mitchie, 1924). Sound-measuring instruments eventually became available in the 20th century and were used by researchers to measure the dangerous levels of noise that results in hearing loss (Wilmot, 1972). By the end of the 20th century, many countries implemented hearing conservation programs that specified a 'maximum SPL of 85 or 90 dBA for worker's noise exposure for an 8-hour work day, with downward adjustments of exposure time for each 3 or 5 dBA increase (Meinke & Neitzel, 2020).

2.1 Noise-induced hearing loss

In the 20th century, noise-induced hearing loss was rigorously investigated in animals, resulting in a more accurate determination of the disease. Chinchillas, rats and guinea pigs have been used repeatedly to study anatomical, physiological, and behavioural effects of continuous and impulse noise exposures that produce either temporary or permanent threshold shifts (Escabi et al., 2019; Scheibe et al., 2000; Trevino et al., 2019). From these studies, exposure to loud noise sound produces a hearing loss, with the magnitude of the initial shift and the degree of recovery depending on characteristics of the exposure in the level, time and frequency domains, and characteristics of the individual. Sound induced damage to the auditory system can be divided into two types: Acoustic trauma, caused due to a single brief exposure to very high-intensity sound, and Noise-Induced Hearing Loss, caused by repeated exposure to moderate sounds. “The equal-energy principle effectively states equal energy will cause equal damage (in any given individual), such that similar cochlear damage may result after exposure to a higher level of noise over a short period as would occur after exposure to a lower level of noise over a longer period” (Ward et al., 1981)

2.2 Effects of noise exposure

The effects of noise exposure can be classified into two types,

- Auditory effects
- Non-auditory effects

2.2.1 Auditory effects

Hearing Threshold shift. The NIHL causes two types of effects on the hearing: temporary threshold shift (TTS) and permanent threshold shift (PTS). When the shift in the hearing threshold recovers back to the baseline level in a few hours, days or weeks after noise exposure, it is termed as temporary threshold shift (TTS). Very high-intensity noise can produce a permanent shift in the hearing threshold (PTS) where the threshold will not recover to the baseline value (Ryan & Bone, 1978). A 50 dB threshold shift immediately after single noise exposure can recover completely, while losses above 50 dB are likely to cause permanent loss of hearing sensitivity (Clark, 1991). TTS can be evolved into PTS if the exposure is repeated or continuous (Lonsbury-Martin et al., 1987), as in occupational noise exposure. Therefore, PTS can be defined as the persistence of threshold shift even after a recovery period after the exposure.

Over time, noise exposure leads to sensory cell damage in the spiral-shaped structure cochlea, especially the hair cells. These sensory hair cells and surrounding structures are vibrated by incoming acoustic signals and then convert this mechanical vibration into electrical events in the form of firings of the eighth cranial nerve fibres (Sataloff, 2006). Chronic exposure to loud noise damages the outer hair cells first, which are highly responsible for high-frequency sounds (3–6 kHz range). Over time, continuous exposure to excessive noise will result in impaired conduction of both low- and high-frequency sounds to the brain. (Kirchner et al., 2012) With the increase in the intensity of noise and duration of exposure, the damage in the sensory cells in the cochlea, the cochlear blood flow will also be impaired. Intense noise exposure leads to a high inflammatory response with the production of inflammatory cytokines and mobilization of immune cells (Frye et al., 2019). Additionally, noise-induced hearing loss increases metabolic stress, which results in local hypoxia and apoptosis of hair cells. (Ylikoski et al., 2008). As a result, the hair cells and their supporting cells will start to disappear and eventually, the nerve will begin to disintegrate and ultimately leads to irreversible hearing loss. With degeneration of the cochlear nerve fibres, there is corresponding degeneration within the central nervous system (Sataloff, 2006). Individuals with noise-induced hearing loss and also sensorineural hearing loss generally have normal-appearing eardrums and middle ear function. (Hong, 2005; Hong et al., 2013).

The auditory effects are commonly assessed with the help of different audiological tests like Pure Tone Audiometry. Audiometric profiles in noise-induced hearing loss usually show acute depression between 3 and 6 kHz (Kirchner et al., 2012). Noise exposure mainly affects the high frequencies, creating a V-shaped dip or notch between 3 to 6 kHz. Historically, noise exposure results in the typical ‘boilermakers’ notch at 4 kHz, spread to the neighbouring frequencies of 3 kHz and 6 kHz (Rabinowitz et al., 2006). The resonance frequency of the outer ear canal and the middle ear is also around 4 kHz, which could be a reason for the notch at 4 kHz (Pierson et al., 1994). In the older population, because of ageing, the notch will start to disappear eventually because presbycusis and noise exposure can also result in hearing loss at 8 kHz is debated (Ali et al., 2015). However, recent studies suggest that frequencies above 8 kHz may be more sensitive to noise damage (Ahmed, 2001; Korres, 2010; Mehrparvar et al., 2014).

On average, hearing loss induced by noise exposure will not exceed 75 dB in high frequencies and no greater than 40 dB in the lower frequencies. However, chronic exposure can result in severe to profound hearing loss in some individuals (Kirchner et al., 2012). The threshold loss in the right and left ear usually will be symmetrical, and asymmetries between left and right ear hearing thresholds are not common, even if doing so it will be less than 5 dB (Dobie, 2014; Royster et al., 1980) at high frequencies or with increasing levels of hearing loss (Berg et al., 2014). Also, individuals with asymmetrical noise-induced hearing loss may experience decreased ability to localize sounds (Hong et al., 2008).

Reduced speech discrimination scores. Noise-induced hearing loss can be associated with a reduction in speech discrimination scores in quiet as well as in the presence of background noise, even in the setting of a normal pure tone audiogram (Liberman et al., 2016). This could be due to the synaptopathy mechanisms, as discussed earlier (Kujawa & Liberman, 2009; Shi et al., 2016) and reduced temporal processing skills (Kumar et al., 2012) as a result of damaged connections between inner hair cells and low spontaneous rate auditory nerve fibres induced by noise, which are essential for temporal processing (Shi et al., 2016). It is recommended to perform speech recognition tests in quiet and in noise along with pure tone thresholds for the effective measurement of noise-induced damage (Kujawa & Liberman, 2009).

In addition, Auditory evoked potentials such as ABR can also detect noise-induced synaptopathy (Kobel et al., 2017). Shreds of evidence are stating that the ABR wave I amplitude reduced after noise exposure in animals with normal. Therefore, ABR wave I could predict the degree of synaptopathy hearing (Fernandez et al., 2015; Liberman & Kujawa, 2017). However, these studies yielded conflicting results in human subjects, with some providing evidence (Stamper & Johnson, 2015) and others not (Prendergast et al., 2017). The different electrode placement may affect the results (Trune et al., 1988), and this makes usage of wave I as a diagnostic predictor for cochlear synaptopathy less ideal (Prell & Brungart, 2016). Reduction in speech understanding ability due to synaptopathy deficits affects workers significantly and constitutes a significant limitation in hearing-critical jobs, resulting in reduced worker's chance of employment. These social effects related to noise-induced hearing loss will not be assessed in the regular hearing test battery.

Tinnitus and other sound-related sensations in the ear. The majority of individual's with noise-induced hearing loss reported having unilateral and bilateral tinnitus (Flores et al., 2015; Nageris et al., 2010). The prevalence of tinnitus among noise-exposed workers is about 24%, which is higher than the overall population's prevalence (14%) (Shargorodsky et al., 2010) and is very much higher in those in the military, up to 80% (Yankaskas, 2013). The severity of the tinnitus may be associated with the degree of noise-induced hearing loss (Dias & Cordeiro, 2008; Mazurek et al.,

2010) and affect the workers' quality of life. Hyperacusis is an auditory perceptual disorder where the person will have less tolerance to moderate-intensity everyday sounds induced by noise exposure (Baguley, 2003). Approximately 86% of hyperacusis patients also reporting tinnitus (Anari et al., 1999; Baguley, 2003). Data from female pre-school teachers exposed to noise at work suggests a model of hyperacusis whereby the prevalence is increased by additional factors such as stress, annoyance, or unrelated leisure noise (Fredriksson et al., 2017; Sheppard et al., 2020).

Otoacoustic emissions (OAE), with their high sensitivity and simplicity in administering, serve as an objective tool for assessing noise-induced hearing loss. In laboratory animals exposed to high noise levels, OAE amplitude reductions showed a good correlation with permanent threshold shift of more than 25 to 35 dB SPL measured by auditory evoked potentials and significant outer hair cell loss measured by histologic cochleograms (Hamernik & Qiu, 2000). Decreases in pure tone audiometry threshold and OAE amplitudes in noise-exposed industrial workers and military personnel were also reported (Attias et al., 1995; Desai et al., 1999). Click-evoked OAE showed excellent sensitivity (92.1%), and specificity (79%) in large sample subjects with noise-induced hearing loss and normal hearing (Attias et al., 2001) OAE can provide an early indication of noise-induced damage to the cochlea before it appears in pure tone audiometry (Job et al., 2009; Sisto et al., 2007)

2.2.2 Non-auditory effects

Non-auditory effects of noise can be defined as any adverse effects caused by exposure to noise on health and well-being, other than effects on the hearing organ and the effects which are due to the masking of auditory information (Butler et al., 1999). The different aspects of noise like frequency, intensity and duration also play a significant role in the non-auditory health effects (Butler et al., 1999). Noise can have a more comprehensive effect on human health and can have harmful effects on other non-auditory systems such as vestibular, cardiovascular, neuroendocrine, and psychological (Passchier-Vermeer & Passchier, 2000).

