MANAGEMENT OF TINNITUS: A COMPARITIVE STUDY

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June 2011

CERTIFICATE

This is to certify that this dissertation entitled ***"Management of tinnitus: A comparative study"*** is the bonafide work submitted in part fulfilment for the degree of Master of Science (Audiology) of the student (Registration No. 09AUD035). 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.

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This is to certify that the dissertation entitled ***"Management of tinnitus: A comparative study"*** has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other university for the award of any Diploma or Degree.

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DECLARATION

This dissertation entitled ***"Management of Tinnitus: A Comparative Study"*** is the result of my own study under the guidance of Mrs. Geetha C., Lecturer, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any other University for the award of any Diploma or Degree.

Mysore,

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Dedicated
to my
Family...

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Chapter 1

INTRODUCTION

'Tinnitus' is derived from a Latin word 'tinnire' which means to tinkle or ring like a bell. McFadden (1982) defines tinnitus as "the conscious experience of sound that originates in the head".

It is a sensation resulting from a malfunction of the cochlea or auditory nerve (Moller, 1984; Jastreboff, 1990). According to Jastreboff (1995) "tinnitus is the perception of sound that results from activity within the nervous system without any corresponding mechanical, vibratory activity within the cochlea, and not related to external stimulation of any kind". The condition is symptomatic of some abnormal state of the auditory system and is not a disease entity in itself. Like pain, tinnitus is a personal, subjective experience that cannot be measured objectively and is described mainly by patient report (Newman & Sandridge, 2006).

Tinnitus is assumed to be the consequence of impaired neural activity that may or may not be due to the peripheral system (Jastreboff, 1990). This dysfunction can be corrected using habituation therapies and sound therapies which in turn results in cortical reorganization (Jastreboff, 1993; Mühlnickel, Elbert, Taub & Flor, 1998; Okamoto, Stracke, Stoll & Pantev, 2010).

Various tinnitus treatment techniques are available which includes medical and surgical management, psychological managements, acoustic therapy and habituation therapy.

Acoustic or sound therapy uses external sounds to provide relief to patients suffering from tinnitus and is said to be useful to any other treatment options (Jastreboff & Hazell, 2004). It is based on tinnitus masking procedures using different prosthetic aids for the management of tinnitus and it includes hearing aids, sound generators or tinnitus maskers. Regardless of the form of treatment, generally, broadband noise is used in one way or another to distract attention from the tinnitus and to reduce the brain's perceived need for stimulation (Jastreboff & Hazell, 2004).

Whereas, Habituation therapy for tinnitus management aims at filtering and blocking the tinnitus related neuronal activity from reaching the area in the brain that is responsible for consciously perceiving tinnitus. The habituation of tinnitus can be achieved through various methods. One of which includes Tinnitus Retraining Therapy (TRT).

TRT is a clinical implementation of the neurophysiological model (Jastreboff, 1990) of tinnitus. Recognition of the importance of the contributory effects of the limbic and autonomic nervous systems is a major aspect of TRT. Reduced detection of the tinnitus signal by the brain at subconscious (sub-cortical) levels is thought to facilitate habituation of tinnitus-induced reactions and, subsequently, habituation of tinnitus perception (i.e., awareness) at the conscious (cortical) level. Counselling is also an essential component of treatment with TRT (Jastreboff, 1993). Patients with more troublesome tinnitus are advised to wear ear-level devices (sound generators) with TRT to optimize the habituation process. However, in TRT, sound generators are not given always and even if they are given, are not given to suppress the tinnitus completely. TRT patients are also advised to wear hearing aids if their hearing loss is considered a significant problem and to improve their communication ability (Jastreboff, 1993).

Henry et al. (2006) reported that TRT had exponentially increasing effects when compared to tinnitus sound generators users especially in patients who had moderate degrees of tinnitus. However, tinnitus maskers or sound generators had greatest effects in the initial 3 months and later both the treatment results were comparable. Although, tinnitus masking and TRT utilize counselling and acoustic stimulation for intervention, the methods differ in fundamental ways.

Another method of acoustic therapy uses music for the treatment of tinnitus and has proven to be a good masker for tinnitus. Davis (1998) has shown that the masking effect of music which is spectrally modified according to the individual's hearing characteristics to be a good rehabilitation for tinnitus sufferers. In this method, music signals are spectrally modified to provide low-frequency emphasis in music's spectral components (Davis, Paki & Hanley, 2007).

Recently, notched-music therapy has been developed as a treatment option for tinnitus (Okamoto et al., 2010). This treatment is based on the notion that tinnitus is generated in the central auditory system, possibly due to maladaptive cortical reorganization. When the input from the peripheral system is decreased, auditory cortex neurons that are deprived of normal thalamo-cortical input (through MGB) do not become inactive. These neurons in turn rewire/ synapse with excitatory inputs from neighbouring neurons. This change in synapse makes the neurons sensitive to neighbouring frequencies and, hence, maladaptively changing the tonotopic maps. These cortical areas may generate tinnitus by means of synchronized spontaneous neural activity (Mühlnickel et al., 1998).

The notched music treatment strategy helps in the reversion of the maladaptive reorganization of a specific cortical area contributing to the perception of tinnitus and also reduces the tinnitus loudness (Okamoto et al., 2010).

Need for the study

Treatment options available for tinnitus are numerous and diverse. Each has its own advantages and disadvantages. TRT has been proven to provide great relief to the patients suffering from chronic tinnitus (Henry et al., 2006). Though, TRT procedure is a structured management technique, this can only be carried out by the audiologist who has undergone a formal training (Henry, Jastreboff, Jastreboff, Schechter & Fausti, 2002). In addition, TRT is also time consuming.

Further, use of tinnitus maskers has also been found to facilitate patients' habituation to tinnitus and also helps in increasing the blood flow to the inner ear (Quirk, Avinash, Nuttall & Miller, 1992) and contributes to the reductions in neural activity responsible for the generation and perception of tinnitus (Folmer, Martin, Shi & Edlefsen, 2006). However, these instruments are generally recommended to be worn for several hours in a day and for several months together. Further, spectral output of these generators varies according to the different instruments, and the maximum output tends to span only about 2½ octaves and to occur within the frequency range between 1000 and 6000 Hz. This can be a disadvantage considering the fact that a broad band noise such as white noise is found to improve tinnitus better than a narrow band signal. Further, these are also expensive and may not be affordable to many individuals; and not very cosmetically appealing, especially for individuals who do not require to wear hearing aids. Hence, an alternate

to this could be providing white noise through an audiometer through the earphones without having to wear a ear level device all through the day.

Hence, the present study aimed to evaluate the effect of tinnitus masking, through an audiometer by delivering white noise to provide tinnitus masking therapy, in the clinical set up, through the earphones.

Notched music therapy developed by Okamoto et al., (2010) is based on the notion that tinnitus is generated in the central auditory system, possibly due to maladaptive cortical reorganization. The notched music treatment strategy has been found to help in the reversion of the maladaptive reorganization of a specific cortical area contributing to the perception of tinnitus and also reduces the tinnitus loudness (Okamoto, et al., 2010).This technique has proven to diminish the perception of tinnitus in persons with hearing loss. However, several individuals who have normal or near normal hearing sensitivity complain of clinically significant tinnitus and the mechanisms involved in the generation of tinnitus in these subjects are not clear.

Hence, we were interested to evaluate the benefit from the notched music therapy in tinnitus patients who have normal or near normal hearing sensitivity to check if they also exhibit similar maladaptive cortical reorganization (that is present in hearing loss subjects) which could be changed by notched music therapy.

