Manipulation of hearing aid gain and tinnitus relief: A paired comparison study

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Abstract

The study aimed to investigate the best amplification strategy for tinnitus relief without compromising speech perception. The objectives were to compare amplification strategies on tinnitus relief using paired comparison method and to measure SNR 50 from three amplification strategies to document speech perception ability. A repeated measure research design was utilized. Twelve participants in the age range of 30-60 years who had mild to moderately severe sloping sensorineural hearing loss with continuous tonal tinnitus were considered. The participants were grouped into mild and severe based on score obtained in Tinnitus Handicap inventory (THI). In each participant, minimum masking level (MML) was used to assess tinnitus pitch and loudness. MML which is the level of noise required to mask tinnitus as a function of frequencies were obtained. A paired comparisons method was carried out to determine the program in which maximum preference score obtained on tinnitus relief by a test hearing aid which was programmed with three programs such as prescriptive, preferred and adjusted gain at tinnitus pitch. SNR 50 was carried out at each of the programs. Each group of participants' significantly preferred hearing aid gain set at tinnitus pitch on tinnitus relief. There was no significant difference between the SNR 50 scores in the three gain settings. An additional gain set at tinnitus pitch after alleviating hearing loss by prescriptive method was found to be the best strategy for effective masking of tinnitus and that led to tinnitus relief without compromising speech perception.

Key words: *Hearing aid, tinnitus,gain*

Introduction

Tinnitus is a sound produced without any external stimulus which originates in the head (Mc Fadden, 1982). Tinnitus is majorly associated with either unilateral or bilateral hearing loss (Kim et al, 2015). Assessment of tinnitus pitch and loudness necessitates in initiating with any rehabilitation program. Minimum Making Level (MML) is one such assessment method which uses masking method (Feldmann, 1971) to assess tinnitus pitch and loudness. In MML an intensity of narrowband noise required to mask tinnitus was determined across frequencies. Wegal and Lane (1924) observed lowest masking level required at a frequency close to tinnitus pitch. The management options for tinnitus includes tinnitus retraining therapy, tinnitus habituation therapy, tinnitus masking equipments (sound generators), hearing aid, notch music therapy, etc. Hearing aids have been considered as a useful tool in tinnitus management (Saltzman & Ersner, 1947). Kicssling (1980) compared hearing aids with maskers for the treatment of tinnitus and concluded that usage of hearing aids was efficient in suppressing tinnitus. This is because hearing aids acts as a masker; reduce awareness on tinnitus; they may facilitate better communication, reduces stress (Newman, 1999; Del Bo & Ambrosetti, 2007); and they may directly act against tinnitus source of generation by reducing drivers of central gain adaptation or inhibition (Moffat et al, 2009).

Modifications in the hearing aid add a meaningful approach on tinnitus relief. Choosing the right fitting formula for individuals with tinnitus is one of the important approaches. In a comparison between DSL (I/O) v4.0 and NAL-NL1 prescription formulae, 80% of the individuals with tinnitus reported less audibility of tinnitus when the hearing aid was programmed using DSL (I/O) v4.0 (Wise 2003). The reason could be a higher low frequency gain is provided especially when they are of low intensities sound (Dillion, 2001). This might have allowed the low frequency ambient noise to sufficiently be audible and mask the tinnitus to certain extent.

The flexibility of current hearing aid technologies lead to the development of fitting approaches specifically intended for the reduction of tinnitus. The fitting of open ear devices in the treatment of tinnitus has been shown to be effective (Del Bo & Ambrosetti, 2007). Wise (2003) varied the compression threshold in hearing aid and its effect on audibility of tinnitus was assessed. Low compression knee-point of 30 dB SPL produced ambient noise significantly louder than compared to compression threshold set at 50 dB SPL.

May (1998); Ricketts and Mueller (1999) assisted the patients to change the options of sensitivity of microphones, noise reduction circuit and volume control who wished to hear speech in background noise and to take maximum advantage of diffuse ambient noise for tinnitus management. The participants of the study switched off noise reduction circuit and changed from directional sensitivity of microphone to omnidirectional. In addition, volume control is changed to obtain tinnitus relief.