Vestibular effects. There are possibilities of noise-induced damage to the sacculocolic pathway and vestibular hair cells (Stewart et al., 2016; Wang et al., 2006). Several human and animal studies on cervical vestibular evoked myogenic potentials (VEMPs) and ocular VEMPs showed reduced, delayed or absent responses (abnormal). These findings support the hypothesis that noise can cause functional damage to the otolithic organs. Therefore, abnormal VEMPs can indicate more severe trauma, resulting in the poorer recovery of hearing (Wang et al., 2006).

Sleep disturbances. Noise can cause sleep disturbance and other deleterious health effects and decrease quality of life (Muzet, 2007). Continuous noise exposure can result in a longer duration of nocturnal awakenings, which usually occurs with noise levels greater than 55 dB (Muzet, 2007). Also, noise exposure results in lightening the threshold of arousal (Muzet, 2007). Although habituation on noise effects on sleep may occur over time (Vallet & Francois, 1982), small sleep deficits may persist for years (Friedmann, 1973). Different processes are explaining how noise exposure affects sleep and are complicated. The secondary effects of noise on sleep are a subjective feeling of decreased sleep quality, tachycardia, increase in stress hormones, and increased cognitive impairment (Stansfeld & Matheson, 2003).

Metabolic disturbances. Occupational noise and chronic environmental noise can increase stress hormones such as cortisol, adrenaline, and noradrenaline (Stansfeld & Matheson, 2003). Unregulated stress responses can have significant implications for numerous biological functions. For instance, chronic noise exposure can result in sleep disturbances, increased difficulty communicating, and disrupted cognition (Passchier-Vermeer & Passchier, 2000). Changes in stress hormone levels are related to the intensity and temporal aspects of the noise. Noise levels presented near the aural threshold of pain (130–140 dB SPL) results in increased release of cortisol (Hartmut Ising et al., 1999), whereas acute noise presented at levels of 90–100 dB(A) increases the release of adrenaline and noradrenaline (Hartmut Ising et al., 1980). The cortisol level varies along with the noise dosage, with the increase in noise level increase in cortisol level reported, which results in increased body stress (Zare et al., 2019).

Cardiovascular diseases. Prolonged stress levels resulting from noise exposure can increase the risk of life-threatening health conditions like cardiovascular disease (Babisch, 2003; Hartmut Ising et al., 1999). Cardiovascular Disease (CVD) is an umbrella term used to refer to a host of disorders of the heart and blood vessels. CVDs are the number one cause of death globally, responsible for 31% of all deaths (Lozano et al., 2012). Since chronic exposure to noise affects the body’s stress response, it is also thought to increase the risk of CVDs. Both occupational and environmental noise exposure can increase the risk of CVDs. Industrial workers exposed to occupational noise in addition to residential traffic noise would be at even greater risk for CVD (Benarroch, 2005; Tarride et al., 2009).

There was a significant association between occupational and air-traffic noise exposure and hypertension (van Kempen et al., 2002). Evans (1993) investigated the relationship between noise exposure and blood pressure and found an increase in blood pressure in noise exposure communities. Several studies suggest that rehearsal in memory can be slowdown by noise (Mohindra & Wilding, 1983). Hockey and

Hamilton (1970) found that “80 dB noise impaired recall of task-irrelevant information, but improved recall of relevant information”.

Cognitive impairments. Noise may cause cognitive impairment from a variety of mechanisms. There are shreds of evidence that demonstrated that children in noisy environments have decreased attention span and have lower performance on cognitive tasks when compared to children in a quiet environment (Cohen et al., 1980, 1981; Hygge et al., 2003). Ljung (2009) found that traffic noise significantly impaired children's reading comprehension ability and primary mathematic performance significantly. Different hypotheses are explaining the reason for the cognitive impairment due to noise exposure. In their hypothesis, Shield & Dockrell (2003) suggested that “the cognitive impairment from noise was due to cognitive coping where children ‘tune out’ excessive stimulation and have generalized poor attention”. In another hypothesis, Poulton (1978) and Shield & Dockrell (2003) suggested that a high level of arousal caused by noise resulted in an inability to concentrate. Similar to the theories of noise-induced CVDs, noise-induced consequences on learning, memory, and brain function could also be mediated by the altered stress responses (Hayes et al., 2019).

Psychological disturbances. The consequences of noise-induced hearing loss to the individual, although not life-threatening, can be distressing. As a result of hearing loss, an individual’s ability to communicate with the environment is limited, leading to increased social stress, depression, embarrassment, poor self-esteem, and relationship difficulties (Hong et al., 2013). A male with severe noise-induced hearing loss attending a party is probably unable to use either communication, listening or monitoring when interacting with the other guests, which lowers the degree of participation in the ‘normal’ world and undermines the self (Hallberg & Barrenäs, 1993). In a noisy environment, the resulting social handicap from communication difficulties is exacerbated, and extremely annoyed people can develop psychological ill-health (Mucci et al., 2020).

Social life and communication. Many of the effects of noise on social life reflect the direct effects of noise on communication. There is evidence that noise may reduce helping behaviour, increase aggression and reduce the processing of social cues seen as irrelevant to task performance (Jones et al., 1981). Hallberg & Barrenäs (1993) reported that participating in parties and other social gatherings along with their husbands with noise-induced hearing loss resulted in stress and vigilance in most spouses and stated that many spouses experienced a change in personality of their husbands when the couple gathered with other people. In addition to that, the impact of noise-induced hearing loss on their interpersonal relationship resulted in four qualitatively different strategies used by the spouses: (a) co-acting, (b) the minimizing, (c) the mediating and (d) the distancing strategies (i.e.) a combination of motivating and demotivating behaviours were seen among spouses with noise-induced hearing loss husbands.

2.3. Dealing with Noise-induced hearing loss

As discussed earlier, awareness about noise-induced hearing loss among health professionals emerged in the early 20th century, but nobody recommended the preventive procedure during those periods. After the intervention of audiometer and other sound measuring instruments, researchers can measure the dangerous sound levels, which helped them understand the effect of noise exposure on human hearing and resulted in the development of hearing conservation programs. By the end of the

20th century, knowledge about the non-auditory effects of noise-induced hearing loss also emerged among health professionals.

However, the current noise regulations aim to reduce the risk of hearing loss at frequencies important for speech perception but do not address other auditory and non-auditory deficits. For the treatment to be more effective, both assessment and management should focus on hearing-related problems (auditory), along with social, psychological and other non-audiological aspects (non-auditory). This can be achieved by including the ICF model (bio-psycho-social model) given by WHO (2001) in the audiological test battery, enabling a broader perspective assessment of a person's health.

2.4. International Classification of Functioning, Disability and Health (ICF)

Classification of health components concerning a person's experience has emerged during the past four decades. In the early 1970s, the imperfection of the International Classification of Diseases (ICD) has been confessed by the World Health Organization in describing the effects of non-acute diseases. As a result of this confession, the International Classification of Impairment, Disability and Handicaps (ICIDH) was developed to explain and classify disabilities (World Health Organisation, 2001). The ICIDH was identified as progress in rehabilitation contexts as it focused on the consequences of diseases. Unluckily, the ICIDH also failed to include the experiences of disability groups (Schneidert et al., 2003). In the mid-1980s, a revision of the ICIDH was initiated, which resulted in the development of updated versions of the ICIDH, lastly designated the International Classification of Functioning, Disability, and Health (ICF) in 2001 (World Health Organisation, 2001). The broader perspective of a person’s health can be assessed from information on diagnosis plus information on functioning.

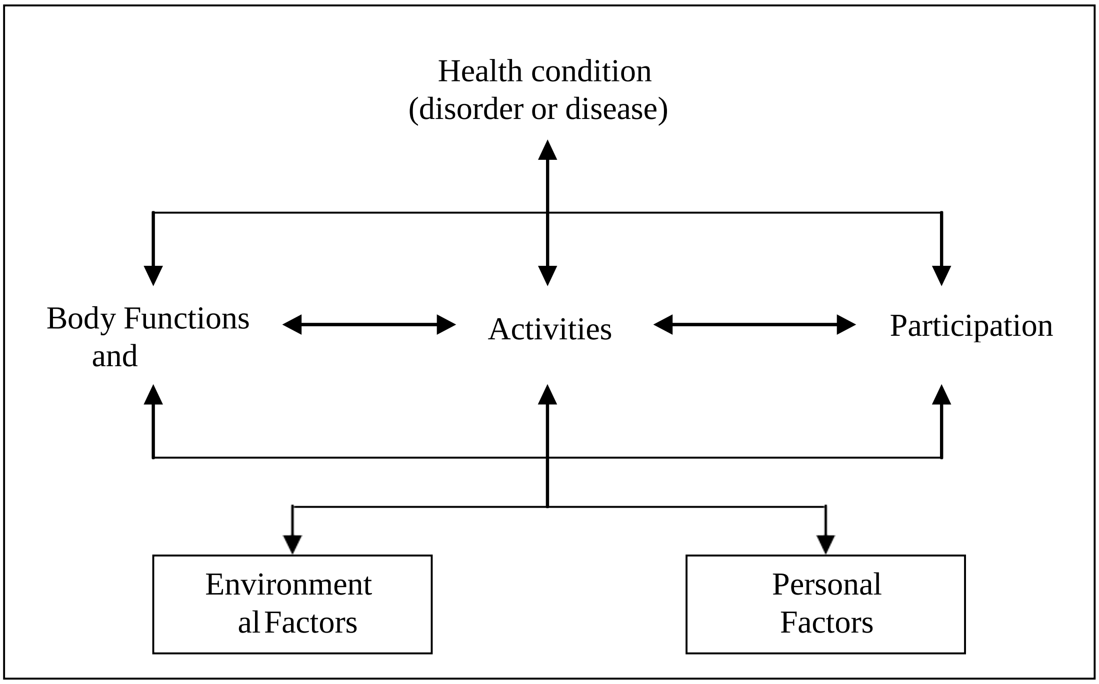
The International Classification of Functioning, Disability and Health (ICF) is both a classification and a conceptual model used when describing features related to health, such as human functioning or disability. It does not classify people but instead represents the health situation of persons with health conditions, i.e., the health and health-related states associated with all health conditions can be described using the ICF (World Health Organisation, 2001). The ICF is based on a bio-psycho-social approach to functioning and health. The concept is developed concerning the perspective of the body, the individual and the society, and also it represents the opposite designations functioning and disability.