Aim of the study:

The present study was taken up to evaluate the efficacy of two intervention procedures for tinnitus sufferers, Notched music therapy and White noise therapy

Objectives of the study:

To evaluate the outcomes of Notched music therapy and White noise therapy

- Using psychoacoustic measurement of tinnitus loudness using loudness matching procedure and
- Using Tinnitus Severity Index Questionnaire (TSIQ) (Folmer, 2000)

Chapter 2

REVIEW OF LITERATURE

Tinnitus is a sensation, specifically, a sound that sometimes causes suffering. Jastreboff (1995) defines tinnitus as "the perception of sound that results from activity within the nervous system without any corresponding mechanical, vibratory activity within the cochlea, and not related to external stimulation of any kind". Tinnitus patients perceive tinnitus as a sound completely different from anything previously experienced in their external environment.

A brief spontaneous tinnitus, lasting for seconds to minutes is a nearly a universal sensation (Axelsson & Ringdahl, 1989). Temporary tinnitus that may last for minutes to hours occurs after noise exposure that is sufficiently intense and/or prolonged which cause temporary damage to the ear. Chronic tinnitus is the one that lasts for more than five minutes and more than once a week or present continuously (Davis & Rafaie, 2000; Dobie, 2004).

Patients with normal auditory threshold may also be suffering from tinnitus (Sanchez, Mak, Pedalini, Levy & Bento, 2005). Many reports on the incidence of tinnitus estimated that about 4% to as high as 32% of adult population suffer from tinnitus (Stouffer & Tyler, 1990; Tyler, Aran, & Dauman, 1992).

Mechanisms of tinnitus:

There are different mechanisms which have been proposed to cause tinnitus.

Mechanisms associated with cochlea:

Discordant damage of inner and outer hair cells:

Noise exposure and ototoxic drugs, cause hair cell damage in the basal turn of the cochlea and OHCs are more susceptible to such damages when compared to the IHCs (Stypulkowski, 1990). In the junction along the cochlea where there are damaged hair cells and normal hair cells, the stereocilia of OHCs are destroyed and IHCs are intact. Jastreboff (1990, 1995) suggested that this would result in imbalanced activity between the type I and type II fibres which in turn results in imbalanced activity along the auditory pathway causing tinnitus. Also in these areas, the tectorial membrane which is usually in contact with OHCs cilla sags down on the intact IHC cilla causing them to depolarize. In support of this theory, Hazell (1987) and Hazell & Jastreboff (1990) showed that some patients with high-frequency hearing loss have tinnitus corresponding to the frequency where the hearing loss begins.

Calcium concentration:

Calcium is fundamental to the normal physiology of the hair cells and there have been suggestions that deficits in calcium handling could be implicated in cochlear malfunction (Zenner & Ernst, 1993). Jastreboff (1990) suggested that reduced extracellular calcium concentration could increase the spontaneous activity and reduced evoked activity within the cochlea increasing the likelihood of developing tinnitus. Both salicylates and quinine cause a rise in intracellular calcium

and release of excitatory neurotransmitter receptors (N-methyl-D-aspartate, NMDA receptors) which triggers tinnitus.

Mechanisms associated with neural pathway:

Dorsal cochlear nucleus:

Following the exposure of tinnitus inducing agents such as loud noise and salicylate drugs, activity in the dorsal cochlear nucleus (DCN) is increased, which may be the possible generation site for tinnitus (Jastreboff, 1990; Kaltenbach, Zhang & Finlayson, 2005). DCN activity is also influenced by the stimulation of non-auditory structures especially the somatosensory system (Levine, 1999).

Medial efferent system:

The medial efferent system is closely related to the reticular formation in the brain and this modifies the pre-existing cochlear tinnitus (Jastreboff & Hazell, 1993), hence plays a role in tinnitus perception (Hazell & Jastreboff, 1990; Eggermont, 2000).

Neurophysiological model:

Jastreboff (1990, 1996 & 1999) explained tinnitus mechanism using the neurophysiological model. It is postulated that, in addition to the classical auditory pathways, other central neural pathways like the limbic system, sympathetic autonomic nervous system (ANS) and reticular formation is involved in tinnitus perception. Peripheral processes may be involved in the generation of tinnitus related activity but the neural networks become tuned to the generation of tinnitus signal,

even when it is of low intensity or intermittent. Negative attitude or beliefs about tinnitus supplies negative reinforcement, which via the Limbic system stimulates the sympathetic ANS for the unpleasant reactions involved perception of tinnitus.

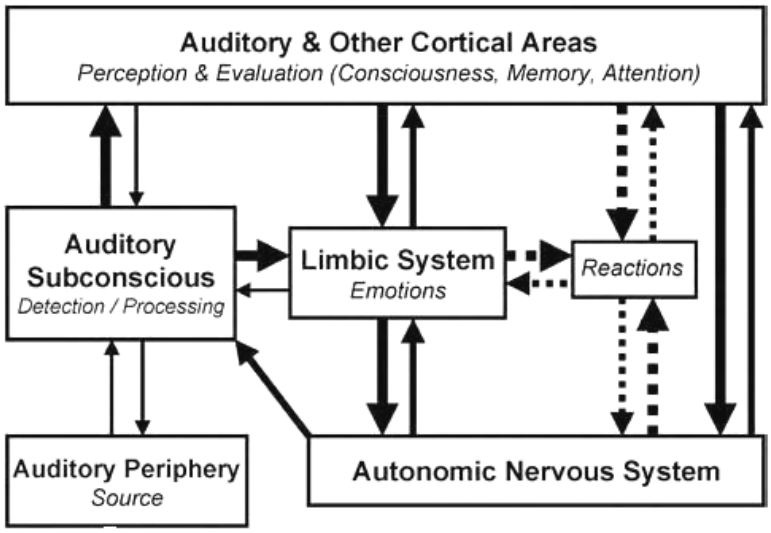

Figure 2.1: Diagrammatic representation of the Jastreboff's Neurophysiological model

Psychological habituation model:

Hallam, Rachman, and Hinchcliffe (1984) presented the psychological model of tinnitus which suggests that there are some neurophysiological disturbances along the auditory pathway anywhere between the cochlea to the cortex, which, gives rise to the perception of tinnitus. However, there may be cases where tinnitus may occur without aural pathology (Heller & Bergman, 1953). Thus, Hallam, Rachman and Hinchcliffe (1984) suggests that the interactions of psychosomatic and somatopsychic reactions are not selectively inhibited by the central neural processes which may be the result of high central nervous system and autonomic nervous system arousal.

Cortical plasticity:

Cortical plasticity refers to the brain's ability to reorganize its functional capacity by reconfiguring its information processing machinery and the programs of learning (Buonomano & Merzenich, 1998; Calford, 2002). Neural plasticity plays a significant role in the development of chronic tinnitus and associated symptoms like hyperacusis and depression (Møller, 2001 & 2003). Tinnitus is accompanied by a change of the tonotopic map or plastic reorganizational changes occurs in auditory cortex which is a result of increase or a decrease peripheral input (Mühlnickel et al., 1998).

Strong association between cortical reorganization and tinnitus opens the possibility that behavioural and pharmacological treatments aimed at altering cortical reorganization might be effective in relieving tinnitus. Recanzone, Schreiner and Merzenich (1993) have shown that there is an increase in the representation of the frequencies involved in an auditory learning paradigm. These results could be used as a basis of a new therapeutic approach to tonal tinnitus by having patients attend to and discriminate some features of acoustic stimuli that are close to the tinnitus frequency to drive cortical reorganization of the non-tinnitus frequencies into the tinnitus representation, thereby reducing it.