Despite numerous studies on hearing aid for tinnitus management, none of the studies showed focus on prescribing sufficient gain at tinnitus pitch on tinnitus relief. Swathi, Shetty, Jijo and Narne (2015) studied acoustic stimulation treatment by changing the gain in

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hearing aid against tinnitus pitch and results revealed that tinnitus is suppressed. It infers that rather than just fitting the hearing aid for their hearing loss, a one step further gain optimization at tinnitus pitch is required for effectively reducing the audibility of tinnitus. However, in their study an attempt was not made in comparing prescribing gain and optimizing gain at tinnitus pitch. Thus, in the present study, a systematic design was utilized to determine the best program to alleviate hearing loss without comprising speech perception and give maximum benefit on tinnitus relief. The following research question was formulated; does gain adjustment at tinnitus pitch lead to tinnitus relief and better speech perception? The present study aimed to compare three gain settings in the hearing aid to arrive at a conclusion that if any of the gain setting can successfully lead to tinnitus relief. Thus, null hypothesis will be none of the gain adjustment strategies in hearing aid has provided tinnitus relief and speech perception scores.

The hearing aid is one among the treatment option available for tinnitus relief. Acoustic stimulation by the hearing aid prescribed for hearing loss has an effect on tinnitus relief but it is not consistent. This is because there is no standard prescription of gain in hearing aid for management of tinnitus. Thus, an attempt was made in the present study to adjust gain in hearing aid in a systematic manner with respect to tinnitus pitch. This kind of gain management in hearing aid could stimulate the neural activity throughout the auditory system and consequently suppress the source generation of tinnitus effectively at central auditory system without compromising speech perception scores. Therefore, the aim of the study was to investigate manipulation of gain in hearing aid on tinnitus relief and speech perception ability.

Methods

A one shot test and randomized repeated measures with comparative and correlative research design was used to study the manipulation of gain in hearing aid on tinnitus relief.

Subject selection criteria

A total of twelve participants with the age range of 30-60 years (mean age= 50.08 years) having acquired bilateral mild to moderately severe sensorineural hearing impairment who have either bilateral or unilateral tonal tinnitus(tinnitus pitch ranging from 250 to 6000Hz) at the time of data collection were recruited for the study. They had normal middle ear status as indicated by 'A' type tympanogram with elevated or absent reflexes at frequencies from 250 Hz to 4 kHz (in octave). They were naïve hearing aid users. Perception of tinnitus was present even after being fitted with hearing aid. Participants were native speakers of Kannada and none of them had any neurological, psychological and cognitive problems. Tinnitus Handicap Inventory was administered and based on the score (Table-1) obtained on it each participant was grouped either to mild group or severe group. The score of seven participants on THI were within mild range and the rest five participants were in the severe range.

Table 1: Details of participants

Age	Pure Tone Average (HL)	Pure Tone Average (SPL)	Tinnitus Pitch	MML	THI raw scores	THI Nominal
50	43.75	56.00	6000	78	18	Mild
50	43.75	56.00	4000	94	18	Mild
56	68.75	81.00	250	64	20	Mild
56	73.75	86.00	250	80	20	Mild
52	55.00	67.25	1500	52	22	Mild
58	67.75	79.75	6000	94	28	Mild
60	32.50	44.75	500	50	28	Mild
58	61.00	69.75	250	72	52	Severe
35	58.75	71.00	3000	57	64	Severe
33	62.50	74.75	3000	84	68	Severe
45	48.75	61.00	1500	80	68	Severe
48	68.75	81.00	250	58	76	Severe

MML: Minimal Masking Level; THI: Tinnitus Handicap Inventory

Test Environment

Tests were carried out in a sound treated double room situation. The noise levels at frequencies from 250 to 8 kHz were within the permissible limits as per ANSI (S3.1; 1991).

Instrumentation

The following instruments and speech materials were used.

1. A calibrated diagnostic two channel audiometer with head phones (TDH-39) was used to measure the hearing sensitivity, speech identification scores, and minimum masking level. Bone vibrator

(B-71) was used to obtain bone conduction thresholds. Loud speaker was used to obtain SNR 50 and to present the sentences to rate the best amplification strategy on tinnitus relief.

2. Personal laptop was used to play the recorded standardized sentences to obtain SNR 50.
3. Sorino X Mini - Receiver in the canal (RIC) digital hearing aid was used, which has the option to switch off directional microphone and deactivate digital noise reduction (DNR). In addition appropriate dome size was selected based on opening of ear canal of each participant.
4. Aux viewer software was used to prepare stimulus for SNR 50.
5. Fonix 7000 hearing aid analyzer and winchap (v-3) were used to measure the gain and output of the hearing aid.

Speech materials

Phonemically balanced (PB) word lists in Kannada developed by Yathiraj and Vijayalakshmi (2005) was used, to obtain open set speech identification score. And standardized three lists of Kannada sentences developed by Geetha, Sharath and Manjula (2013) were used to obtain SNR 50 from different programs and also to rate the best program in hearing aid which gives tinnitus relief.