The classification describes human functioning with the positive concepts of body functions, body structures, activities, and participation. Disability, in the ICF, is defined with the negative terms impairments (i.e., problems in body structures or functions), activity limitations, and participation restrictions. Accordingly, disability is described in terms of functioning, i.e., when the level of functioning is ‘below a determined threshold along a continuum for a specific health domain (Bickenbach et al., 2012), functioning becomes a disability. Moreover, ICF explains the external factors, i.e., (Contextual factors) to understand human functioning and disability better. This context in the ICF is described as environmental factors and personal factors. Hence, the ICF is multidimensional, mentioning the importance of both internal and external influences on human functioning and disability.

2.5 ICF – A Conceptual Model

Figure 2.1

Interactions Between the Components of ICF (World Health Organisation, 2001)



The ICF is an interactive model in which each factor can influence others in a complex way of interactions. A fundamental standpoint in the model is the non-causal relationship between different components (Cieza et al., 2008; Cummins et al., 2010). Though functioning is associated with a health condition, it is not always viewed as a direct consequence. Instead, it is a consequence of a complex interaction between the health condition and contextual factors (Bickenbach et al., 2012).

2.5.1 Activities & Participation

Activity refers to ‘the execution of a task or an action by an individual and should be valued concerning the nine life areas listed in the ICF (e.g., communication, interpersonal interactions and relationships, major life areas). These life areas are shared between activities and participation, with the result that, in each area, there can be either of the two concepts. If an individual has difficulties executing a task or an action, this difficulty is referred to as an activity limitation (World Health Organisation, 2001).

‘Participation’ is closely connected to the activity, defined as ‘involvement in a life situation’. The problems that an individual may experience in the involvement in life situations are denoted as participation restrictions. Participation in a life situation means ‘taking part’, ‘being included’ or ‘being engaged’ in an area of life (World Health Organisation, 2001).

2.5.2 Body functions & Body structures

Located to the left in the model are the dimensions of body functions and body structures. Body functions refer to the physiological processes of body systems (including psychological functions), whereas body structures are the anatomical parts of the body (organs, limbs). The negative aspect of these two concepts is denoted as the shared notion of ‘impairment’.

2.5.3 Contextual factors

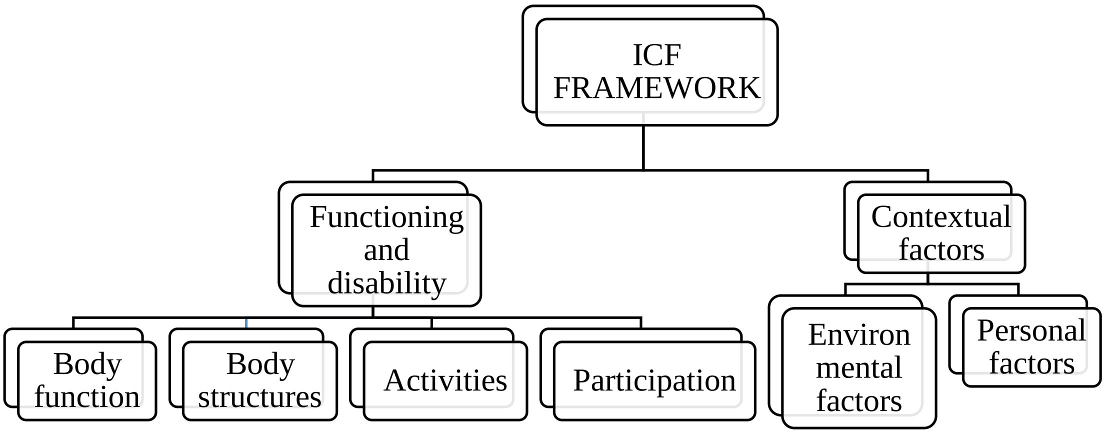
In the ICF, contextual factors include two dimensions that might influence the health of an individual with a health condition, environmental factors and personal factors. The main difference between these two factors is the actual localization in relation to the individual, with environmental factors being viewed as external factors to the individual. In contrast, personal factors are internal. ‘personal factors are the particular background of an individual`s life and living and comprise features of the individual that are not part of a health condition or health state. These factors may include gender, race, age, other health conditions, fitness, lifestyle, habits, upbringing, coping styles,…’ (World Health Organisation, 2001). Environmental factors in the ICF are viewed as human-related, i.e., social and attitudinal, or physical (World Health Organisation, 2001). Environmental factors are always considered as having a positive or negative influence on the functioning of an individual in the specific situation classified and are therefore referred to as either facilitators or hindrances/barriers. On the one hand, environmental factors are described as the individual environment, i.e., the natural environment or the 'face-to-face' environment, which the individual might come in contact with. On the other hand, they include the societal environment, described as the informal and formal structural systems within the individuals' living context (World Health Organisation, 2001).

2.6 ICF –Classification

As a whole, ICF classifies health conditions into two parts: (i) functioning and disability; and (ii) contextual factors. These two parts are further subdivided into the following components: body functions, body structures, activities and participation, environmental factors, and personal factors (Schneidert et al., 2003). The physiological functioning of body systems is included in body function, such as sound detection. In contrast, anatomical parts of the body are included in the body structures (e.g.) Ear, heart. The execution of a task or action by an individual and participation comes under the activities. Environmental factors contain the physical and social environment where people live (e.g.) family support and relationship. And, the intrinsic part of the individual not associated with the health condition is related to the personal factors (e.g.) Age, gender.

Figure 2.2

ICF framework and Its Domains



2.7 ICF Core Sets

To facilitate the applicability of ICF in clinical settings or research, the WHO initiated the ICF core sets projects (Bickenbach et al., 2012; Stucki & Grimby, 2004). In total, the ICF model contains over 1500 categories, which makes its implementation in clinical practice and research challenges. To address this challenge, ICF Core Sets have been developed. ICF Core Sets include the ICF categories that are most relevant for describing the functioning of persons with specific health conditions. A core set is a set of ICF categories of particular relevance for a certain diagnosis or health condition. Core sets have been developed for various conditions. There are two kinds of core sets: comprehensive core sets, consisting of all ICF categories relevant to the specific area, and brief core sets, which are more compressed versions of the comprehensive core sets (Selb et al., 2015). Until 2017, 35 core sets for different health conditions, circumstances, situations, and generic core sets have been developed (Stucki et al., 2017). In 2008, an ICF core sets project targeting adults with HL was initiated (Danermark et al., 2010). In other core set projects, several other types of outcome measures have been identified when targeting the researcher perspective, such as standard provider-reported or third-party-reported measures (e.g. clinician assessments), nonstandard measures (e.g. single questions) (Escorpizo et al., 2011), clinical measures (e.g. joint pain or joint swelling), and technical measures (e.g. X-ray) (Zochling et al., 2006).

To conclude, the usefulness of ICF goes beyond that of measuring population health. With ICF, it is possible to identify those environmental factors that impact areas of participation such as education, transportation, or housing, maybe determinants of health (Cerniauskaite et al., 2011). Including ICF in assessing noise-induced hearing loss will give a better outcome than the conventional audiological test battery.

Chapter III

METHODS

3.1 Research design and Participants

A combination of prospective (qualitative telephonic interview method) and retrospective (auditory correlates) study design was used. Individuals with NIHL who reported to the department of clinical services and underwent audiological testing at the department of Audiology were considered for the study. A total of 83 case files were obtained and scrutinized for inclusion criteria (discussed below). A total of 45 participants were included in this study in the age range of 35 - 65 years with a mean age of 52.7 ± 8.00 SD. Informed consent was obtained from all the participants before carrying out the phone interview.

3.2 Inclusion Criteria

The participants who had minimal exposure to industrial noise exposure [>90 dB (A)] for more than three years (with a minimum of 8 hours/day exposure) were included in the study. The participants had sensorineural hearing loss (any degree) with an air-bone gap not exceeding 10 dB HL. These participants did not have any complaints or history of ear abnormality (structural or neurological), cognitive deficits or speech and language deficits. The former conditions were ruled out by the presence of 'A' type of tympanogram and the presence of acoustic reflexes for at least 500 and 1000 Hz, while the latter conditions were ruled out in a detailed case interview. The demographic details, including age, gender, general health status, the onset of hearing loss, duration of noise exposure, is shown in Table 3.1.

Table 3.1

Demographic Information of the Participants in the Study.