Assessment of tinnitus:

A psychoacoustic test battery should be administered for the patient with tinnitus. The combined testing should enable the assessment of the auditory system with respect to hearing sensitivity, loudness tolerance, and tinnitus. Audiometric evaluation should include the following tests (Henry, 2004):

- Pure-tone thresholds for octave frequencies 250 Hz through 8 kHz and mid-octaves at 1500 Hz, 3000 Hz and 6000 Hz
- Speech recognition thresholds and word recognition thresholds at patients' most comfortable level
- Tinnitus loudness and pitch matching
- Minimum masking levels (MMLs)
- Residual inhibition
- Loudness Discomfort Level (LDLs)
- Otoacoustic emissions (DPOAE, TEOAE and contralateral suppression of OAEs)
- Immittance (reflex thresholds and decay)
- Auditory brainstem responses (ABR) to rule out retrocochlear pathology
- Tinnitus questionnaires

Assessment of tinnitus also plays an important role in measuring the outcomes of different therapy approaches. Further, some therapy approaches modify external sounds such as music (Okamoto, Stracke, Stoll & Pantev, 2010) based on the pitch of tinnitus to provide tinnitus masking.

Tinnitus management:

Tinnitus is a widespread medical problem that at present is treatable in a variety of ways but not curable (Tyler and Baker, 1983). Categories of treatment include:

Medical management:

Many medical conditions such as neoplasm, vascular lesions, adenoma, Meniere's disease, acoustic neuroma etc., often results in tinnitus. Treatment to these

conditions will help in subsiding tinnitus to a larger extent in many cases (Perry & Gantz, 2000).

Several medications that claim to provide relief to the tinnitus sufferers have come up in the recent past. However, there is no proper evidence to prove the same. Few of the drugs including Aspirin in a high dose (400mg/kg) can induce tinnitus very predictably (Mongan, Kelly, Nies, Porter, & Paulus, 1973; Evans, Wilson & Borerwe, 1981). Importantly, salicylate-induced tinnitus disappears once the dose of the drug is decreased (Jastreboff, Brennan & Sasaki, 1991; McFadden, 1982).

Antidepressants are commonly prescribed for tinnitus. However, there is no indication that one specific type of antidepressant is more likely to lead to tinnitus as a side effect, or have a beneficial effect on tinnitus (Robinson, Viirre & Stein, 2007).

Surgical management:

Tinnitus can change or can be induced by procedures performed to correct a specific pathology (e.g., perilymphatic fistula, otosclerosis, Meniere's syndrome). It is very important to counsel patients before operation that tinnitus may temporally increase or emerge just after surgery as a consequence of blocking of the ear canal and middle ear with blood clot and/or a surgical dressing. Failure to do this may cause serious alarm that temporary postoperative tinnitus, which is common, is an indicator that something has gone wrong with the procedure. As a result of this anxiety, tinnitus may increase and become persistent.

In the literature, there are a limited number of reports of auditory nerve section for tinnitus alone. Fisch (1970) reported that one of four patients had a positive response with respect to tinnitus. Most data on ablative surgery come from studies of the treatment of Meniere's syndrome or vestibular schwannomas (Baguley, Moffat &

Hardy, 1992; Silverstein, Haberkamp & Smouha, 1986). In Meniere's syndrome, labyrinthectomy or vestibular nerve section often result in a rapid recovery from incapacitating vertigo, but tinnitus is typically unchanged. The elevation of a mood state may result in a dramatic improvement in general stress level, and through this mechanism alleviate tinnitus in some patients (Jastreboff & Hazell, 2004).

Electrical Suppression:

Hazell, Jastreboff, Meerton and Conway (1993) demonstrated that by delivering a low frequency, sinusoidal electrical stimulation through a round-window electrode can be useful in tinnitus suppression. Electrical stimulation of the ear using cochlear implants is a new treatment for chronic tinnitus and remains a potential avenue of further development. Studies by Hong, Rubenstein, Wehner and Horn (2003) and Rubenstein, Tyler, Johnson and Brown (2003) have shown nearly complete inhibition of tinnitus in their patients who had undergone cochlear implants.

Psychological Treatment:

Psychological forms of treatment are not designed to reduce or remove the perceived tinnitus rather it helps the individual to cope up with the effects of tinnitus on the quality of life. Different psychological treatment options available include relaxation training, biofeedback, hypnosis, and cognitive-behavioural intervention (Wilson & Henry, 2000).

Relaxation training:

Tinnitus sufferers are generally tense and anxious, and relaxation training will be helpful in such patients (McKenna, 2000). Most common approach of relaxation training is the Progressive Muscle relaxation (Bernstein & Borkovec, 1973), which involves tensing and relaxing different muscle groups (arms, back, face, neck, shoulders and legs) using a series of structured exercises. A small amount of tension is often applied initially to provide a means of learning to discriminate between tension and relaxation. For long, relaxation technique has been employed in patients with insomnia (Morin, Culbert & Schwartz, 1994). However, a small proportion of tinnitus patients may derive some benefit from this therapy (Henry & Wilson, 2000).

Biofeedback training:

Biofeedback training aims to change in response to the symptoms of tinnitus and also other conditions in the environment that contribute to the stress. It is useful in treating tinnitus sufferers for whom the cause is stress or in cases where the symptoms may be triggered or exacerbated by stress (Borton & Clark, 1988; Borton, Moore & Clark, 1981; Elfener et al., 1981; Erlandsson, Carlsson & Svensson, 1989; Grossan, 1976, Haralombous et al., 1987; House 1978; Kirsch et al., 1987; Svihovec & Carmen, 1982; Walsh & Gerley, 1985; White et al., 1986).

Schwartz (1995) formulated how the biofeedback method works when used to treat tinnitus patients. It includes habituation effects, distraction, improved sleep, cognitive changes and reduced muscle tension. Habituation refers to the repeated pairing of the tinnitus with relaxation response (Schwartz, 1995). This in turn helps in reducing the association of tinnitus with stress, tension and irritation or vice versa. The patients may also be taught to distract their attention away from tinnitus by

focusing on their breathing pattern, thoughts or other internal stimuli (Jakes, Hallam, Rachman & Hinchcliffe, 1986). Results of studies examining the efficacy of biofeedback have generally been supportive of biofeedback as a viable option in the treatment of tinnitus (Kirsch, Blanchard & Parnes, 1989).

Cognitive behavioural therapy:

Cognitive behavioural therapy is the therapeutic effort to modify maladaptive thoughts and behaviours associated with tinnitus by applying systematic and measurable implementation of strategies designed to alter these behaviours (Beck et al., 1979; Meichenbaum, 1977; Mahoney, 1974; Bandura, 1977; Andersson et al., 2002). There are two main components: one is cognitive restructuring or an attempt to reconceptualise the problems presented by tinnitus into a form that is amendable to a viable solution. This basically helps the patients think differently and adopt a different attitude. The other component is the behavioural modification. This includes, counselling the patients about tinnitus and the treatments available are, cognitive restructuring and behavioural modifications like Imagery techniques: focusing thoughts on something pleasant, Attention control and Relaxation training (Henry & Wilson, 2001).

Acoustic Therapy:

Acoustic or sound therapy uses external sounds to provide relief to patients suffering from tinnitus. The rationale of this therapy is to increase the level of external sounds in the patients' environment to decrease the perception of tinnitus. It is a non-invasive therapy technique that has no side-effects and often results in immediate

relief from tinnitus. It facilitates patients' habituation to tinnitus and reduces the frustrations and anxiety associated with tinnitus (Folmer et al., 2006).

Tinnitus masking:

Many studies have revealed that masking of tinnitus does not follow the psychoacoustic rules that were established for the masking of one sound by another (Feldmann, 1971; Formby & Gjerdingen, 1980; Hazell, 1981; Mitchell, 1983; Mitchell, Vernon, & Creedon, 1993; Penner, 1987; Penner & Klafter, 1992; Shailer, Tyler, & Coles, 1981; Tyler & Conrad-Armes, 1984).