Stimulus preparation for SNR 50

Speech shaped noise having spectrum similar to that of standardized sentence was prepared. The procedure of generating speech shaped noise is given elsewhere (Shetty and Mendhakar, 2015). Three lists of standardized Kannada sentence were used, which are phonetically and phonemically balanced. Each sentence in the list comprised of five target words. For each sentence, root mean square (RMS) was identified and then noise was added at desired SNR. The first list of ten sentences was mixed with speech shaped noise at different signal to noise ratios ranging from +12 dB to -6 dB SNR in 2 dB step size. The onset of noise was started 500 ms before the onset of each sentence and continued for 500 ms after the offset of the sentence. A smooth ramp (rise and fall time) was made to the noise using cosine function to avoid unintended effects. The following formula was used to add noise to each sentence. Similarly, to the other two lists of sentences noise was added at different SNR using similar procedure as specified earlier. Below mentioned code was used to generate desired SNR in Aux Viewer software.

SNR=wave("filename")**@ rms >>**

500 ramp (wave ("noise")@ rms,20)

Procedure

The following procedures were utilized for subject selection and to study the manipulation of gain in hearing aid on relief from tinnitus and speech perception.

Subject selection: The pure tone thresholds for air conduction at octave frequencies from 250 Hz to 8 kHz were obtained using +10 and -5 dB procedure as specified by Carhart and Jerger (1959). The bone conduction thresholds from 250 Hz to 4 kHz were identified using similar procedure. One of the lists of phonetically balanced word list developed by Yathiraj and Vijayalakshmi (2005) was presented through headphones. Each participant was instructed to repeat the word heard. The number of correctly identified words were counted and converted into percentage. Tympanometry was carried out using 226Hz probe frequency and pressure rate varied from 200/600 daPa. Ipsilateral and contralateral reflexes were found at 500 to 4 k Hz (in octave) by varying the intensity insteps of 5 dB to notice a minimum change in the compliance of tympanic membrane.

Administration of Tinnitus Handicap Inventory: Tinnitus Handicap Inventory (THI) is a quantitative measure which comprised of 25 questions (Newman et al. 1996). The standardized Kannada version of this test developed by Zacharia et al (2012) which was utilized to assess the degree of severity of tinnitus and its effect on the daily living and communication handicap. Each question was rated on a three point rating scale 'yes' as 4, 'sometimes' as 2, and 'no' as zero. The maximum score that can be obtained from this test battery is 100. The scoring pattern is 2-16 slight, 18-36 mild, 38-56 moderate, 58-76 severe and 78-100 catastrophic.

Tinnitus pitch: In order to obtain the tinnitus pitch, a standardized procedure by Henry et al. (2002) was adopted. The ear contralateral to the ear in which tinnitus was present was selected to deliver different tones of frequencies from 125 Hz to 8000 Hz in octaves mid octaves through headphones at the most comfortable level. Each participant was instructed to indicate if the pitch (frequency) of the tone presented and their perceived tinnitus pitch are same or different. If the participants could not exactly match the pitch, they were told to report the tone which was closest to their pitch of tinnitus. The pitch at which participant indicated it as same, or the nearest as that of their tinnitus was considered as the tinnitus pitch.

Tinnitus Minimum Masking Level: The procedure of tinnitus making level is adopted from the masking curve concept by Feldmann (1971). Each participant was instructed to pay attention to tinnitus and report minimum level at which tinnitus was masked by a narrow band noise. A narrowband noise was presented at threshold level through the headphones to the ear in which tinnitus was present. The level of it was increased in 1 dB step until the intensity of noise was just sufficient to mask the tinnitus. Likewise at different frequencies (250 Hz, 500 Hz, 750 Hz, 1000 Hz, 1500 Hz, 2000Hz, 3000Hz, 4000Hz, 6000 Hz, 8000 Hz) a minimum masking level (MML) at which tinnitus was suppressed were measured. The procedure was carried out thrice for the consistency of results. A relative gain as a function of frequency was calculated by taking the difference between MML at each frequency and MML at tinnitus pitch.

Programming and recording the output of hearing aid at tinnitus pitch: Sorino X Mini RIC hearing aid was programmed using DSL i/p (v-5) in which appropriate gain was prescribed with respect to the participant's hearing loss. The option of directionality was disabled, noise reduction circuit was switched off and compression threshold was set at 30 dB SPL. To verify gain in hearing aid real ear insertion method was performed on each participant test ear (tinnitus ear). Each participant was seated at 12 inch distance from loudspeaker and positioned at 450 azimuth.