Demographic information	Mean (± one SD)
Sample size (n)	45
Gender	All males
Age (years)	52.67 ± 8.00
Total number of years of Noise exposure	26.38 ± 7.90
Duration of noise exposure per day (hours)	8.40 ± 0.87

Note. SD = Standard Deviation

3.3 Ethical Considerations

In the present study, all the testing procedures were carried out on humans using non-invasive techniques, adhering to the guidelines of the institutional research advisory board. The approval from the ethical committee of the institute was also received before conducting the study. All the procedures were explained to the participants, and informed consent was taken from all the study participants.

3.4 Procedure

The study was conducted in three phases.

3.4.1 Phase I: Obtaining responses to open-ended questions

In a retrospective analysis, case files were collected from the medical record section from 2013 to 2020, diagnosed with the NIHL condition. The demographic (including age, gender, general health status, the onset of hearing loss, duration of noise exposure, and prior investigation) information about the participants was noted. Two open-ended questions were adopted from Granberg et al. (2014). These questions were related to the impact of noise-induced hearing loss in terms of the problem faced and life effects associated with the noise-induced hearing loss: (a) A problem question (PQ): Make a list of things you find challenging or problems you have due to your hearing problem. List as many as you think of; (b) a life effects question (LEQ): Please state the effects of the hearing problem on your day-to-day life. List all the effects, as many as you can.

Answers to these open-ended questions can elicit responses that can be coded based upon the different ICF components: body structure and functions, activities & Participation, environmental factors, and personal factors that will cover participant's perspectives on aspects of the disability and the effects of noise-induced hearing loss on daily life. The questions were given to the three native Kannada speakers and were translated to Kannada. A translation that was agreed upon by 2/3 native speakers was considered for use in the study. These questions were reverse translated into English to see for translation errors (if any). The responses with translation errors were given to another blinded referee whose coding was used to accept or reject a particular code for the question. The finalized questions were loaded onto a google form containing three sections. Section 1 explained the purpose of the study, and informed consent was obtained. Section 2 targeted demographic details and the two open-ended questions (both in English and Kannada languages). Section 3 comprised of auditory test results. The questions in each section used in the data collection are given in Appendix 1.

The participants were contacted through mobile phones and were informed about this study; only those willing to participate were included. They were given two options either answer these questions with the google form link or answer through the mobile phone. The mobile conversations were recorded and later transcribed verbatim with the help of native Kannada speakers.

3.4.2 Phase II: International Classification of Functioning, Disability and Health (ICF) coding

All the data were linked to the ICF framework, with the help of an analysis method developed and referred to as the 'seven steps linking procedure' (Hsieh & Shannon, 2005). The seven steps are (1) meaningful unit identification, (2) defining the significant concept(s), (3) underlying meaning interpretation, (4) determining the linking unit(s), (5) appropriate ICF category derivation, (6) documenting the linking rule applied, and (7) verifying the representativeness of the ICF categories chosen. The transcribed responses were given to 3 coders to improve the reliability of the coding process. They were taught about these coding processes and were asked to code for all the responses individually. The number of individual responses for PQ and LEQ and total responses (PQ + LEQ) was determined. If there was any disagreement in the coding, it was discussed between the coders, and a final consensus was obtained. Reliability analysis for these three coders coded responses was carried out using IBM Statistical Package Social Sciences (SPSS) version 26.0 (SPSS Inc, Chicago). The frequency counts for each code and overall domains were obtained using SPSS, while the graphic representation was conducted using GraphPad Prism version 9.0 software (Graph Pad, California).

3.4.5 Phase 3: A retrospective collection of auditory effects from clinical records

The data collection for audiological profiling was done retrospectively by studying the corresponding case reports from the medical records section, Department of Clinical Services (DCS), AIISH Mysore. Clients enrolled and evaluated in AIISH (reported and assessed between 2013 and 2019) with the cause of noise-induced hearing loss (as mentioned in case files) were considered. The test results in pure tone audiometry (Pure Tone Average, Degree of hearing loss and configuration of hearing loss) and Speech audiometry (Speech recognition thresholds and speech identification scores) were noted, with the demographic details as presented in Table 3.2. These data were entered by the experimenter on the google form (Section III in G-form).

Table 3.2

The Audiological Profile of the Participants Considered in the Study

Audiological Profile	Mean (± one SD)	
	Right Ear	Left Ear
Pure Tone Average (dBHL)	26.31 ± 10.44	26.49 ±13.62
Speech Recognition Threshold (dBHL)	25.78 ± 11.02	25.89 ± 11.80
Speech Identification Score	98% ± 0.03	98% ± 0.06
Configuration of hearing loss (%)		
Flat	7 (15.56)	10 (22.22)
Noise-Notched	20 (44.44)	16 (35.56)
Sloping	10 (22.22)	11 (24.44)
U-Shaped	8 (17.78)	8 (17.78)
Degree of hearing loss (%)		
Normal	7 (15.56)	8 (17.78)
Minimal	17 (37.78)	15 (33.33)
Mild	17 (37.78)	18 (40.00)
Moderate	3 (6.67)	3 (6.67)
Moderately Severe	1 (2.22)	1 (2.22)
Tympanometry (%)		
A – Type tympanogram	45 (100)	45 (100)
Oto-Acouctic Emission (%)		
Normal	8 (17.78)	8 (17.78)
Partial Dysfunction	7 (15.56)	6 (13.33)
Complete Dysfunction	30 (68.18)	31 (70.45)

Reflexometry (%)		
Ipsilateral responses		
Present	22 (48.89)	13 (28.89)
Absent	23 (51.11)	32 (71.11)
Contralateral responses		
Present	17 (37.78)	12 (26.67)
Absent	28 (62.22)	33 (73.33)
Symmetry (%)		
Symmetrical	38 (84.44)	
Asymmetrical	7 (15.56)	

Note. SD = Standard Deviation

3.5 Quantitative Data Analyses

The statistical analysis was carried out using IBM SPSS version 26.0 and GraphPad Prism 9 software. Descriptive statistics for means and standard deviation (SD) were obtained. The total number of responses for the PQ and LEQ questions were obtained. An inter-rater reliability check was carried out using Bland-Altman agreement analysis. This analysis was carried out for combined scores (PQ + LEQ) of each following domains: body function (BF), activity limitation and participation restriction (AL), and environmental factors (EF). In addition, Bland–Altman agreement analysis was also done on the composite score (BF, AL and EF). The difference in the ratings of the coders against the average ratings in all the above domains of ICF was compared. The limits of agreement are shown in a 95% confidence interval where variations between two raters should fall with ± 1.96 standard deviations (SD) of the difference scores (Giavarina, 2015) to determine any significant differences between the coder ratings.

After determining the agreement between the coders, the normality check was performed using Shapiro Wilk's test. Based on the results of the normality test, Wilcoxon signed-rank test was conducted to check for the significant difference between the number of responses. Whenever significant, the effect size was calculated by using the formula $r = (Z/\sqrt{N})$. To determine the relationship between the problems mentioned in the PQ and LEQ questions with the audiological variables, the test of Spearman's rho correlation coefficient was performed. The two-tailed significance level of $p < 0.05$ was considered statistically significant for all the analyses.

Chapter IV

RESULTS

The present study was carried out to profile the perceptual correlates of noise exposure and correlate them with conventional clinical measures. The participants were 45 individuals with NIHL, and they were given two open-ended questions and the response to two open-ended questions were collected through a phone call which was recorded and transcribed verbatim and converted to ICF codes with the help of three trained coders. Later the audiological data were collected from their case files. Descriptive and inferential statistics were carried out using SPSS (version 26.0) software. Shapiro Wilk's test of normality was done to check whether the data is normally distributed or not, and this study's data were found to be non-normally distributed ($p < 0.05$). Hence, non-parametric inferential statistics was carried out for further analysis. The results of the study are explained in the following headings:

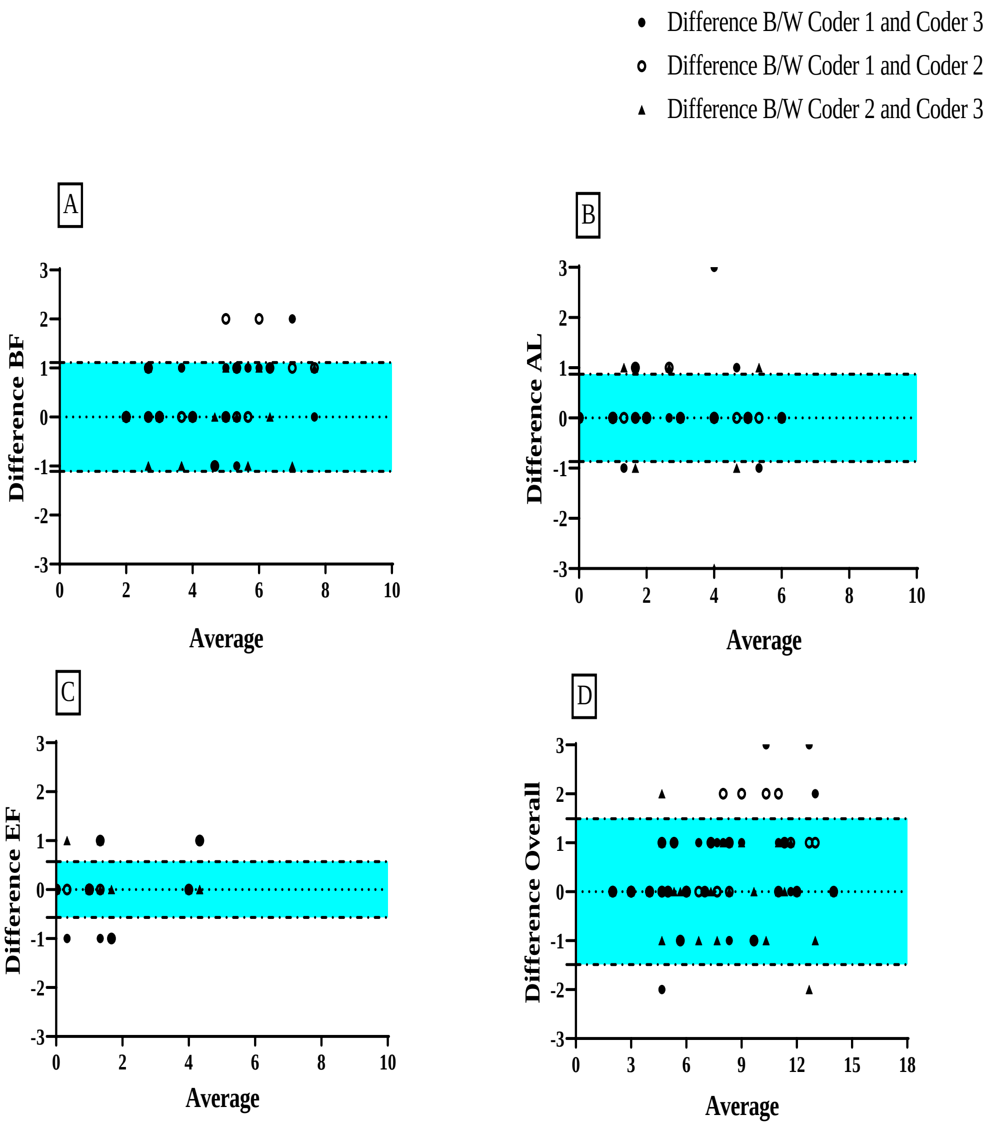
- 4.1 Inter-Coder reliability estimation
- 4.2 Quantification of problem and life effects of noise-induced hearing loss
- 4.3 Impairment of Body Function
- 4.4 Activity Limitations and Participation Restrictions
- 4.5 Environmental factors and personal factors

4.1 Inter-Coder reliability estimation

The results of the modified Bland-Altman plot depicting the average of the total codes on the x-axis and the difference in total frequency of coder ratings (1 vs 2; 2 vs 3; 1 vs 3) on the y-axis is shown in Figure 4.1 (A-D). On visual inspection of the Bland-Altman plot, it is apparent that most of the composite frequency of the coders (92 out of 102) fell within the limits of variance (±1.96 SD, blue shaded area in Figure 4.1 D). The analyses of the outliers in Figure 4.1 (D) showed that 10 out of 102 observations did not correlate well, accounting for an error of 7.40%. The percentage of inter-rater reliability in composite scores was approximately 92.60%, indicative of high reliability in the rater codings for overall responses. Similarly, Bland-Altman inter-rater agreement analyses for domain wise codings indicated a biasing error of 2.22%, 10.37%, and 8.14% for combined scores (PQ and LEQ) of body function (BF), activity limitation and participation restriction (AL), and environmental factors (EF). The corresponding inter-rater reliability was 97.78%, 89.63% and 91.86%.

Figure 4.1

Bland-Altman Plot Depicting Inter-Rater Variability for Each ICF Domain



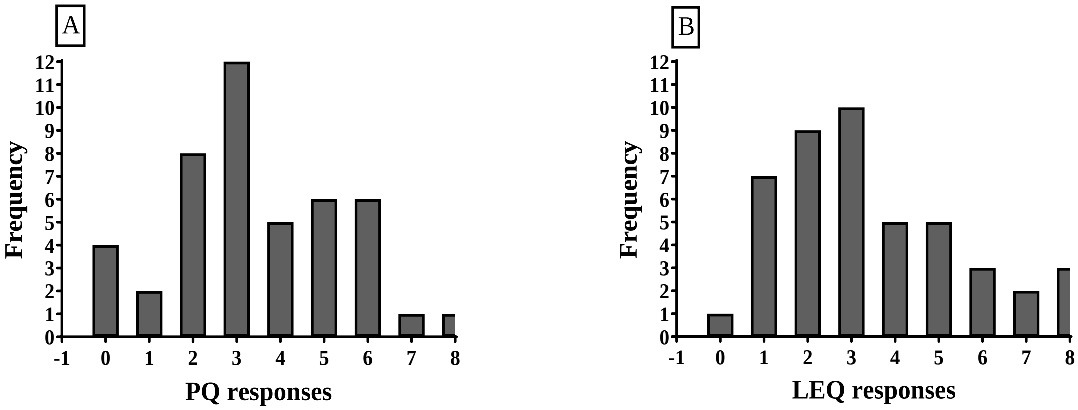
Note. (A) Body function, (B) Activity limitation and participation restrictions, (C) Environmental factors and (D) Overall responses. The blue shaded area represents the limits of agreement (± 1.96 SD) for each sub-domain and overall responses.

4.2 Quantification of problem and life effects of noise-induced hearing loss

Using two open-ended questions, a total of 311 responses (PQ: 155 responses, and LEQ: 156 responses) were obtained from 45 adults with NIHL. The number of meaningful responses ranged from 0 to 8, and most of the participants provided 2-5 meaningful responses for both the questions, as shown in Figure 4.2.

Figure 4.2

The Bar Graph Depicting the Number of Problems Listed in (A) PQ and (B) LEQ



The overall mean number of responses per participant was 3.44 and 3.46 for PQ and LEQ, respectively. No significant differences were observed in the total number of responses between the two questions, as seen in Table 4.1. But there was a significant difference between the two questions in the body function, activity limitations and participation restriction and environmental factors individually. The LEQ mean scores were higher in body function (2.20), and environmental factors (0.84) and the PQ mean scores were higher for activity limitations and participation restriction (1.80).

Table 4.1

Number of Responses in Each of the ICF Domains Listed in the Two Questions

Category	PQ Mean (± one SD)	LEQ Mean (± one SD)	Wilcoxon (Z)	Sig. (*p*)	Effect size r = (Z/√N)
All responses	3.44 (1.92)	3.46 (2.08)	- 0.32	0.74	
Body function	1.62 (0.88)	2.20 (1.50)	- 2.03	0.04	-0.15
Activity limitations and participation restriction	1.80 (1.45)	0.29 (0.68)	- 4.78	0.00	-0.50
Environmental factors	0.02 (0.15)	0.84 (1.15)	- 4.60	0.00	-0.73
Personal factors	0.04 (0.20)	0.08 (0.28)	- 0.82	0.41	

Note. SD= Standard Deviation

Spearman's rank correlation for demographic data and the audiological results reveals a significant relationship ($p < 0.05$) between audiological parameters and the total number of years of exposure and age. There was no significant correlation between audiological parameters and the duration of noise exposure.

Audiological parameters except symmetry and SIS showed a significant correlation with age (demographic data). Also, reflexometry showed a significant correlation with the total number of years of exposure, while other audiological parameters showed no significant correlation.

Table 4.2

Relationship Between Demographic Information and Audiological Variables

Audiological parameter	Spearman's rho Correlation		Significance (*p*)	
	RE	LE	RE	LE
Correlation between age and audiological parameters				
PTA	0.40*	0.50*	0.01	0.00
SRT	0.46*	0.45*	0.00	0.00
SIS	-0.04	-0.20	0.77	0.19
Degree of hearing loss	0.47*	0.60*	0.00	0.00
Configuration of hearing loss	0.55*	0.52*	0.00	0.00
Symmetry	-0.23		0.13	
Reflexometry				
Ipsi	0.27	0.48*	0.08	0.00
Contra	0.31*	0.42*	0.04	0.00
OAE	0.49*	0.50*	0.00	0.00
Correlation between duration of noise exposure and audiological parameters				
PTA	-0.02	-0.07	0.88	0.67
SRT	-0.22	-0.19	0.15	0.22
SIS	-0.06	0.07	0.71	0.63
Degree of hearing loss	0.00	-0.08	0.99	0.59
Configuration of hearing loss	-0.04	0.01	0.80	0.93
Symmetry	0.06		0.68	
Reflexometry				
Ipsi	-0.15	-0.13	0.33	0.39
Contra	-0.12	-0.24	0.44	0.11
OAE	-0.20	-0.20	0.19	0.18

Correlation between the total number of years of noise exposure and audiological parameters				
PTA	0.13	0.18	0.41	0.23
SRT	0.22	0.28	0.15	0.07
SIS	-0.29	-0.11	0.05	0.46
Degree of hearing loss	0.18	0.26	0.24	0.08
Configuration of hearing loss	0.17	0.22	0.26	0.16
Symmetry	-0.01		0.95	
Reflexometry				
Ipsi	0.34*	0.39*	0.02	0.01
Contra	0.29	0.33*	0.05	0.03
OAE	0.27	0.27	0.08	0.07

Note. PTA = Pure Tone Average, SRT = Speech Recognition Threshold, SIS = Speech Identification Score, OAE = Oto-Acoustic Emission

* indicates correlation is significant at the 0.05 level (2-tailed).

The Spearman's rho correlation between the number of responses to PQ and LEQ and the audiological variables showed that there was no significant relationship ($p < 0.05$) between the number of responses in PQ and LEQ questions and any of the audiological variables (Table 4.3).