Tinnitus suppression by external noise is not frequency dependent (Feldmann 1969a, 1969b, 1971). Hence, suppression of tinnitus can be achieved with tones far outside the critical band of the perceived tinnitus pitch. By which it is also easier to achieve suppression with broadband rather than a narrow band of noise. Therefore, tuning the masker to any perceived tinnitus pitch or any particular frequency is irrelevant (Jastreboff & Hazell, 2004).

Hearing Aids:

Hearing aids are another form of acoustic therapy. Patients having hearing loss associated with tinnitus receive multiple benefits from hearing aids which includes improved sound localization and identification, improved speech understanding and reduced tinnitus (Jastreboff & Hazell, 2004). Many patients also report reductions in psychological effects associated with tinnitus (Folmer et al., 2006).

However, hearing aids cannot be used for patients having normal hearing sensitivity and patients having hyperacusis associated with tinnitus. In such patients, tinnitus maskers or sound generators are useful (Folmer et al., 2006).

Sound generators:

In-the-ear (ITE) sound generators also called 'maskers' deliver broad-band sound frequencies (typically 100 to 8000 Hz) and can provide immediate benefits for tinnitus patients by making the tinnitus less noticeable (Vernon & Schleuning, 1978) by decreasing the tinnitus signal-to-noise (background) ratio. It facilitates patients' habituation to tinnitus and also helps in increasing the blood flow to the inner ear (Quirk et al., 1992) and contributes to the reductions in neural activity responsible for the generation and perception of tinnitus (Folmer et al., 2006).

Sound generators are recommended to patients with normal or near normal hearing, patients with sound hypersensitivity and to those who report that sound provides immediate relief from tinnitus (Folmer et al., 2006).

Environmental enrichment:

Tinnitus becomes more noticeable in a quiet environment. Hence patients with tinnitus are advised to add pleasant sound to the environment that is too quiet using tabletop machines, cassette and CD players, tabletop water fountains, fans and air purifiers (Folmer et al., 2006). This is especially very useful in patients who suffer from insomnia due to tinnitus (Folmer & Greist, 2000; Folmer, 2002). In addition to the above mentioned devices, it is recommended that patients with insomnia due to tinnitus use other devices such as pillows with speakers, headband speakers, headphones and earpieces connected to the CD or MP3 players.

Other tinnitus maskers include, custom sound CDs available commercially (Dynamic Tinnitus Mitigation, DTM-6a) (Johnson, 1998; Vernon & Meikle, 2000). Listening to these sounds on a regular basis has found to be useful in tinnitus sufferers (Henry, Rheinsburg & Zaugg, 2004).

Acoustic Desensitization Protocol:

Acoustic Desensitization Protocol incorporates principles of system desensitization, habituation therapy, music therapy and clinical psychology. In involves spectral modification of music signals which provides low-frequency emphasis in music's spectral components. The acoustic signal is spectrally modified in a tailored and patented manner according to each patient's audiogram using customization algorithms developed by Davis (1998) and is fine-tuned over several clinical trials. Signal customization, along with the use of high-fidelity earphones provides comfortable listening volume across a wide frequency range despite hearing loss (Davis et al., 1995). The spectrally modified music is played through a special device called the "Neuromonics" had significant improvement in the tinnitus loudness and questionnaire scores (Davis, Paki & Hanley, 2007).

Custom-made tailored notched music treatment:

A more direct approach, which targets the tinnitus percept, was developed recently by Okamoto et al., (2010). The study has shown that tinnitus loudness can be significantly diminished by an enjoyable, low-cost, custom tailored notched music treatment, potentially via reversing maladaptive auditory cortex (Mühlnickel et al., 1998; Møller, 2001 & 2003). Cortical organization can be modified by behavioural training, and attempts have been made to reduce tinnitus loudness by exposing

chronic tinnitus patients to self-chosen, enjoyable music, which was modified ("notched") to contain no energy in the frequency range surrounding the individual tinnitus frequency.

This modification in the music introduces a functional deafferentation of auditory neurons corresponding to the eliminated frequency band, and because this frequency band overlaps the individual tinnitus frequency, the notched music no longer stimulates the cortical area corresponding to the tinnitus frequency, although it still excites the surrounding neurons (Mühlnickel et al., 1998; Recanzone, Schreiner & Merzenich, 1993). Thus, the neurons, which are not stimulated due to the notch, are presumably actively suppressed via lateral inhibitory inputs originating from surrounding neurons. Alternatively, listening to the target notched music could have induced synaptic and/or cellular plasticity mechanisms. For instance, the deprivation from auditory input in the frequency range of the tinnitus frequency could have caused long-term depression of auditory neurons corresponding to the tinnitus frequency.

Tinnitus habituation therapy:

Habituation therapy is based on the habituation model given by Hallam, Rachman and Hinchcliffe (1984). This is therapy aims at filtering and blocking the tinnitus related neuronal activity from reaching the area in the brain that is responsible for consciously perceiving tinnitus. One of the habituation therapies is the TRT.

Tinnitus Retraining Therapy:

Tinnitus retraining therapy is a well defined, structured method for the treatment of tinnitus (Henry, et al., 2003). It is the clinical implementation of 'neurophysiological model' (Jastreboff, 1990). Recognition of the importance of the contributory effects of the limbic and autonomic nervous systems is a major aspect of this treatment model. Reduced detection of the tinnitus signal by the brain at subconscious (sub-cortical) levels is thought to facilitate habituation of tinnitus-induced reactions and, subsequently, habituation of tinnitus perception (i.e., awareness) at the conscious (cortical) level. TRT is a habituation therapy and the administration of TRT involves three steps, assessment, directive counselling and sound therapy.

Assessment procedure includes an initial interview, detailed audiological, medical and psychological evaluation, categorization of patients into different groups based on the evaluation. Categorizing helps in understanding and differentiating the patient's subjective difficulties associated with tinnitus (hearing loss and hyperacusis).

Counselling is the essential component of treatment with TRT (Jastreboff, 1993). Jastreboff (1993) stated, "Proper counselling, including a clear explanation of the physiology of hearing and present knowledge about tinnitus generation and perception, is the first and essential part of any treatment". For TRT, a specific protocol of educational counselling has been designed to "demystify" a patient's tinnitus, i.e., to remove negative thoughts associated with the tinnitus. The premise of TRT is that these negative associations must be removed for habituation to occur, which is the primary objective of treatment.

Patients with more troublesome tinnitus are advised to wear ear-level devices (sound generators, hearing aids, or combination instruments) to optimize the

habituation process. Sound therapy is thought to be effective only when the emotional responses have been neutralized (Henry, et al., 2003).

Many researchers have evaluated the TRT method and have found to be effective in the treatment of tinnitus (Henry, et al., 2003, Henry, et al., 2006).

However, TRT is merely a symptomatic management based approach (Okamoto et al., 2010) and there is a great need for causal treatment approaches targeting the perception of tinnitus more directly. Recent neurophysiological studies indicate that behavioural training can be a powerful means to reverse maladaptive cortical reorganization (Taub, Uswatte & Elbert, 2002; Elbert & Rockstroh, 2004)

Outcome measures:

A comprehensive tinnitus assessment and management is insufficient without obtaining the measures that quantify the symptom adequately. This can be achieved done using measures such as psychoacoustic measures of tinnitus pitch and loudness, and subjective perception of tinnitus using questionnaires. These measures also serve as outcome measures (Henry & Meikle, 2000) for tinnitus therapy.

Tinnitus is most of the time subjective, psychoacoustic measurement of tinnitus pitch and loudness has been found to be good outcome measures. Further, tinnitus is fundamentally a self report phenomenon and questionnaire may serve as a means to identify those patients who may benefit from intervention. Questionnaire also helps in counselling the patients by identifying specific problems that are encountered by the patient and the clinician can directly address the areas of concern or discover the maladaptive thoughts or behaviours.