The probe tip detached from probe unit was marked 5 mm past the end of the doom of RIC hearing aid. Later the probe tip was attached to probe unit and inserted into the ear canal (tinnitus ear) till the marking of probe tube was visible at tragal notch. Winchamp (v3) software was loaded in the personal laptop which was connected to the Fonix 7000 hearing aid analyzer. The measurements were carried out through the software. The levelling was done once the probe tube was inserted into the ear canal. The real ear unaided response (REUR) was measured for digi speech at 65 dB SPL. The output SPL at the level of ear canal was measured at octave frequencies from 0.25 kHz to 8 kHz.

Further, without changing the position of probe tube at ear canal, the hearing aid programmed at 'prescribed' gain (P1) settings was fitted on subjects' ear. The real ear aided response (REAR) was measured (at octave frequencies from 0.25 kHz to 8 kHz) for the digi speech presented at 65 dB SPL. The Fonix 7000 hearing aid analyzer automatically calculates the real ear insertion gain (REIG) at octave frequencies from 0.25 kHz to 8 kHz by subtracting REAR from REUR. It was ensured that REIG was almost matched to the prescriptive target by increasing the prescriptive gain in hearing aid. From the REIG curve the gain (in SPL) at the tinnitus pitch (P1) was noted down.

In addition, without changing a position of probe tube and hearing aid, second program was activated in the test hearing aid. In the second program gain level was set according to the preference of participant. The recorded Ling six sounds were used to set the gain at preferred level. These recorded Ling six sounds were presented at 65 dB SPL at random order. Each participant was instructed to judge the loudness and clarity of these sounds informally. Depending on the participant's response the gain with respect to the spectrum of each sound was programmed. From the REIG curve the gain (in SPL) at the tinnitus pitch (P2) was measured.

Further, third program was activated in the same hearing aid. In the third program, the gain in hearing aid at tinnitus pitch was varied systematically. Each participant was instructed to pay attention to the tinnitus and report level of hearing aid gain at which tinnitus was masked. To arrive at gain on tinnitus suppression the standardized sentences were presented at 65 dB SPL and the gain in hearing aid was systematically increased in 1 dB step size till the point where tinnitus was suppressed by the hearing aid. The minimum gain at which the participant reports suppression of tinnitus is defined as gain at tinnitus pitch. From the REIG curve the gain (in SPL) at the tinnitus pitch (P3) was measured.

Finally, gain at tinnitus pitch was calculated by subtracting the gain (in SPL) between programs (P1, P2 and P3) at tinnitus pitch. A total of two gain differences at tinnitus pitch were determined (i.e P3-P1and P3-P2).

SNR 50: Ten sentences embedded at different SNRs were randomized. Each sentence was presented at 65 dB SPL in aided condition. The participants were instructed to repeat the sentence heard. The SNR level at which the testing started (L) and number of correctly recognized target words in each sentence was noted down. The total number of target words from all sentences was added (T). Also, the total number of words per decrement (W) and SNR decrement step size in each sentence (d) were noted down. The obtained values were substituted to the given equation adapted by Spearman-Karber to determine SNR 50 % (Finney, 1952). The below equation was used to calculate the SNR 50. From each study participant the SNR 50 was obtained from all three programs of hearing aid.

$$50 \text{ point} = L + (0.5*d) - d\,(T)/W$$

Judgment of tinnitus relief from three programs in hearing aid using paired comparison: A paired comparison judgment was used to obtain the best program in hearing aid in which maximum relief was attained. A total of three comparisons (prescriptive gain, preferred gain and adjusted gain) were made per trial. Each participant was instructed to choose one program which gave tinnitus relief against other program by listening to a sentence presented at 65 dB SPL, delivered through loudspeaker. The best program was selected from a total of three comparisons which were presented in Round Robin Tournament format. A preference score of one mark was assigned for the best program. Likewise three trials were performed and it was ensured that three comparisons in each trial were randomized. Finally the number of times each program was selected on relief from tinnitus was noted down.

Statistical Analyses

Descriptive analyses was performed for the data of MML; preference percentage and gain difference. Relationship between MML and gain at tinnitus pitch was determined using Spearman's product moment correlation. In the next step, Friedmen's test was conducted to investigate difference in preference score. If significant difference was present, then Wilcoxon signed rand test was performed. In the next step, Friedmen's test was performed to determine difference in SNR 50 between programs. Further, Mann Whitney U test was conducted to see difference between groups on SNR 50.