Table 4.3

Relationship Between the Number of the Responses to Problem and Life Effects Question and the Audiological Variables

Audiological parameter	Spearman's rho Correlation		Significance (*p*)	
	RE	LE	RE	LE
Correlation between overall PQ and audiological parameters				
PTA	0.07	0.14	0.66	0.36
SRT	0.06	0.11	0.68	0.48
SIS	0.01	-0.08	0.95	0.58
Degree of hearing loss	0.08	0.20	0.59	0.18
Configuration of hearing loss	-0.10	-0.01	0.51	0.94
Symmetry	-0.25		0.10	
Reflexometry				
Ipsi	0.12	0.06	0.45	0.70
Contra	0.16	0.08	0.30	0.58
OAE	0.08	0.02	0.63	0.88
Correlation between overall LEQ and audiological parameters				
PTA	0.05	0.09	0.76	0.54
SRT	0.07	0.10	0.66	0.50
SIS	-0.07	-0.16	0.63	0.29
Degree of hearing loss	0.08	0.10	0.58	0.51
Configuration of hearing loss	-0.09	-0.11	0.54	0.47
Symmetry	0.04		0.79	

Reflexometry				
Ipsi	-0.10	-0.05	0.51	0.76
Contra	0.02	0.09	0.91	0.55
OAE	-0.10	-0.13	0.52	0.40

Note. RE= Right Ear, LE= Left Ear, PTA= Pure Tone Average, SRT= Speech Recognition Threshold, SIS= Speech Identification Score, OAE= Oto-Acoustic Emission

4.3 Impairment of Body Function

Impairment of body function was the most frequently listed problem and life effects associated with NIHL. The frequency of each code in body structure and function is shown in Table 4.4. There were 172 responses, with 76 responses from PQ and 96 from the LEQ. The most frequently occurring category was "hearing functions" (b230). Other frequently occurring categories included: "hearing function, Unspecified" (b2309), "Range of emotion" (b1522), "Endocrine gland functions" (b555), "Ringing in ears or tinnitus" (b2400), and " Pain in head and neck" (b28010).

Table 4.4

Frequency Counts of All the Responses Under the Domain of Impairments of Body Functions

Function	ICF code	PQ (n= 76)	LEQ (n=96)	Total
Hearing functions	b230	23	0	23
Range of emotion	b1522	0	17	17
Endocrine gland functions	b555	0	14	14
Hearing functions, unspecified	b2309	20	0	20
Ringing in ears or tinnitus	b2400	16	0	16
Pain in head and neck	b28010	0	14	14
Amount of sleep	b1340	0	11	11
Speech discrimination	b2304	14	0	14
Increased blood pressure	b4200	0	9	9
Digestive functions	b515	0	6	6
Onset of sleep	b1341	0	4	4
Heart functions	b410	0	5	5
Sound detection	b2300	3	0	3
Pain in upper limb	b28015	0	3	3
Dizziness	b2401	0	2	2
Sensory functions related to temperature and other stimuli, other specified	b2708	0	1	1
Sensitivity to vibration	b2701	0	1	1
Sensitivity to a noxious stimulus	b2703	0	1	1
Sensations associated with hearing and vestibular function	b240	0	1	1

Sensations associated with cardiovascular and respiratory functions	b460	0	1	1
Pain in lower limb	b28016	0	1	1
Pain in body part, other specified	b28018	0	1	1
Energy level	b1300	0	1	1
Emotional functions, unspecified	b1529	0	1	1
Emotional functions, other specified	b1528	0	1	1
Sensation of pain	b280	0	1	1

4.4 Activity Limitations and Participation Restrictions

Activity limitations and participation restrictions were impacted second most frequently, with responses, including 86 responses from PQ and 8 from LEQ. The most frequently occurring category was "communicating with - receiving - spoken messages" (d310)" which had 23 responses and was followed, "focusing attention" (d160), "using telecommunication devices" (d3600), "using communication techniques" (d3602) and "speaking" (d330) shown in Table 4.5.

Table 4.5

Frequency counts of all the responses under the domain of Activity Limitation and Participation Restrictions

Function	ICF code	PQ (n=86)	LEQ (n=8)	Total
Communicating with - receiving - spoken messages	d310	30	0	30
Using telecommunication devices	d3600	14	0	14
Using communication techniques	d3602	14	0	14
Focusing attention	d160	16	0	16
Speaking	d330	5	0	5
Communicating with - receiving - body gestures	d315	0	7	7
Communicating - receiving, other specified and unspecified	d329	6	0	6
Using communication devices and techniques	d360	1	0	1
Undertaking a single task	d210	0	1	1

4.5 Environmental factors and personal factors

This was the least mentioned category with 39 responses, including 1 from PQ and 38 from LEQ. The most frequently occurring categories included "Sound intensity" (e2500), which had 26 responses. This is followed by "individual attitudes of immediate family members" (e410), "individual attitudes of extended family members" (e415) and "individual attitudes of friends" (e420) shown in Table 4.6. Coping styles are the only responses mentioned in the personal factor with an overall count of 6 (2 responses in PQ and 4 in LEQ). The most frequently occurring categories are given in Figure. 4.3.

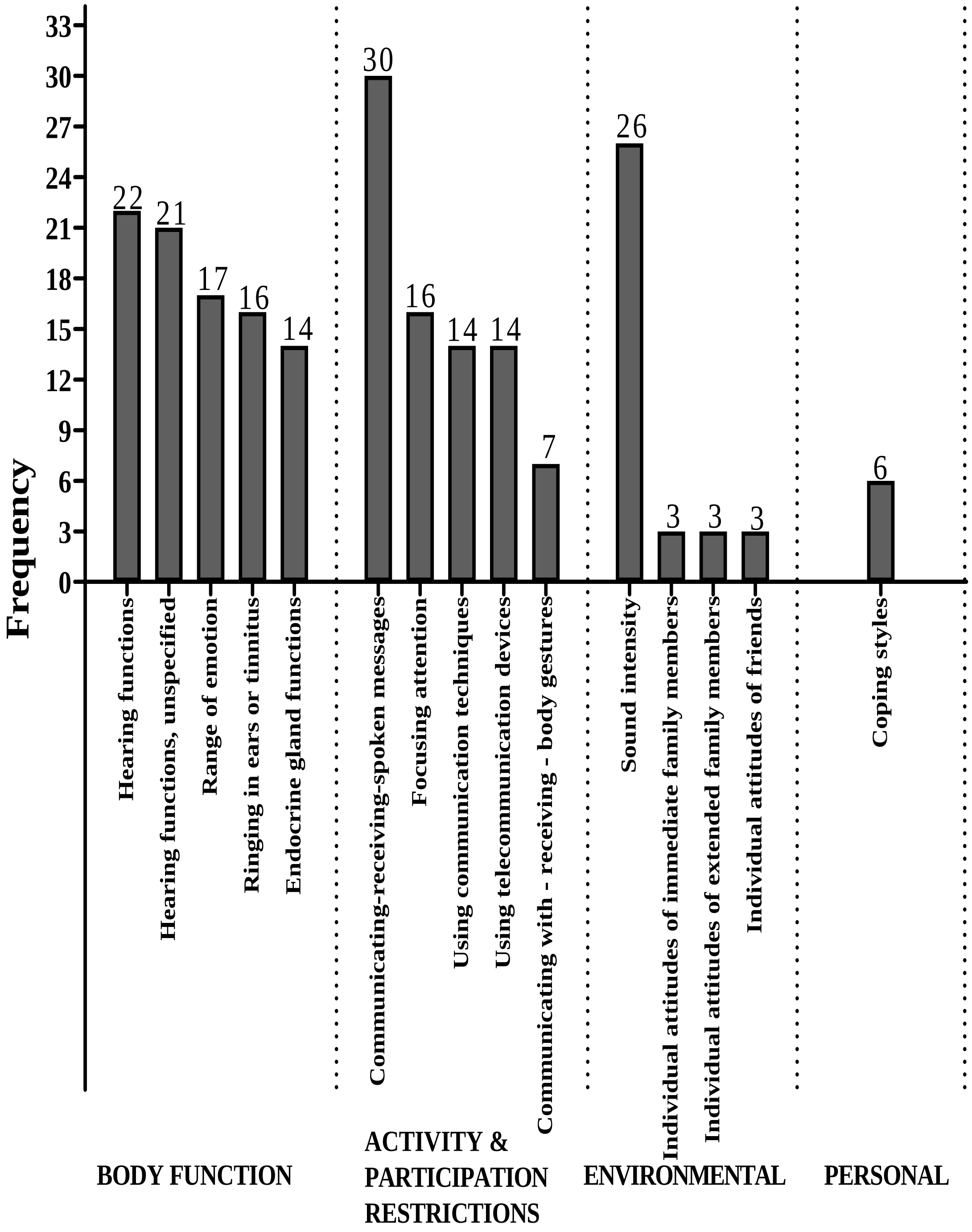
Table 4.6

Frequency Counts of All the Responses Under the Domain of Environmental Factors

Function	ICF code	PQ (n=1)	LEQ (n=38)	Total
Sound intensity	e2500	0	26	26
Individual attitudes of immediate family members	e410	0	3	3
Individual attitudes of friends	e420	0	3	3
Individual attitudes of extended family members	e415	0	3	3
Attitudes, unspecified	e499	0	2	2
Individual attitudes of acquaintances, peers, colleagues, neighbours and community members	e425	0	1	1
Sound quality	e2501	1	0	1

Figure 4.3

The Bar Graph Depicting the Most Frequently Reported Factors Impacted Due to NIHL for All Domains.