Henry et al. (2006) found that the questionnaires served as a useful measure in documenting the outcomes of two intervention procedures, tinnitus masking and TRT. The questionnaires used in this study were Tinnitus Handicap Inventory (THI) (Newman, Jacobson & Spitzer, 1996), Tinnitus Handicap Questionnaire (THQ) (Kuk, Tyler, Russell & Jordan, 1990) and Tinnitus Severity Index (TSI) (Meikle, Griest, Stewart & Press, 1995).

From the review of literature, it can be said that there are not many studies that evaluate simple, less time consuming techniques for the management of tinnitus. Further, there are very few studies which compare the efficacy of different methods for treating tinnitus.

Chapter 3

METHOD

The following method was adopted to test the objective of the study.

Participants:

Ten participants (4 males and 6 females) in age group of 20 to 60 years (mean age of 38.5 years) with clinically significant tinnitus were included in the study. All subjects had chronic continuous tonal tinnitus and had either unilateral tinnitus (6 subjects) or bilateral tinnitus (4 subjects). The tinnitus frequency did not exceed 8 kHz and the subjects' hearing sensitivity was not greater than minimal hearing impairment ($\leq$ 25 dB HL). All the subjects who participated in the study had partial or complete residual inhibition and no history of middle ear pathology, no history neurological or no history psychiatric problems.

Table 3.1:

Details of the subjects of the present study

Subject no.	**Age/Gender**	**Pure tone average**	
		Right	**Left**
1	24/F	8.3	0
2	20/F	8.3	8.3
3	49/M	10	10
4	50/M	16.6	11.6
5	24/F	6.6	6.6
6	48/F	16.6	13.3
7	45/F	18.3	25
8	60/ M	15	20
9	35/F	11.6	11.6
10	30/M	16.6	8.3
Mean	38.5	12.79	11.47

Participants who were willing to attend therapy were randomly assigned into two groups.

- First group receiving notched-music therapy
- Second group receiving white noise therapy

Procedure:

The entire evaluation and the therapy sessions were carried out in a double sound treated room, with the ambient noise levels within the permissible limits (as specified by ANSI S3.1-1999). The following procedure was adopted for the routine hearing evaluation and tinnitus evaluation.

Routine Audiological evaluation:

Routine audiological evaluation was carried out to track patients' air conduction thresholds from 250 Hz through 8 kHz and bone conduction thresholds from 250 Hz through 4 KHz at octave intervals. This was done through a calibrated Madsen Orbiter 922 diagnostic audiometer with TDH 39 supra aural earphones housed in MX-41/AR ear cushions. Speech audiometry was carried out to find their speech recognition threshold, speech identification scores and comfortable levels. Tympanometry and assessment of acoustic reflex thresholds were carried out to rule out any middle ear pathology and Eustachian tube dysfunction using Grason Stadler Inc. (GSI) Tympstar clinical immittance meter. ENT clearance was obtained for all participants prior to tinnitus evaluation.

Tinnitus evaluation:

Case history:

A detailed case history regarding their tinnitus was obtained prior to the assessment of tinnitus. This included the type of tinnitus (continuous/intermittent),

nature of tinnitus, the onset of tinnitus, any associated events and lateralization of tinnitus, etc.

Psychophysical assessment of tinnitus:

Pre-therapy assessment of tinnitus pitch and loudness were tracked using pitch matching and loudness matching respectively. This served as the baseline for the therapy. Following assessment procedure were adopted to track the pitch and loudness of tinnitus.

- ***Pitch match****:*

To track the appropriate tinnitus pitch, pure tone was presented (as all patients had tonal tinnitus) in successive, discrete steps. Initially a 1 kHz pure tone was presented at not more than 10 dB SL. This procedure was adopted from Henry (2006). In this procedure, the subjects were asked to indicate whether their tinnitus pitch is above or below the presented tone. Based on their response, the frequency was varied above or below 1 kHz at different octaves and at mid octaves. When the patient indicates that their tinnitus pitch was nearer, 3-Alternate Forced Choice (3-AFC) procedure was used. 3-AFC procedure was used to obtain exact pitch of the tinnitus and to avoid octave confusion. In this procedure, 3 pure tones of different frequencies were presented; 1) tone which was half-octave above the pitch matched, 2) tone which was same as the pitch matched by the patient and 3) tone which was half-octave below the matched pitch. Among the three tones the subject had to indicate the tone that was best matched to their tinnitus. The matched tinnitus pitch served as the basis for the music modification for notched music therapy.

In clients with unilateral tinnitus, the signal was presented to the ear opposite to the side where the tinnitus was perceived. In clients with bilateral tinnitus, the signal was presented to the ear with lesser threshold when the hearing sensitivity was asymmetrical (as all the participants with bilateral tinnitus reported of equal tinnitus loudness in both ears).

The tinnitus pitch was matched four times on two different days and the median across pitch matches was considered as the tinnitus frequency. This served as the basis for the music modification for notched music therapy.

- ***Loudness match:***

Loudness match was carried out using balance technique. For this, frequency of the tone was same as the tinnitus pitch.

The signal was varied in intensity in ascending technique till the patient first heard the signal. This level was taken as the threshold. Further, the signal level was increased in 5 dB steps till the subject indicated that it was equal in loudness with his/her tinnitus. The difference between the threshold and intensity of the reference signal was considered to be the tinnitus loudness, which was expressed in dB SL (Meikle, Henry & Mitchell, 1996).

Evaluation of the tinnitus loudness was matched four times on two different days and the median across pitch matches was considered as the tinnitus loudness.

- ***Residual Inhibition:***

Residual inhibition was done to see if there was any change in the tinnitus following the auditory stimulation. This was done using white noise which was

presented bilaterally at 70 dB SPL. All the participants in the study had partial or complete inhibition of tinnitus.

Administration of questionnaire:

For the pre- and post-therapy assessment of tinnitus severity, along with assessment of tinnitus loudness, Tinnitus Severity Index Questionnaire (TSIQ) (Appendix) was used. This questionnaire was given by Folmer (2002). This questionnaire constitutes of 12 items to assess patients' reaction to tinnitus and its interference. The response option for each item has 5 levels; never, rarely, sometimes, usually, always. This was adopted from Tinnitus Severity Index (TSI) questionnaire developed by Meikle et al. (1995). Apart from this, TSIQ also constitutes of rating the loudness of tinnitus perceived by the patient. This loudness rating scale was adopted from an abbreviated version of Beck Depression Inventory (aBDI) (Beck & Beck, 1972). Loudness rating is done on a 10 point rating scale, where 1 indicates that the tinnitus is very quiet and 10 indicates that the tinnitus is very loud. The TSIQ questionnaire scores vary between a minimum of 13 and a maximum of 65.

The questionnaire was administered to both the groups prior to the therapy and the scores were noted. This served as the baseline for assessing subjects' perception of tinnitus before the therapy. Post therapy administration of the questionnaire was also done during therapy (after 10 sessions) and post therapy (at the termination of the therapy).

Procedure for tinnitus therapy:

Procedure for white noise therapy:

For white noise therapy, Madsen Orbiter 922 diagnostic audiometer was used to generate and present white noise. The patients were comfortably seated and supra aural earphones (TDH-39) were placed. The white noise was presented to both the ears at 20 dB SL (Jastreboff, 1993). The therapy was carried out for the duration of 60 minutes per session. Each patient underwent therapy for 20 sessions.

Procedure for notched-music therapy:

For notched music therapy, Indian instrumental music was chosen. A total of 7 tracks were selected. These tracks were played twice for the duration of 60 minutes.