Results

The aim of the experiment was to investigate manipulation of gain in hearing aid on tinnitus relief and speech perception. The Minimum Masking Level (MML) required to suppress tinnitus were measured at different frequencies. Correlation between MML at tinnitus pitch and gain at tinnitus pitch was investigated. The analysis of the paired comparison was performed to check for the best program, which led to the relief from tinnitus. In addition, preference of hearing aid (in percentage) on tinnitus relief from study participants was documented. Further, a gain differences between programs at the tinnitus pitch were examined. The effect of manipulation of gain on speech perception was analyzed. These data were subjected to statistical analyses using the Statistical Package for Social Sciences (SPSS) software (version 17.0).

Minimum Masking Level

Figure 1 represents relative gain plotted as a function of frequency, in each participant of mild group. Each curve represents the amount of masking noise at different frequencies required to suppress tinnitus and this was descriptively analyzed. The black dotted circle indicates tinnitus pitch. From Figure 1 it can be observed that for low pitch tinnitus (250 Hz and 500 Hz) to be suppressed, more amount of masking noise was required above tinnitus pitch than at tinnitus pitch. In participants who had tinnitus at 1500 Hz; 4000 Hz; 3000 Hz and 6000 Hz frequency, a masking noise at below and above tinnitus pitch required more noise level than at tinnitus pitch. Further, it is also found that immediate adjacent frequencies (above and below) near tinnitus pitch required less noise level to suppress tinnitus. However, far frequencies with respect to tinnitus pitch required more level of noise to suppress tinnitus. Similar observations were found in severe group (Figure 2).

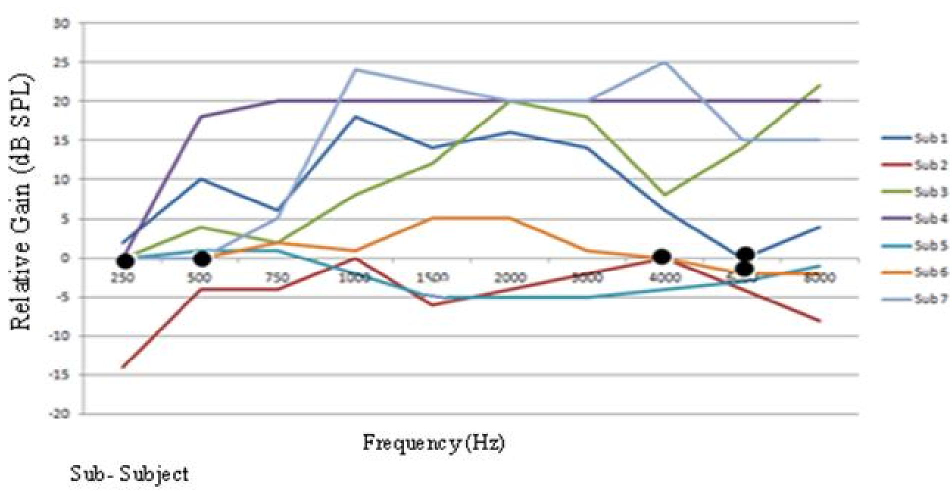

Figure 1: The relative gain as a function of frequency for mild group

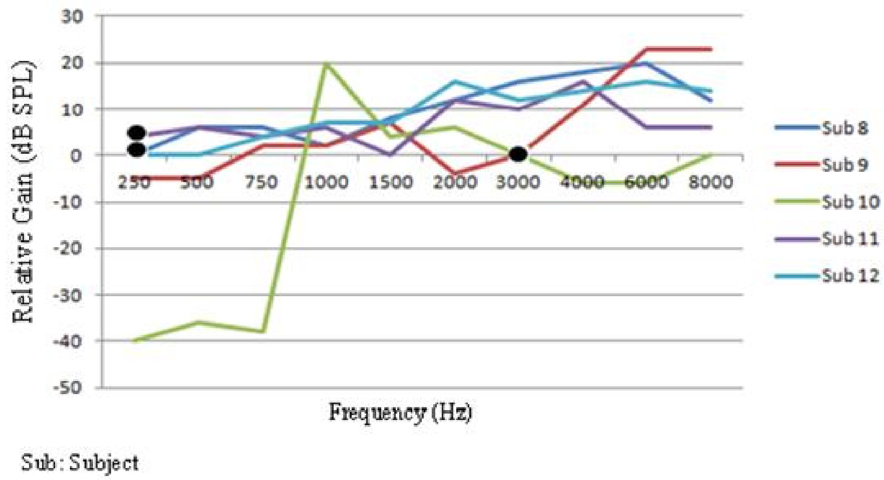

Figure 2: The relative gain as a function of frequency for severe group

Relation between MML at tinnitus pitch and gain at tinnitus pitch

The MML at the tinnitus pitch and the gain provided by the hearing aid at the tinnitus pitch in the three programs were subjected to Spearman's correlation. This was performed in each group. In mild group, result revealed no significant correlation between the MML at the tinnitus pitch and the gain provided by the hearing aid at the tinnitus pitch in P1 (N= 12, rs= .24, p > .05); P2 (N= 12 rs= .29, p > .05) and; P3 (N = 12 rs= .28, p > .05).