Chapter V

DISCUSSION

The present study investigated problems (PQ) and life effects (LEQ) experienced by 45 factory workers using an open-ended questioning approach. Responses from each participant were coded using the ICF classification system. There were 311 meaningful responses (PQ: 155 responses, and LEQ: 156 responses) from the participants, with 2-4 meaningful responses from each. These responses accentuate the need for understanding the multi-faceted nature of noise-induced hearing loss (NIHL) and its impact on various domains (other than the auditory domain). Also, it points that including an open-ended questioning approach has a significant effect in generating the appropriate responses to the effects of noise-induced hearing loss. The PQ or LEQ responses were not correlated with the audiological variables PTA, SRT and SIS. This signifies the need to understand the other confounding factors that are associated with NIHL. And these confounding factors cannot be identified by the conventional audiological assessment alone because not even a single audiological factor correlated with the confounding factors.

5.1 Problem and life effects of noise-induced hearing loss

Spearman's rank correlation for demographic data and the audiological results reveals a significant relationship ($p < 0.05$) between audiological parameters and the total number of years of exposure and age. With the increase in age, the total number of years of exposure also increases, also blood pressure and serum cholesterol levels increase, so the elderly population are more susceptible to NIHL when compared to the younger population (Toppila et al., 2009). The duration of noise exposure showed no significant correlation between the audiological parameters. The mean duration of noise exposure per day was 8.40 is with a standard deviation of ± 0.87. According to OSHA (2013), noise can result in permanent sensorineural hearing loss when there is an impulse noise at a very high level of around 130-140 dB, or a high level of exposures equal to an average SPL of 85 dB(A) or higher for eight hours. Even though the duration of exposure is greater than 8 hours, it is not correlated. If the exact amount of exposure noise is known, the noise dose for each participant can be calculated, which in turn would result in expected results.

Audiological parameters except symmetry and SIS showed a significant correlation with age (demographic data). The mean SIS scores for the right and the left ear is 98% for both ears. It is almost equal to the person with normal hearing. Since the degree of loss ranged from normal to moderate, the SIS scores are not affected. For a better understanding of their speech perception, a speech in noise test should have been done. Kujawa and Liberman (2009) recommended performing speech recognition tests in quiet and in noise along with pure tone thresholds for the effective measurement of noise-induced damage.

5.2 Functioning and disability

When compared to other domains in ICF, body function was the most frequently affected domain. In body function, "Hearing functions" (b230) and "hearing function, Unspecified" (b2309) are the two domains with the most responses overall at 43 responses (Figure 4.3). The occurrence of hearing loss as a result of prolonged exposure to a noise level greater than 85 dB(A) without ear protection is well documented in the literature (Ahmed, 2001; Behar et al., 2018; Berger et al., 1977; Zaw et al., 2020). Also, Noise-induced hearing loss preferentially damages the basal region, with hearing loss beginning typically around 4 kHz or 6 kHz, results in a V-shape dip or notch (Dobie, 1985; Kirchner et al., 2012; Rabinowitz et al., 2006). The retrospective investigation of the audiogram of the participants also had similar findings, with nearly 50% of the participants had a more significant loss at 4 kHz with a noise-notch.

Range of emotion (b1522) and Endocrine gland functions (b555) are the next most affected responses in the body functions domain (Figure 4.3), with 17 and 14 responses, respectively. Hearing loss limits a person's social communication abilities, resulting in increased social stress, depression, embarrassment, poor self-esteem, and relationship difficulties (Eggermont, 2014; Hong et al., 2013; Smith, 1991). These findings accentuate the necessity to assess the emotional functioning in detail for the person with noise-induced hearing loss. Endocrine gland functions (b555) and Digestive functions (b515) both together have 20 responses in the body function (Table 4.4) Spreng (2000), in his paper, indicated that an increase in cortisol level as a result of noise exposure could result in an intestinal problem. Also, the participants included are older adults with a mean age of 52.82 years, so the age-related changes in the digestive tract and endocrine gland may also play a role in their digestive problems. A number of characterized polypeptide hormones have been localized in specific gastroenteropancreatic endocrine cells. Gastroenteropancreatic hormones regulate carbohydrate metabolism, gastric acid secretion, pancreatic exocrine and gallbladder function, gastrointestinal motility and blood flow. Complex changes occur within the endocrine system with ageing. Diabetes mellitus is the most important metabolic disorder related to a gastroenteropancreatic hormone imbalance(Saffrey, 2014; Track, 1980). These findings indicate the need for the assessment of gastroenteropancreatic function so that an audiologist can refer the patient to the gastroenterologist.

"Ringing in ears or tinnitus" (b2400) is the next most reported domain in body function. There was already one study using ICF on tinnitus by Manchaiah et al. (2018), where they discussed the problems and life effects of a person with tinnitus. However, this study was in the general population and did not directly tap on difficulties in NIHL listeners. The prevalence of tinnitus was shown to be higher (24%) than the overall population (14%) among the noise-exposed workers (Shargorodsky et al., 2010). Tinnitus was also associated with other comorbid conditions such as anxiety, depression, and sleep disorders (Bhatt et al., 2017; Manchaiah et al., 2018). Based on our findings and evidence, it is recommended to undergo a detailed tinnitus evaluation for those who report ringing sensations in the ears after being exposed to industrial noise. Also, based on the findings from the Manchaiah et al. (2018) study, including ICF during the tinnitus assessment will result in a better outcome in the NIHL population and indicated the need for an otolaryngologist referral who can medically manage these deficits.

In addition to the above body functions, "Amount of sleep" (b1340) and "Onset of sleep (b1341)" together have 15 responses accounting to be the next frequently affected domain in body function (Table 4.4). Noise exposure can cause sleep disturbance (Passchier-Vermeer & Passchier, 2000) and other health effects, affecting the quality of life (Muzet, 2007). So assessing sleep function with an appropriate tool is essential for the ideal treatment plan.

"Communicating with - receiving - spoken messages" (d310) is the most frequently affected domain in the activity limitation and participation restriction with 30 responses, which is followed by "Focusing attention" (d160) with 16 responses, "Using telecommunication devices" (d3600) and "Using communication techniques" (d3602) each had 14 responses respectively. The participants had reported that they have a problem understanding the speech in person, and many times they will be expecting repetitions or gestures. Also, speech understanding difficulty is seen while using a phone where the gestural cues are impossible, and these functions are related to the hearing function. When the hearing function is affected, that may result in poor speech understanding. The speech identifications scores were also reduced for 1/5th of the participants. These findings were already reported in the literature (Kujawa & Liberman, 2009; Ryan et al., 2016). The speech understanding ability is commonly assessed in most audiological setups. It is recommended to do speech understanding testing in quiet and in the presence of noise (Kujawa & Liberman, 2009). "Focusing attention" (d160) is the 2nd most frequently affected domain in the activity limitation and participation restriction. Noise may cause cognitive impairment, such as decreased attention (Cohen et al., 1980; Shield & Dockrell, 2003). These shreds of evidence signify the need to assess the attention domain, which is commonly not assessed all the time.

5.3 Contextual Factors

These are the least mentioned domains in the present study. "Sound intensity" (e2500) is the most frequently mentioned domain in the environmental factors. The participants reported that soft speech was not clear, and most of the time, they will be expecting others to speak loudly. People with mild hearing loss require slightly higher intensity sounds for a better understanding of speech when compared to normal-hearing listeners (Dubno et al., 1984). These problems are overcome by using appropriate hearing aids based on their hearing loss with better features like wide dynamic range compression (Walden et al., 2000). The other frequently affected domains are

"Individual attitudes of immediate family members", "extended family members", and "friends", and their ICF codes are e410, e415 and 3420, respectively. The participants had reported that because of their hearing problem, their family members, friends and other known person are avoiding them in family functions and losing their patience. Based on these findings assessing these domains and including family members and others during the treatment will be a better option to overcome these hurdles. Grenness et al. (2016), with the help of a case study, explained how audiologists could implement patient and family-centred care when working with older adults and their significant others.

"Coping styles" is the only personal factor reported by the participants with 4 responses. The participants mentioned that they are habituated with noise and hearing loss. The coping model is consisting of controlling and avoiding strategies (Hallberg & Barrenäs, 1995). Hallberg & Carlsson (1991) recommended that the hearing health professionals encourage the patients with noise-induced hearing loss to accept their hearing loss and seek help instead of denying their hearing problem.

5.4 Study implications

The biopsychosocial approach in assessing the impact of noise-induced hearing loss (NIHL) gives a better understanding. The assessment procedures should focus on each and every aspect of a person affected by a particular problem or a condition. Based on the finding from the present study, it is clear that the people with noise-induced hearing loss are not experiencing the issues in one domain but in all the domains (e.g., Body function – Hearing function, Range of emotion; Activity limitation and participation restriction - Communicating with - receiving - spoken messages, Communication devices; and Environmental factors - Individual attitudes of immediate family members", "extended family members" and "friends"). Therefore, the ICF framework can and should be used to guide audiology services for adults with hearing loss (Grenness et al., 2016), including those with NIHL. Based on the deficits enlisted in the open-ended questions, a structured questionnaire covering all the domains was developed based on ICF core sets to help Audiologists verify the other signs and symptoms of the NIHL in the patient, as shown in Appendix II. In addition, the findings of the study can also be used to guide the development and planning of NIHL rehabilitation measures based on the most frequent and problematic conditions that can be compiled from the questionnaire given in Appendix II.

5.5 Strengths and limitations of the Study

The study used open-ended questions, which have the advantage of covering broader aspects than structured questions (Manchaiah et al., 2018; Stephens & Pyykkö, 2011). This approach is perhaps more ecologically valid for the purpose of this study. The number of responses to each question was high in this study. The ICF codes are more reliable since we included three coders.

Although this study is the preliminary attempt in understanding the psychosocial impact of NIHL, using the standard ICF guidelines, the low sample size of the study limits its generalization. Hence future studies might address this shortcoming by including more participants. In addition, the inclusion of female and male subjects (in contrast to only males used in the study) can determine gender-specific effects of NIHL on the overall health, using a similar framework. Moreover, the study opens new avenues of promising research in the groups of others professionals who also experience deleterious effects of noise (e.g., musicians, drivers etc.).

Chapter VI

SUMMARY AND CONCLUSIONS

This study investigated the problems and life effects experienced by people with tinnitus. The total number of responses for the two questions is almost the same (PQ-155 and LEQ-156), with no significant differences between responses. Body function is the most frequently affected, which is followed by activity limitations and participation restrictions. The environmental factors and personal factors had the less number of responses. The most frequently listed function is "Hearing functions" (b230), "Range of emotion" (b1522), "Endocrine gland functions" (b555), "hearing function, Unspecified" (b2309), and "Ringing in ears or tinnitus" (b2400). The most frequently occurring responses related to activity limitation and participation restriction were "Communicating with - receiving - spoken messages" (d310), Using telecommunication devices (d3600), Using communication techniques (d3602) and "Focusing attention" (d160). The most frequently occurring responses related to environmental factors were "Sound intensity" (e2500), "Individual attitudes of immediate family members" (e410), "Individual attitudes of extended family members" (e415) and "Individual attitudes of friends" (e420). Coping styles are the only domain listed in the personal factors. These PQ or LEQ responses were not correlated with the demographic and audiological findings. This signifies the need to understand the other confounding factors that are associated with noise-induced hearing loss. From the results, it is clear that the open-ended questions were very much helpful in gathering required information with a broader range of issues. Based on these findings, future audiological assessment protocols for noise-induced hearing loss can address these problem areas along with the audiological test battery for a better outcome.

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APPENDIX I

QUESTIONNAIRE

SECTION – 1

NOTE: ***The script on the left is in Kannada, as the study was carried out in the native language of participants***

DEMOGRAPHIC DETAILS

1. Name: ……… ಹೆಸರು: ……….
2. Date of Birth: ………. ಹುಟ್ಟಿದ ದಿನ: ……….
3. Case Number: ………. ಕೇಸ್ ಸಂಖ್ಯೆ: ……….
4. Profession ………. ವೃತ್ತಿ: ……….
5. Where do you work? (company name) ……………………..

   ನೀವು ಎಲ್ಲಿ ಕೆಲಸ ಮಾಡುತ್ತಿದ್ದೀರಿ? (ಸಂಸ್ಥೆಯ ಹೆಸರು) ……………………..
6. Duration of Noise Exposure per day (hours) ……….

   ದಿನಕ್ಕೆ ಶಬ್ದ ಮಾನ್ಯತೆ ಅವಧಿ (ಗಂಟೆಗಳಲ್ಲಿ) ……….

SECTION - 2

ICF BASED QUESTIONS

1. MAKE A LIST OF THINGS YOU FIND CHALLENGING OR PROBLEMS YOU HAVE DUE TO YOUR HEARING PROBLEM. LIST AS MANY AS YOU THINK OF

1. ನಿಮ್ಮ ಶ್ರವಣ ಸಮಸ್ಯೆಯಿಂದ ಆಗುತ್ತಿರುವ ತೊಂದರೆಗಳನ್ನು ಪಟ್ಟಿಮಾಡಿ? ಶ್ರವಣದೋಷದಿಂದ ನಿಮ್ಮಗೆ ಉಂಟಾಗುತ್ತಿರುವ ಎಲ್ಲಾ ಸಮಸ್ಯೆಗಳನ್ನು ಪಟ್ಟಿ ಮಾಡಿ.

a. Do you want to answer by text? ನೀವು ಬರಹದ (ಟೆಕ್ಸ್ಟ್ ಮೆಸೇಜ್) ಮೂಲಕ ಉತ್ತರಿಸುವಿರ?

b. Do you want to upload image? ಉತ್ತರಗಳನ್ನು ಬರೆದು ,ಅದರ ಚಿತ್ರ ತೆಗೆದು ಕಳುಹಿಸುವಿರ ?

c. Do you want to upload a voice recording? ನಿಮ್ಮ ಉತ್ತರಗಳನ್ನು ಮಾತಿನಲ್ಲಿ ರೆಕೊರ್ಡ್ (ವೊಯಸ್ಸ್ ನೋಟ್) ಮಾಡಿ ಕಳುಹಿಸುವಿರ ?

2. PLEASE STATE THE EFFECTS OF HEARING PROBLEM ON YOUR DAY TO DAY LIFE. LIST ALL THE EFFECTS, AS MANY AS YOU CAN

2. ಈ ಶ್ರವಣದೋಷವು ನಿಮ್ಮ ದಿನನಿತ್ಯದ ಜೀವನದಲ್ಲಿ ಯಾವ ರೀತಿಯಲ್ಲಿ ಪರಿಣಾಮ ಬೀರುತ್ತದೆ ಎಂಬುದನ್ನು ಪಟ್ಟಿ ಮಾಡಿ ತಿಳಿಸಿ

a. Do you want to answer by text? ನೀವು ಬರಹದ (ಟೆಕ್ಸ್ಟ್ ಮೆಸೇಜ್) ಮೂಲಕ ಉತ್ತರಿಸುವಿರ?

b. Do you want to upload image? ಉತ್ತರಗಳನ್ನು ಬರೆದು ,ಅದರ ಚಿತ್ರ ತೆಗೆದು ಕಳುಹಿಸುವಿರ ?

c. Do you want to upload a voice recording? ನಿಮ್ಮ ಉತ್ತರಗಳನ್ನು ಮಾತಿನಲ್ಲಿ ರೆಕೊಡ್ರ್ (ವೊಯಸ್ಸ್ ನೋಟ್) ಮಾಡಿ ಕಳುಹಿಸುವಿರ ?

SECTION – 3

AUDIOLOGICAL TEST RESULTS FOR BOTH EARS

1. Pure Tone Audiometry test results (Type) ……….
2. Pure Tone Audiometry test results (Degree) ……….
3. Pure Tone Audiometry test results (Pattern) ……….
4. Pure Tone Audiometry test results (Symmetry) ……….
5. Speech Audiometry test results ……….
6. Immitance Test Results ……….
7. Oto Acoustic Emission Test Results ……….
8. Electro Physiological test results ……….
9. Other test results ……….

APPENDIX II

QUESTIONNAIRE ON HEALTH-AND QUALITY OF LIFE CHANGES ASSOCIATED WITH NOISE-INDUCED HEARING LOSS

Please read each of the questions carefully and rate them based on their severity

No problem - 1
Slightly - 2
Moderately - 3
Severely - 4
Very Severely - 5

S. NO	Question	Severity				
	Body Function					
1	Do you have a complaint of hearing loss? If yes, how severe it is?	1	2	3	4	5
2	Do you hear any ringing kind of sound from your ear?	1	2	3	4	5
3	Do you have a sleeping problem? If yes, how severe it is?	1	2	3	4	5
4	Do you have a gastric problem or other digestive related problems? If yes, how severe it is?	1	2	3	4	5
5	Do you get irritated by loud sounds?	1	2	3	4	5
6	Do you feel bad if someone finds out that you have hearing loss?	1	2	3	4	5
7	Are you getting angry more frequently? If yes, how severe it is?	1	2	3	4	5
8	Do you have any endocrine problems like diabetes?	1	2	3	4	5
9	Because of your hearing problem, if someone avoids you, How you will react or feel?	1	2	3	4	5

10	Are you experiencing a headache after sound exposure? If yes, how severe it is?	1	2	3	4	5
11	Do you have heart problems?	1	2	3	4	5
12	Are you experiencing pain in your hands/legs/joints after sound exposure? If yes, how severe it is?	1	2	3	4	5
13	Are you experiencing giddiness frequently? If yes, how severe it is?	1	2	3	4	5
	Activity Limitation and Participation Restrictions					
14	Can you understand soft speech?	1	2	3	4	5
15	Can you understand speech from a long-distance?	1	2	3	4	5
16	Are you asking for repetitions?	1	2	3	4	5
17	Do you need visual cues for a better understanding of speech?	1	2	3	4	5
18	Are you able to understand speech through the phone?	1	2	3	4	5
	Environmental factors					
19	Do you have difficulty in understanding speech in the presence of noise?	1	2	3	4	5
20	How your family members and friends are treating you? Do you feel like they are avoiding you because of your hearing loss?	1	2	3	4	5
21	If you ask for repetition, are they (family and friends) ready to repeat?	1	2	3	4	5
22	Have you ever been avoided from any social gathering because of your hearing loss?	1	2	3	4	5
23	Are you following your regular routine or habits, or the hearing loss restricts any of them?	1	2	3	4	5
	Personal factors					
24	Do you feel any changes in your lifestyle after hearing loss?	1	2	3	4	5
25	Are you coping up with your problems faced due to NIHL?	1	2	3	4	5