Each track was filtered using the FFT filter available in the Adobe Audition 3.0 software. Through this filter, a notch was created in the spectrum of music. The frequency of the notch was same as tinnitus pitch and the bandwidth of the notch was of one octave width. The same method was carried out for each track and later all the tracks were temporally aligned. The music delivered to both ears was filtered identically and was presented at 20 dB SL. This technique was adopted from Okamoto, Stracke, Stoll & Pantev (2010).

Therapy was a passive listening task and the subjects were made to read a newspaper or a novel during the therapy session. Each subject underwent therapy for 20 sessions.

Post-therapy evaluation of tinnitus pitch and loudness along with administration of Tinnitus severity index questionnaire were carried out during the course of the therapy (after 10 sessions) and at the termination of therapy (after 20 sessions) for both the groups of participants.

The loudness of the perceived tinnitus and the questionnaire scores across the three therapy conditions were taken for further analysis.

To see if the effects of therapy were present even after withdrawing the therapy, patients were telephoned to ask if there was any change in the tinnitus after 15 days following the therapy.

Chapter 4

RESULTS

The study aimed to evaluate the benefit from White noise therapy and Tailor-made Notched music therapy which are two intervention procedures to treat tinnitus.

Ten subjects with chronic continuous tonal tinnitus were included in the study. Each of the two therapy groups had five participants who received therapy for 20 sessions with one hour duration per session.

For evaluating the efficacy of two therapy techniques, the measures considered were:

- Psychoacoustic measurement of loudness of tinnitus measured trough loudness matching procedure, which is hereafter referred as tinnitus loudness
- Tinnitus Severity Index Questionnaire (TSIQ) scores

The pre and post tinnitus loudness measured across three intervals, that is, pre therapy, post therapy-after 10 sessions, post therapy- after 20 sessions, using loudness matching and the Tinnitus Severity Index Questionnaire scores for the two groups were analysed using statistical measure, Statistical Package for the Social Sciences (SPSS for windows, Version 18) software.

1. Evaluation of the efficacy of notched music therapy

a. Using tinnitus loudness:

Five individuals (2 males and 3 females) with chronic continuous tinnitus underwent Notched Music therapy. Prior to the therapy tinnitus evaluation was carried out for all participants. Results of pre-therapy tinnitus evaluation for each subject who received Notched music therapy are given in the Table 4.1.

Table 4.1:

Details of tinnitus evaluation of subjects who underwent notched music therapy

Subject no.	**Matched Tinnitus pitch (in Hz)**	**Matched tinnitus loudness (in dB SL)**		
		Pre therapy	**Post therapy (after 10 sessions)**	**Post therapy (after 20 sessions)**
1	8000	40	20	Complete inhibition of tinnitus
2	3000	40	25	0
3	8000	40	25	15
4	4000	20	10	Complete inhibition of tinnitus
5	8000	45	30	15

It can be observed from the Table 4.1 that the tinnitus loudness has reduced for three subjects after therapy, whereas two of the subjects (Subject 1 & Subject 4) had complete inhibition of tinnitus.

Hence, during the statistical analysis of post-therapy data, only data from three subjects were considered. Friedman's test, which is equivalent of one-way ANOVA with repeated measures, was used to evaluate the benefit of notched music therapy.

Table 4.2:

Comparison of tinnitus loudness across three intervals for Notched music therapy

Conditions	**Number of subjects**	**Mean and SD**	**Chi-Square value**	**Level of significance (df= 2)**
Pre therapy	5	37.00 (9.747)	6.000	0.050*
Post therapy (after 10 sessions)	5	22.00 (7.583)	6.000	0.050*
Post therapy (after 20 sessions)	3	8.33 (7.638)	6.000	0.050*

*- $p \leq 0.05$

Table 4.2 shows a significant difference between the baseline and across the therapy sessions at $p \leq 0.05$ level of significance. To further investigate which of the two conditions differed significantly, Wilcoxon Signed Rank test was carried out. The results are given in table 4.3.

Table 4.3:

Comparison of tinnitus loudness measured across three intervals for Notched music therapy

Conditions	z- value	Significance level
Pre and Post therapy (10)	-2.060	0.039*
Pre and Post therapy (20)	-1.604	0.109
Post therapy (10) and Post therapy (20)	-1.604	0.109

*p- ≤0.05

The results revealed a significant difference ($p < 0.05$) between the baseline and after 10 sessions. However, no significant difference ($p > 0.05$) was seen between baseline and after 20 sessions and between two post therapy conditions (10 sessions and 20 sessions).

This is because, for two of the subjects, tinnitus loudness could not be matched as there was no tinnitus at the termination of therapy. Hence, tinnitus loudness of only three subjects was considered for post therapy (20 sessions) condition for the analysis. However, on subjective analysis of individual data there was a difference in the tinnitus loudness for all subjects receiving Notched music therapy.

b. Using Questionnaire scores:

Tinnitus Severity Index Questionnaire (TSIQ) scores across the three therapy intervals were compared using Friedman's test. Results of the test are given in the table 4.4.

Table 4.4:

Comparison of questionnaire scores across three intervals for Notched music therapy

Conditions	Number of subjects	Mean and SD	Chi-Square value	Significance level (df= 2)
Pre therapy	5	33.40 (6.229)	10.000	0.007*
Post therapy (after 10 sessions)	5	23.20 (5.167)	10.000	0.007*
Post therapy (after 20 sessions)	5	15.40 (2.608)	10.000	0.007*

*- $p \leq 0.01$

Results revealed a significant difference between the baseline and across the therapy sessions at $p \leq 0.01$ level of significance. Wilcoxon Signed Rank test was carried out to further investigate the questionnaire scores across three intervals. Results of Wilcoxon Signed Rank test are shown in Table 4.5.

Table 4.5:

Comparison of questionnaire scores across three intervals for Notched music therapy

Conditions	z- value	Significance level
Pre and Post therapy (10)	-2.032	0.042*
Pre and Post therapy (20)	-2.023	0.043*
Post therapy (10) and Post therapy (20)	-2.023	0.043*

*p- ≤ 0.05

From the Table 4.5, it is clear that there is a significant difference in the questionnaire scores between pre therapy and between two post therapy conditions at $p \leq 0.05$ level of significance.

2. Evaluation of the efficacy of White noise therapy

a. Using loudness measures

Five participants (2 males and 3 females) with chronic tinnitus underwent White noise therapy. Results of pre-therapy tinnitus evaluation for each subject who received White noise therapy are given in the Table 4.6.

Table 4.6:

Details of tinnitus evaluation of subjects who underwent White noise therapy

Subject no.	**Matched Tinnitus pitch (in Hz)**	**Matched tinnitus loudness (in dB SL)**		
		Pre therapy	**Post therapy (after 10 sessions)**	**Post therapy (after 20 sessions)**
1	125	30	20	5
2	4000	35	25	10
3	3000	25	15	0
4	125	40	20	0
5	1000	30	20	5

It can be observed from the Table 4.6 that the loudness of the tinnitus perceived reduced after therapy. Friedman's test was carried out to see if the reduction in loudness of the tinnitus was statistically significant or not.

Table 4.7:

Comparison of tinnitus loudness across three intervals for White noise therapy

Conditions	**Number of subjects**	**Mean and SD**	**Chi-Square Value**	**Significance level (df= 2)**
Pre therapy	5	32.00 (5.701)	10.000	0.007*
Post therapy (after 10 sessions)	5	20.00 (3.536)	10.000	0.007*
Post therapy (after 20 sessions)	5	4.00 (4.183)	10.000	0.007*

*- $p \leq 0.01$

Table 4.7 shows a significant difference between the baseline and across the therapy sessions at $p \leq 0.01$ level of significance. To further investigate, which of the two conditions differed significantly, Wilcoxon Signed Rank test was carried out. Results of Wilcoxon Signed Rank test are given in Table 4.8.