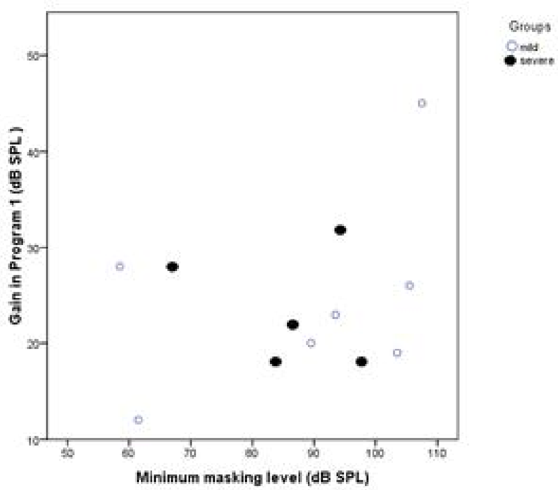

Figure 3: Correlation between MML at tinnitus pitch and gain in P1 at tinnitus pitch.

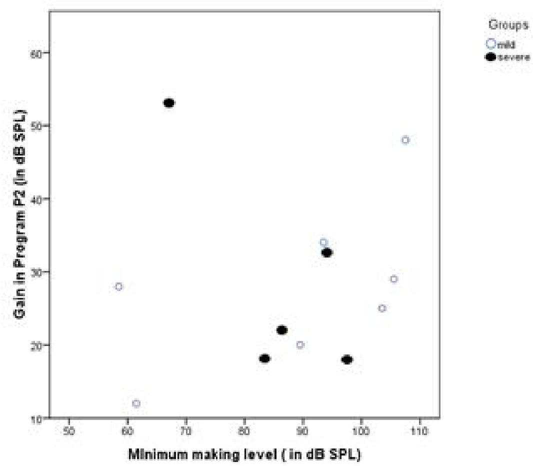

Figure 4: Correlation between MML at tinnitus pitch and gain in P2 at tinnitus pitch.

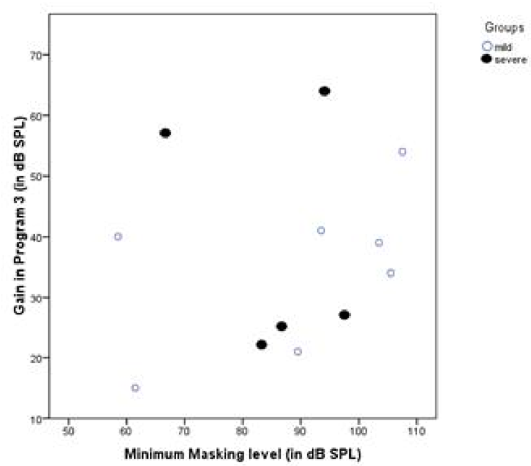

Figure 5: Correlation between MML at tinnitus pitch and gain in P3 at tinnitus pitch.

Paired Comparison

The preference scores obtained from three different programs using paired comparison were analyzed using Friedman test. The test was performed separately for the mild group and severe group. For the mild group, the results showed a significant effect of preference scores between programs on tinnitus relief

[? 2 (2) = 6.88, $p < 0.05$]. Further, a Wilcoxon matched pairs signed rank test was conducted to determine which program has caused difference in the preference score on tinnitus relief in the mild group. Results of this analysis indicated that there was a significant difference in preference score between P1 and P3 ($z = -2.53$, $p < 0.05$) and; P2 and P3 ($z = -2.11$, $p < 0.05$) on tinnitus relief. However there was no significant difference in preference score between P1 and P2 programs on tinnitus relief ($z = -0.175$, $p > 0.05$). Whereas, in severe group, it was found that there was a significant difference in preference score between three programs on tinnitus relief [? 2 (2) = 10.00, $p < 0.05$]. Further in order to ascertain which program might have caused significant preference on tinnitus relief, a Wilcoxon matched pairs signed rank test was conducted for the severe group. It was found that there was a significant difference in preference score between programs P1 and P2 ($z = -2.23$, $p < 0.05$); P2 and P3 ($z = -2.23$, $p < 0.05$); and P1and P3 ($z = -2.23$, $p < .05$) on tinnitus relief. The results indicate that P3 was the preferred program and received significantly more favorable ranking than P1 and P2 on tinnitus relief.

Preference Percentage

The round Robin tournament revealed the preference of the best program on tinnitus relief. In the mild group, 57.14% (4/7 participants) of the participants preferred gain at tinnitus pitch, 42.85(3/7 participants) of the participants opted for the preferred gain and none of them preferred the prescriptive gain. Whereas in severe group, 80% (4/5 participants) of the participants preferred gain at tinnitus pitch, 20% (1/5 participants) of the participants opted for the preferred gain and none of them preferred the prescriptive gain. Thus, in both the groups a majority of them preferred gain at tinnitus pitch to obtain maximum relief from tinnitus than the other programs.

Gain Difference

The gain differences between programs at the tinnitus pitch were obtained in each group. From Table 2, it was observed that more gain was required in P1 and P2 than P3 to suppress tinnitus. For the mild group, a gain of 10 dB more was required in P1 to suppress tinnitus than P3. In addition, a gain of 6.4 dB more was required in P2 to suppress tinnitus than P3. For the severe group, a gain of 15.6 dB more was required in P1 to suppress tinnitus than P3. In addition, a gain of 10.4 dB more is required in P2 to suppress tinnitus than P3.

Table 2: Gain difference between programs in each group

Group		P3-P1	P3-P2
Mild	Mean	10.14	6.42
	SD	7.104	4.79
Severe	Mean	15.60	10.40
	SD	14.25	11.73

SNR 50

The SNR 50 was obtained from each program from the participants of each group. These data was subjected to a Friedman test to evaluate differences in SNR 50 between prescriptive gain (Mean =4.28, SD =4.08), preferred gain (Mean =3.21, SD=2.65) and gain at tinnitus pitch (Mean =3.50, SD=2.54). The test result revealed that there was no statistically significant [? 2 (2) = 1.14, $p > 0.05$] between programs on SNR 50. In severe group, the SNR 50 obtained from prescriptive gain was Mean= 6.50 with SD= 4.06; preferred gain was Mean=5.60 with SD= 3.71; and gain at tinnitus pitch was Mean=4.50 with SD=3.62. The data of SNR 50 from three programs were subjected to Friedman test. It revealed that there was no statistically significant [? 2 (2) = 4.10, $p > 0.05$] between program on SNR 50. It infers that SNR 50 was similar for all three programs. This was true for each group.

Further, to ascertain if there was any significant difference between groups on SNR 50, a Mann - Whitney U test was performed. It was found that there was no significant difference ($U = 136.00$, $z = -0.69$) between mild (mean=3.66, SD= 3.04) and severe (mean=5.53, SD= 3.62) groups on SNR 50.

Discussion

The aim of the study was to determine the best gain setting in hearing aid on tinnitus relief. From the study participants of each group, minimum masking level (MML) was obtained to document tinnitus suppression in them. Irrespective of group, if tinnitus was at high pitch, more level of noise was required at low and high frequencies than noise level at tinnitus pitch to mask the tinnitus (Penner, 1987). Conversely, tinnitus at low pitch required more level of high frequency noise than at tinnitus pitch to mask the tinnitus (Zwicker, 1974). Tinnitus, at mid pitch, required a relatively lesser amount of low frequency noise than high frequency to suppress tinnitus. The outcome of the MML result on tinnitus suppression can be explained by psychophysical tuning curve and hearing loss associated with them.

At high pitch tinnitus, basal part of cochlea excites even in absence of stimulation (phantom perception). For it to be suppressed, low frequency noise level required was way high. This is because all the participants had minimal to mild hearing loss at low frequency region and it generally stimulates at apical region of cochlea required more level of noise to just mask the tinnitus at high pitch, which excites at basal part of cochlea. In addition, high frequency stimulation above high-pitched tinnitus required high level of noise for it to mask. This could be attributed to more number of outer hair cells damage and consequent loosening of basilar membrane stiffness at basal part of cochlea, which reflected in high frequency hearing loss. Further, high frequency stimulation above high pitch tinnitus excites at basal turn and required high level of noise to suppress tinnitus.

At low pitch tinnitus, apical part of cochlea excites in the absence of stimulation. It was found that higher level of masking noise at high frequency was required for it to suppress than at tinnitus pitch. The reason could be loss at high frequencies and presentation of high frequency noise level excites basal turn of cochlea and would require more level of noise to suppress low pitch tinnitus which excites at apical region of cochlea. However, tinnitus suppression at mid pitch required higher amount of noise at high frequency than at low frequency. This is because poorer threshold at high frequency excites at basal turn of cochlea and required more level for it to suppress the tinnitus, which excites at middle portion of cochlear turn.

Masking of tinnitus by a narrow band signal was helpful in judging the level of signal frequency masks their perceived tinnitus. This can act as a good indicator that when the incoming signal is loud enough can lead to tinnitus masking and eventually relief can be seen in them. Intervention with hearing aid serves two purposes. It alleviates hearing loss by appropriate gain and eventually masks the audible tinnitus. Thus, in the present study gain setting in hearing aid was experimentally altered to see in which program participants have got maximum benefit. In the first program the gain was set according to the hearing loss, which was prescribed by prescriptive formula. In another setting the gain was altered depending on subjective preference by listening through Ling six sounds. With these two programs in hearing aid subject reports a tinnitus perception. This could be because the participants from each group were unable to segregate tinnitus from sentence perception, even though the instruction given to them to ignore tinnitus. This suggests there would be stronger connection between source generator at different parts of auditory structure and brain on tinnitus percept. Thus, hearing aid at these gain settings showed less benefit in ignoring the tinnitus. The results of the study is in consonance with the research report of Moore (1982) who demonstrated a separation into attended and unattended streams termed as the figure ground phenomenon can be one of the contributing factor for tinnitus relief.

It was evident that loudness of the tinnitus would be more than 5 to 10 dB above threshold (Goodwin & Johnson, 1980). After treating audibility with hearing aid, a gain at tinnitus pitch was linearly increased in step of 1 dB until participants report tinnitus suppression. It was observed that, irrespective of group, gain difference between preferred; prescriptive gain setting and gain at tinnitus pitch ranged from 6 to 10 dB and 10 to 15 dB, respectively. This indicates a gain set at tinnitus pitch was approximately matched or well above the loudness of tinnitus. Threshold of audibility was alleviated by prescriptive formula and additional gain at tinnitus pitch suppresses tinnitus. Thus, gain set at tinnitus pitch reported positive outcome. This is because amplified frequency response of sentence at tinnitus pitch masks the tinnitus effectively.

It was found that, there was no correlation between MML at the tinnitus pitch and the gain at the tinnitus pitch. This clearly indicates that the loudness of tinnitus and the amount of gain required to obtain tinnitus relief are not directly linked. This is because tinnitus loudness is independent irrespective of hearing loss. However, gain in hearing aid is dependent on degree of hearing loss. These discrepancies perhaps have caused no relation between tinnitus loudness and gain set in hearing aid at tinnitus pitch on tinnitus relief. The result of present study concur with the research report of Tyler and Conrad- Armes (1984) who reports pattern of noise growth in sensorineural hearing loss is not well understood. However, in paired comparison the study participants of mild [57.14% (4/7 participants)]; and severe [80 % (4/5 participants)] group have showed significant preference of program three on tinnitus suppression. The gain setting in program three could have caused effective masking on tinnitus suppression. The study is in consonance with previous study by Swathi et al. (2015) who reported that increasing gain at tinnitus pitch was effective to cause tinnitus suppression especially when the tinnitus pitch is above 5 kHz.

The primary purpose of hearing aid was actually to alleviate hearing loss and improve speech perception. With gain adjustment at tinnitus pitch hearing aid should not compromise the primary purpose of improving speech perception. Thus, in the present study SNR 50 was compared between three programs. Results revealed SNR 50 remained unaffected with gain set at tinnitus pitch from other gain settings of preferred and prescriptive methods.

To conclude, minimal masking level at tinnitus pitch approximately guides clinician to set the gain at tinnitus pitch. The positive finding of program three on tinnitus relief shed light in setting gain at tinnitus pitch. In addition, primary concern of hearing aid on speech perception is not compromised in setting gain at tinnitus pitch. Thus, null hypothesis is rejected and the present study highlights a gain setting at tinnitus pitch as per individual requirement can tackle both hearing loss and associated tinnitus without affection speech perception.

Conclusions

Hearing aid is one of the rehabilitative options available for tinnitus management. In the present study, it was found that a majority of the participants preferred increased gain at tinnitus pitch in comparison to the other programs. The participants of 'mild' and 'severe' groups required about 6-10 dB and 10 -15 dB increase in gain for tinnitus relief, respectively. This is because after amplification frequency response of sentence at tinnitus pitch masks the tinnitus effectively. In addition there was no difference between the SNR 50 scores in the three gain settings. It infers that hearing aid masks the tinnitus effectively when its gain is set at tinnitus pitch without compromising speech perception.

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