Table 4.8:

Comparison of tinnitus loudness measured across three intervals for White noise therapy

Conditions	z- value	Significance level
Pre and Post therapy (10)	-2.121	0.034*
Pre and Post therapy (20)	-2.121	0.034*
Post therapy (10) and Post therapy (20)	-2.121	0.034*

*p- ≤0.05

From the Table 4.8, it is clear that there is a significant difference ($p \leq 0.05$) between the baseline and after 10 sessions, between baseline and after 20 sessions and between 10 sessions and 20 sessions, post therapy.

b. Using questionnaire scores:

Tinnitus Severity Index Questionnaire (TSIQ) scores across the three therapy intervals were compared using Friedman's test. Results of the test are given in the table 4.9.

Table 4.9:

Comparison of questionnaire scores across three intervals for White noise therapy

Conditions	**Number of subjects**	**Mean and SD**	**Chi-Square value**	**Significance level (df= 2)**
Pre therapy	5	42.80 (6.380)	10.000	0.007*
Post therapy (after 10 sessions)	5	30.60 (6.731)	10.000	0.007*
Post therapy (after 20 sessions)	5	17.00 (2.345)	10.000	0.007*

*- $p \leq 0.01$

Results revealed a significant difference between the baseline and across the therapy sessions at $p \leq 0.01$ level of significance, similar to tinnitus loudness.

Wilcoxon Signed Rank test was carried out to further investigate the questionnaire scores across three therapy intervals. Results of Wilcoxon Signed Rank test are shown in Table 4.10.

Table 4.10:

Comparison of questionnaire scores measured across the intervals for White noise therapy

Conditions	z- value	Significance level
Pre and Post therapy (10)	-2.023	0.043*
Pre and Post therapy (20)	-2.023	0.043*
Post therapy (10) and Post therapy (20)	-2.023	0.043*

*p- ≤0.05

From the Table 4.10, it is clear that there is a significant difference in the questionnaire scores between pre therapy and between two post therapy conditions at p≤0.05 level of significance.

3. Comparison between the Notched music therapy and White noise therapy:

Mann Whitney U test was carried out to compare the benefit obtained between the two therapy procedures for tinnitus loudness and questionnaire scores across the therapy intervals. Results of the Mann Whitney U test are given in the table 4.11 and table 4.12.

Table 4.11:

Results of Mann Whitney U test for Notched music and White noise therapy for tinnitus loudness

Conditions	**Number of subjects**	**Mean and SD**	**Mann Whitney U value**	**z- value**	**Significance level**
Pre therapy	10	34.50 (7.976)	6.500	-1.297	0.195
Post therapy (after 10 sessions)	10	21.00 (5.676)	8.500	-0.873	0.382
Post therapy (after 20 sessions)	8	5.63 (5.630)	4.500	-0.928	0.353

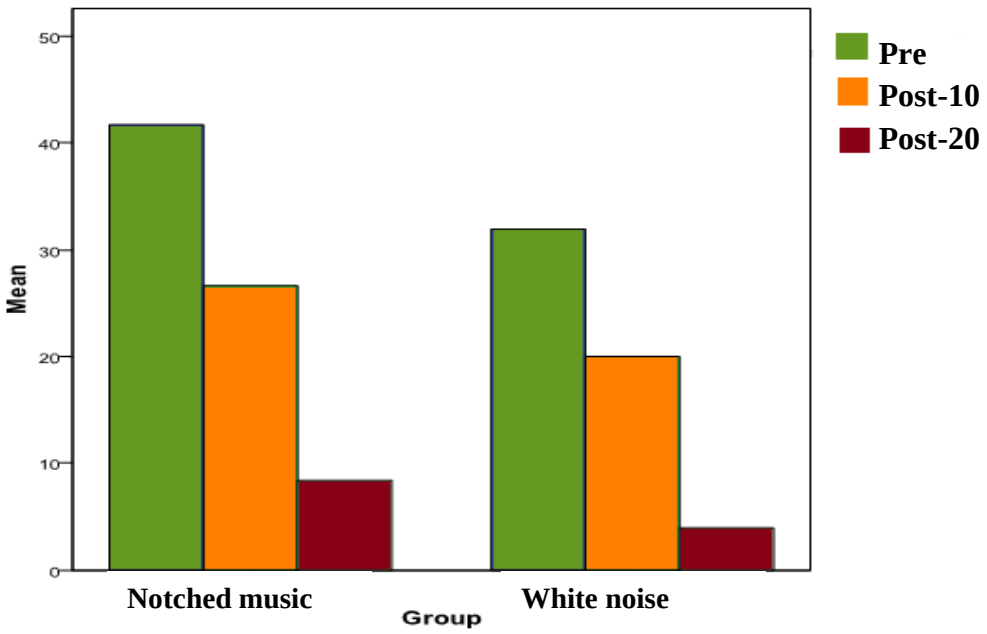

Figure 4.1: Loudness measured pre-therapy, post therapy after 10 sessions and 20 sessions for both the therapy groups.

Table 4.12:

Results of Mann Whitney U test for Notched music and White noise therapy for questionnaire scores

Conditions	**Number of subjects**	**Mean and SD**	**Mann Whitney U value**	**z- value**	**Significance level**
Pre therapy	10	38.10 (7.738)	3.500	-1.886	0.059
Post therapy (after 10 sessions)	10	26.90 (6.871)	6.000	-1.362	0.173
Post therapy (after 20 sessions)	10	16.20 (2.486)	7.500	-1.640	0.287

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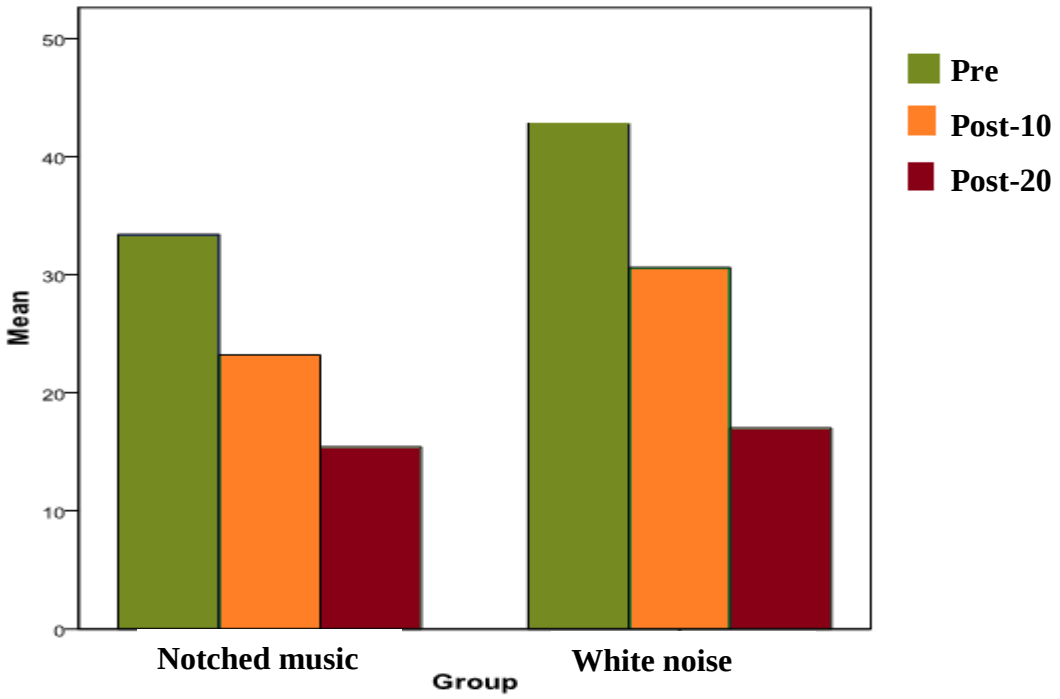

Figure 4.2: Questionnaire scores pre-therapy, post therapy after 10 sessions and 20 sessions for both the therapy groups.

It is clear from the Table 4.11 and 4.12 that there is no statistically significant difference ($p \leq 0.05$) between the two therapy techniques for tinnitus loudness and the questionnaire scores. However, on subjective analysis of individual data there was a difference in the tinnitus loudness and questionnaire scores with subjects receiving Notched music therapy having greater improvement. This can be observed in figures 4.1 and 4.2. Further, two of the five subjects receiving Notched music therapy, reported complete inhibition of tinnitus.

To see if the effects of therapy were present even after withdrawing the therapy, patients were telephoned to ask if there was any change in the tinnitus after 15 days following the therapy. None of the subjects reported of any change in the tinnitus loudness after 15 days after withdrawal of therapy.

Chapter 5

DISCUSSION

The results obtained from different statistical analysis for psychoacoustic measure of tinnitus loudness and questionnaire scores for both the therapy techniques are discussed below.

1. Evaluation of the efficacy of notched music therapy using psychoacoustic measurement of tinnitus loudness and questionnaire scores:

Results of comparison of pre therapy and post therapy psychoacoustic measurement of tinnitus loudness and questionnaire scores showed decrease in the loudness at the termination of therapy in three subjects. Whereas, two had a complete inhibition of tinnitus which indicates that the therapy was successful in ameliorating tinnitus completely.

The above mentioned observation is in support of the notion that tinnitus loudness can be significantly diminished by custom tailored notched music treatment (Okamoto, Stracke, Stoll & Pantev, 2010). Tailor-made notched music treatment strategy helps in complete suppression of tinnitus by reorganizing the maladaptive auditory cortex (Rauschecker, 1995; Blood & Zatorre, 2001; Elbert & Rockstroh, 2004) even in subjects with normal/near normal hearing sensitivity. However, in Okamoto, Stracke, Stoll & Pantev (2010) study, the therapy using the tailor-made notched music treatment was given over a period of 12 months. However, in the present study, only with 20 hours of therapy, there was an improvement seen. This

could be attributed to the peripheral loss that the subjects in Okamoto, Stracke, Stoll & Pantev's study had, which might have lead to more maladaptive cortical reorganization

Pantev, Wollbrink, Roberts, Engelien and Lütkenhöner (1999), demonstrated that listening to notched music reduces the cortical activity corresponding to the notch centre frequency, which may be due to the lateral inhibition. The target notched music introduces a functional deafferentation of auditory neurons corresponding to the eliminated frequency band, and because this frequency band overlaps the individual tinnitus frequency, the notched music no longer stimulates the cortical area corresponding to the tinnitus frequency, although it still excites surrounding neurons.

Thus, the neurons, which were not stimulated due to the notch, were presumably actively suppressed via lateral inhibitory inputs originating from surrounding neurons (Pantev, et al., 1999; Pantev et al., 2004; Okamoto, Kakigi, Gunji & Pantev, 2007).

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2. Evaluation of the efficacy of White noise therapy using tinnitus loudness and questionnaire scores:

Similar to the results of Notched-music therapy, results of comparison of pre and post therapy psychoacoustic measurement of tinnitus loudness and questionnaire scores also showed decrease in the loudness at the termination of White noise therapy in all the subjects. However, none of the subjects showed complete inhibition.

This result is in correlation with the earlier studies that used broadband noise generators for the masking of tinnitus (Henry et al., 2006; Vernon & Schleuning,

1978; Henry & Meikle, 2000; Kitajima, Kitahara & Kodama, 1987; Shailer, Tyler & Coles, 1981). Hence, white noise therapy given in a clinical set up is useful at least to suppress the tinnitus. This therapy has an advantage over the noise generators, which are take home devices and have to be worn all the time.

3. Comparison between the Notched music therapy and White noise therapy:

The comparison between the two therapies revealed no statistical significant difference; this may be because only data from three subjects receiving Notched music therapy were considered for analysis. However, subjective analysis of individual data revealed a difference in the tinnitus loudness and questionnaire scores. This revealed that subjects receiving Notched music therapy showed greater improvement when compared to White noise therapy. Hence, Notched-music, which is tailor made for each subject might be a better option to treat tinnitus when compared to White noise.

Chapter 6

SUMMARY AND CONCLUSION

Tinnitus is a sensation resulting from a malfunction of the cochlea or auditory nerve (Moller, 1984; Jastreboff, 1990). This condition is symptomatic of some abnormal state of the auditory system and is not a disease entity in itself. Like pain, tinnitus is a personal, subjective experience that cannot be measured objectively and is described mainly by patient report (Newman & Sandridge, 2006).

This dysfunction can be corrected using habituation therapies and sound therapies which in turn results in cortical reorganization (Jastreboff, 1993; Mühlnickel, et al., 1998; Okamoto, et al., 2010).

Various tinnitus treatment techniques are available of which acoustic therapy has proven to be useful in providing relief to patients suffering from tinnitus (Jastreboff & Hazell, 2004).

The present study aimed to evaluate the benefit from White noise therapy and Tailor-made Notched music therapy, which are two of the intervention procedures to treat tinnitus.

Ten subjects with chronic continuous tonal tinnitus were included in the study. Each of the two therapy groups had five participants who received therapy for 20 sessions with one hour duration per session.

For evaluating the efficacy of two therapy techniques, the measures considered were:

- Tinnitus loudness measured trough loudness matching procedure
- Tinnitus Severity Index Questionnaire (TSIQ) scores

Both the therapy techniques provided significant benefit in treating tinnitus. Hence, white noise therapy in a clinical set up can be considered as an option of tinnitus treatment at least to suppress the tinnitus, to some extent. It can also be concluded that even tinnitus subjects who have near normal hearing sensitivity have maladaptive cortical reorganization, which can be corrected with tailor made notched-music therapy. Further, notched music therapy was found to provide more benefit than white noise therapy, though this difference was not statistically significant.

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Appendix

Tinnitus Severity Index Questions

Directions: For the questions below, please **CIRCLE** the number that best describes you.

Does your tinnitus						
		Never	**Rarely**	**Sometimes**	**Usually**	**Always**
1	Make you feel irritable or nervous	1	2	3	4	5
2	Make you feel tired or stressed	1	2	3	4	5
3	Make it difficult for you to relax	1	2	3	4	5
4	Make it uncomfortable to be in a quiet room	1	2	3	4	5
5	Make it difficult to concentrate	1	2	3	4	5
6	Make it harder to interact pleasantly with others	1	2	3	4	5
7	Interfere with your required activities (work, home, care, or other responsibilities)	1	2	3	4	5
8	Interfere with your social activities or other things you do in your leisure time	1	2	3	4	5
9	Interfere with your overall enjoyment of life	1	2	3	4	5
10	How much of an effort is it for you to **ignore** tinnitus when it is present?					
	Can easily ignore it	1				
	Can ignore it with some effort	2				
	It takes considerable effort	3				
	Can never ignore it	4				
11	How much **discomfort** do you usually experience when your tinnitus is present?					
	No discomfort	1				
	Mild discomfort	2				
	Moderate discomfort	3				
	A great deal of discomfort	4				
12	Does your tinnitus interfere with sleep?					
	No	1				
	Yes, sometimes	2				
	Yes, often	3				
	Yes, always	4				

On the scale below, **CIRCLE** the number that best describes the loudness of your usual tinnitus									
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Very Quiet					Intermediate				Very Loud

Total Score: