



Gain adjustment at tinnitus pitch to manage both tinnitus and speech perception in noise

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ABSTRACT

To investigate how much gain variation is required from prescription to effect tinnitus percept, and if this revised prescription affects speech recognition. Twenty participants who experienced catastrophic tinnitus even after fitted with hearing aid were included. Participants were grouped based on their tinnitus pitch and the prescriptive formula used to fit hearing aid. They were evaluated for handicap from tinnitus using Tinnitus Handicap Inventory (THI). Hearing aid was programmed using either NAL- NL2 or DSL (I/o) v5 prescriptive formula and gain at tinnitus pitch was adjusted till the tinnitus get suppressed. SNR 50 was determined soon after fitted with hearing aid and 30 days of hearing aid use. Further, THI and international outcome inventory for hearing aid (IOI-HA) were determined after 30 days of hearing aid use. A significant higher gain adjustment was needed at tinnitus pitch to reduce tinnitus percept using NAL- NL2 than DSL (I/o) v5 prescriptive formula. Further, SNR 50 was not affected by either tinnitus pitch or revised prescription formulas. However, SNR 50 improved after 30 days of hearing aid use. A 76% of the participants' experienced habituation to perception after 30 days of hearing aid use, 10% had slight, 10% had mild, and 4% had a moderate degree of tinnitus on THI. On IOA-HA, 96% (N=19) of participants have reported satisfactory, and 4% (N=1) reported moderate benefit from hearing aid. Irrespective of prescriptive formula adjusting gain at tinnitus pitch is an efficient method to reduce tinnitus symptoms and improve speech perception.

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1. Introduction

Tinnitus is a perception of sound that results exclusively from the activity within the nervous system without any corresponding mechanical vibratory activity within the cochlea and not related to external stimulation of any kind (Jastreboff, 1995). Tinnitus in some individuals are caused by outer hair cell damage. The imbalanced input at dorsal cochlear nucleus from damaged outer and inner hair cells leads to abnormal spontaneous activity. This abnormal neural activity is perceived as tinnitus (Jastreboff, 1990). Chery- Croze et al. (1994) explained the role of efferent mechanism in tinnitus patients where IHC damage was present, any efferent inhibition of the

OHCs in that area will be reduced due to decreased afferent input. That efferent innervation are shared with neighbouring OHCs innervated with healthy IHCs, where reduced efferent inhibition is observed giving rise highly active portion of the basilar membrane, resulting tinnitus sound. Approximately 30 million people are suffering from tinnitus which constitutes 10% of the entire population of the United States (Kochkin et al., 2011). In a prevalence study of tinnitus in 2695 individuals who had otological problems, 14.33% reported tinnitus (Kumaran and Geetha, 2013). Of the 453 of these individuals with hearing loss, 82.4% had concomitant tinnitus. It is a well-established fact that hearing aid is a common rehabilitative tool for tinnitus relief. Surr et al. (1985) surveyed the effect of amplification on tinnitus management from 200 naïve hearing aid users who had tinnitus. About 62% of them reported a total or partial relief from tinnitus while using hearing aids. In a similar line of investigation, Trotter and Donaldson (2008) reported replacing analogue hearing aids with binaural digital hearing aids caused significant relief. Shekhawat et al. (2013) reviewed 29 studies on the role of hearing aids in tinnitus management. 27 of

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the 29 studies supported the use of hearing aids for tinnitus management. However, the percentage of benefit from hearing aid use on tinnitus relief ranged from 32% to 82%. Recently, researchers are studying characteristics of tinnitus and how the fitting of hearing aids can assist with tinnitus relief.

McNeill et al. (2012) conducted the study to assess the effect of hearing aids on the perception of tinnitus pitch. Their findings suggest that whenever the pitch of the tinnitus falls within the frequency response of the hearing aid, score on Tinnitus Reaction Questionnaire (TRQ; Wilson et al., 1991) showed a reduced reaction to tinnitus. This indicates that hearing aid effectively masked tinnitus. In contrast, whenever the pitch of tinnitus was outside the frequency response of conventional hearing aid, then the effectiveness of hearing aid on tinnitus suppression is questionable (Folmer and Carroll, 2006; Schaette et al., 2010). The results of the previous study influenced another research question, whether high bandwidth amplification may be useful in high-pitch tinnitus. Moffat et al. (2009) examined the effect of amplification on objectively measured tinnitus pitch characteristics. They compared the results of two distinct amplification gain profiles in patients with a dominant tinnitus pitch that was typically above or equal to 4 kHz. A standard amplification group received gain that was limited to the low and medium ends of the audible spectrum (with minimal amplification above 4 kHz). A high-bandwidth amplification group received gain that provided enhanced audibility at 4–6 kHz. They found that the tinnitus was reduced with a smaller magnitude in the conventional amplification group and not at all in the high bandwidth group after a month of hearing aid use. Lack of plasticity to the tinnitus percept for high-bandwidth amplification may arise from the extent of hearing loss.

A fitting formula assigns appropriate gain in a hearing aid to alleviate hearing loss and sometimes reduces tinnitus percept by amplifying background noise. In Desired Sensation Level (DSL) input/output (I/o) a loudness-equalization technique was used to equalize loudness for each frequency channel separately. This method was considered to offer a perceptible and comfortable signal. However, NAL-NL1 utilized a loudness-normalization technique in an attempt to optimize intelligibility and normalize overall loudness. The difference in gain frequency responses implemented in these fitting formulas may lead to relatively higher gain at lower frequency regions in DSL compared to NAL-NL1. Wise (2003) studied the effect of two prescriptive formulas DSL (I/o) v4 & NAL-NL1 on tinnitus relief. It was noted that DSL (I/o) v4 resulted in reduced tinnitus perception in 80% of the participants. However, DSL (I/o) v4 caused higher annoyance to environmental sounds than NAL-NL1. Thus, it was recommended to use DSL (I/o) v4 in a quiet environment in those individuals who have tinnitus. In the similar line of study Shekhawat et al. (2013a,b) determined gain settings by utilizing a master hearing aid that maximally suppresses tinnitus perception on three groups of participants based on their tinnitus pitch (<4 k Hz, 4 to 8 k Hz, > 8 k Hz). Results showed that gain settings equivalent to DSL (I/o) v5 resulted in maximum suppression of tinnitus in all three tinnitus pitch groups. Both of the previous studies have concluded that DSL (I/o) v5 would be a good starting point for prescription of hearing aid for tinnitus management. However, the participants of Wise (2003) had reported difficulty in speech perception when hearing aid gain was set to DSL (I/o) v5 compared to NAL-NL-1. Hence, it was recommended using a hearing aid with multiple programs, one for effective communication and the other for tinnitus relief. It means a client with hearing loss and tinnitus has to change the programs to lessen tinnitus and to appreciate the perception of speech. However, if the client has a physical dexterity problem (especially hand coordination) or is reluctant to change programs according to the situation, hearing aid benefit will be reduced. Hence, the present study

attempts to determine the optimum gain setting in hearing aid without changing the program to get relief from tinnitus without compromising speech understanding. The study aimed to investigate the effect of fitting formulas and gain adjustment at tinnitus pitch on tinnitus relief and speech perception ability in noise. The following objectives were formulated 1) to determine the effect of gain adjustment on tinnitus perception in low and high pitch tinnitus groups 2) to compare SNR 50 using NAL NL 2 and DSL (I/o) v 5.0 fitting formulae in high and low pitch tinnitus groups and 3) to compare tinnitus relief data and SNR-50 scores pre and post-hearing aid use.

2. Method

Twenty participants in the age range of 25–65 years (mean = 48.28 years) having bilateral symmetrical sensorineural hearing loss were chosen for the study. All the participants had aidable hearing loss ranging from mild to a severe degree. All the participants had experienced catastrophic tinnitus in one or both ears for a minimum duration of one year. Catastrophic is defined as always heard, disturbed sleep pattern and difficulty with any activity (Newman et al., 1998). Those participants who had experienced tinnitus even after fitted with hearing aid were included in the study. The participants chosen were naive hearing aids users and were native speakers of Kannada language. All the participants had normal middle ear functioning and did not have any neurological or psychological problems. These participants were divided into two groups based on the pitch of the tinnitus (low (N = 8) and high (N = 12) pitch tinnitus groups and fitting formula (NAL NL 2 (N = 11) and DSL i/o v5 (N = 9) groups) (Table 1). Participants were divided into a low and high-frequency tinnitus group depending on whether their tinnitus was perceived as being below 5000 Hz or above 5000 Hz. 5000 Hz was used as the demarcating frequency given a standard hearing aid's amplification response falls below 5000 Hz. The study was approved by the institutional review board of AIISH Research ethical committee. Informed consent received from each participant and explained the procedure before collecting the data from them. Timeline and the test administered on study participants are represented in Figure-1, Hearing, and tinnitus testing was carried out in a sound-treated double room, with the ambient noise levels within permissible limits as recommended by ANSI (1999).

2.1. Tinnitus pitch and loudness matching

Tinnitus was assessed regarding pitch, loudness, and residual inhibition. Jastreboff et al. (1992) method was adopted to measure the client's tinnitus pitch and loudness. A calibrated diagnostic two-channel audiometer Maico MA 53 with the TDH 39 headphone was used to obtain tinnitus pitch and loudness. The ear not having tinnitus was used for matching of tinnitus pitch and loudness if the subject is having unilateral tinnitus whereas ipsilateral matching was done for individuals having bilateral tinnitus. It is recommended to do the loudness matching first before pitch matching. Loudness matching was performed at octave frequencies from 125 Hz to 8000 Hz (above 8 kHz if required). For loudness matching the initial presentation, the level was 5 dB SL (Jastreboff et al., 1992), and it was varied in 1 dB step till the patient was able to match the loudness. To match the pitch, a pair of loudness matched tones were presented sequentially. Each participant was instructed to report the tone that was closer to his/her tinnitus. This procedure continued for consecutive octave frequencies until the participant was able to match the pitch. The pitch and loudness matching were done twice for each participant, before and after 30 days of hearing aid fitting. The participants were divided into two groups based on

Table 1
Representing demographic data, tinnitus evaluation and the fitting formula used to program the hearing aid for each participant.

SI No	Age	Gender	PTA (dB HL)	#Tinnitus Pitch (Hz)	#Tinnitus Loudness (dB HL)	Fitting formula	Cause	\$Tinnitus Pitch (Hz)	\$Tinnitus Loudness (dB HL)	\$ THI
1	45	M	67.5	4990	93	DSL I/o	Noise exposure	4500	43	Habituation to perception
2	47	F	71	8000	76	NAL-NL1	Noise exposure	7450	66	Habituation to perception
3	62	M	57.5	125	70	NAL-NL1	Presbycusis	300	50	Slight
4	28	F	46.5	2020	70	NAL-NL1	Ménière's disease	290	64	Habituation to perception
5	26	M	58.75	451	56	DSL I/o	Eustachian tube	562	36	Habituation to perception
6	47	M	37	4125	78	NAL-NL1	Unknown	3054	65	Habituation to perception
7	64	M	56.5	4050	84	DSL I/o	Ménière's disease	4500	64	Habituation to perception
8	59	F	68.75	2020	75	NAL-NL1	Unknown	2560	64	Habituation to perception
9	68	M	63.75	7750	97	DSL I/o	presbycusis	7951	67	Habituation to perception
10	46	M	65	6000	88	NAL-NL1	presbycusis	6251	58	Habituation to perception
11	62	M	70	752	93	DSL I/o	Eustachian tube	954	53	Slight
12	40	F	73.75	4121	76	DSL I/o	Noise exposure	3500	66	Habituation to perception
13	44	F	78.7	8012	78	DSL I/o	Noise exposure	7500	68	Habituation to perception
14	44	F	73.7	8026	80	DSL I/o	Noise exposure	7564	70	Mild
15	52	M	40	11900	100	DSL I/o	Noise exposure	11900	50	Moderate
16	58	M	77.5	6030	75	NAL-NL1	Sudden hearing loss	5961	65	Habituation to perception
17	63	F	57.5	254	70	NAL-NL1	presbycusis	1520	64	Habituation to perception
18	64	F	68.75	1003	75	NAL-NL1	presbycusis	350	53	Habituation to perception
19	24	F	67.5	250	71	NAL-NL1	Unknown	1520	64	Mild
20	25	M	66.20	4010	65	NAL-NL1	Ménière's disease	3502	65	Habituation to perception

Note: PTA = pure tone Average; # Day -1; \$ Day -2.

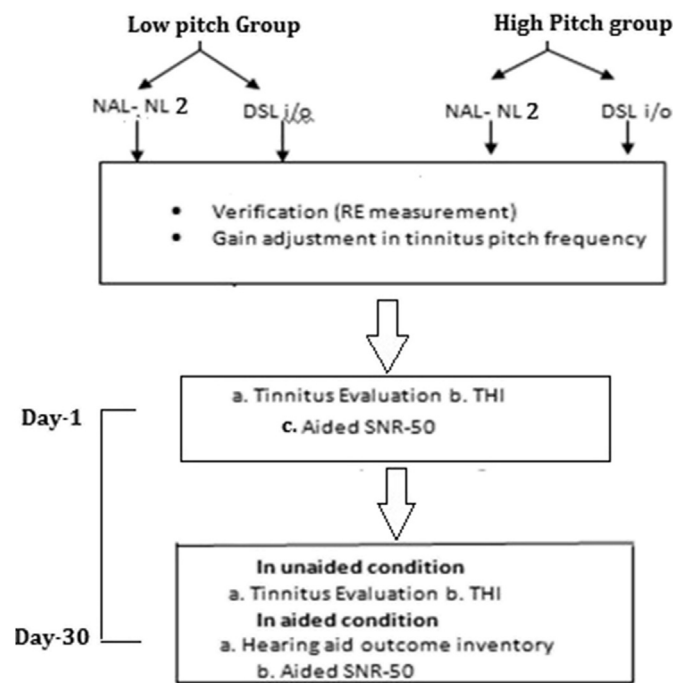


Fig. 1. Timeline and test administered on participants.

their tinnitus pitch. Those individuals with a tinnitus pitch of less than 5 kHz were assigned to the low pitch group. The high pitch group's participants had a tinnitus pitch greater than 5 kHz. The division of the two tinnitus groups was based on the frequency response of standard hearing aids which have a maximum high pass frequency response of 5.8 kHz.

2.2. Tinnitus Handicap Inventory

Tinnitus Handicap Inventory is a questionnaire in English comprising of 25 items (Newman et al., 1998). Each item can be answered as 'yes,' 'sometimes' and 'no' with responses allocated

scores of 4, 2 and 0, respectively. The maximum score obtained from this test battery is 100. Based on the score tinnitus severity can be slight (2–16), mild (18–36), moderate (38–56), severe (58–76) and catastrophic (78–100). The standardized Kannada version of THI developed by Zacharia et al. (2012) was utilized. The test was administered twice, once at the time of selection of study participants and another interval was after 30 days of hearing aid usage.

2.3. Hearing aid programming and real ear measurement

Each participant was fitted with a fourteen channel receiver in the canal digital hearing aid (frequency response 0.25 kHz–5.8 kHz). Using the hearing aid specific module in the NOAH software, the hearing aid was programmed, either using NAL-NL 2 or DSL (I/o) v5 fitting formulae. Parameters such as noise reduction, feedback reduction were switched off, but omnidirectional microphone setting was enabled. The same hearing aid was used for all the participants of the study. Also, a data logging option in the software was utilized to assess the average number of hours in a month the hearing aid was worn.

Further, Fonix 7000 hearing aid test system (version 1.63) was used to match the gain of hearing aid with the target gain real ear insertion response (REIR). REIR was calculated by subtracting the sound pressure level of real ear aided response (REAR) from real ear unaided response (REUR) at frequencies from 0.25 kHz to 8 kHz (in one-octave frequency). Gain at different frequencies in the hearing aid was adjusted such that it was closely matched to the target gain of NAL NL 2 prescriptive formula. For the hearing aids programmed using DSL (I/o) v5 fitting formula, WINCHAP (v 3.00) software was used along with hearing aid test system to adjust and verify the gain to match the target levels.

2.3.1. Adjusting gain of hearing aid at tinnitus pitch

Standardized recorded Kannada sentences (Geetha et al., 2014) were presented at 65 dB SPL through a loudspeaker positioned on meter away with 45 azimuth from the participant. A gain of the hearing aid was varied in one dB step size at or near the tinnitus pitch until the participant gets maximum relief from tinnitus. If the pitch of the tinnitus is away from the frequency response of the hearing aid, then a gain in the channel having the maximum high-

frequency handle was varied to suppress tinnitus. Real ear aided measurement was repeated at this setting of the hearing aid. Adjusted gain at tinnitus pitch is operationally defined as the difference in gain between prescribed gain for hearing loss at tinnitus pitch and gain set at tinnitus pitch to suppress it.

2.4. Speech perception in noise

2.4.1. Generation of speech spectrum noise

A speech-shaped noise was generated to match the long-term average spectrum of sentence material. This was done to determine the SNR 50 accurately. Any five lists (list 2– list 6) of sentences developed by Geetha et al. (2014) were randomly selected. Each list consisted of ten sentences were concatenated. The concatenated sentences were subjected to Fast Fourier Transformer (FFT). The phase of the FFT was randomized and converted back to a wave file by the inverse FFT. The noise generated had only minimal amplitude variation and a frequency spectrum that corresponded with the long-term average spectrum of the sentences. The RMS level of the noise was matched to the same level as that of the sentences.

2.4.2. Noise mixing to target stimuli at different SNRs

Speech noise was mixed with a sentence at desired SNRs using AUX viewer (version 1.27) software. The syntax used in Aux Viewer to derive the desired SNR is given below. Initially, the root means square ('rms') of each sentence was computed. To obtain particular SNR, the rms of noise was assigned with respect to the rms of each sentence. The onset of noise was preceded by 500 ms ('>') from the onset of each sentence and continued till 500 ms after the offset. A 'ramp' (rise and fall time) was made to the noise using a cosine function to avoid unintended effects. The following formula was used to add noise to each sentence.

SNR = wave (file name) @ rms> 500 + ramp (wave ("noise") @ rms, 20)

2.4.3. Presentation of stimuli and scoring

Each sentence in a list was prepared at a particular SNR. Hence, a total of 10 SNRs were used, from –6 to +12 in 2 dB step size. These ten sentences at different SNRs were presented randomly. Each participant wearing hearing aid was instructed to repeat the sentences they heard. The presentation level of sentences was fixed at 40 dB HL. The total number of keywords repeated in each sentence at each SNR was recorded. SNR-50 was calculated using the below-mentioned formula.

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

The SNR level at which the testing started (L) and a number of recognized target words in each sentence were noted down. The total number of target words from all sentences were added (T). Also, the total number of words per decrement (W) and SNR decrement step size in each sentence (d) was noted down. The obtained values were substituted to the given equation adapted by Spearman-Kärber to determine SNR 50% (Finney, 1952).

This procedure was carried out at the time of hearing aid fitting to verify that the speech understanding was not compromised when the gain of hearing aid was revised (adjusted to the pitch of the tinnitus). It was administered once again after 30 days of hearing aid use.

2.5. International Outcome Inventory- Hearing Aids (IOI- HA)

The **IOI- HA** translated version in Kannada developed by Yashaswini et al. (2010) was utilized to assess the benefit from the hearing aid. **IOI- HA** was administered after 30 days of hearing aid use. It consists of seven questions, and each question assesses different domains such as a) use (measured in hours/day), b) benefit c) residual activity d) satisfaction e) residual participant restriction f) impact and g) quality of life. Each question has five response options. For Question 1, hours of device usage are categorized from "no hours" of usage (given a score of 0) through to more than 8 h a day (given a score of 5). For questions 2–7, responses ranged from amplification having a negative effect on an individual through to the individual experiencing no difficulty in listening with amplification. No difficulty in listening was assigned five marks, and a negative experience was scored 1. The average score from study participants was calculated for each question. It gives the measure of whether the patient is not satisfied, slightly satisfied, moderately satisfied or highly satisfied by the hearing aid.

2.6. Statistical analysis

The data on adjusted gain and SNR 50 were obtained from the participants who were grouped based on their tinnitus pitch (low and high) and hearing aid prescriptive formulae (NAL-NL2 and DSL (I/o) v5). These data were subjected to descriptive and inferential statistical analyses. A Kruskal-Willis test was performed to analyze any significant difference between prescriptive formulae on adjusted gain and SNR 50. Here, the data on adjusted gain and SNR 50 served as dependent variable whereas grouping of participants was made based on tinnitus pitch and prescriptive formula served as independent variables.

Further, data on SNR 50 obtained soon after fitted with hearing aid and after 30 days of hearing aid use was compared using the Wilcoxon signed-rank test. Additionally, Tinnitus Handicap Index (THI) and International Outcome Inventory- Hearing Aids (IOI-HA) were measured from the study participants after 30 days of hearing aid use. The Statistical Package for Social Sciences (SPSS) software (version 17) was utilized to carry out the statistical analyses. The analyses performed under each objective are reported as follows.

3. Results

3.1. The gain adjusted at tinnitus pitch and perception of speech in noise

Adjusted gain to suppress tinnitus and SNR 50 were compared in the study participants grouped based on the fitting formulae. A Kruskal-Willis test was performed to analyze any significant difference between prescriptive formulae on adjusted gain and SNR 50. Results revealed that significantly higher gain adjustment was needed to suppress tinnitus by NAL-NL 2 [3.54 (2.42) dB SPL, N = 11] prescriptive formula compared to DSL (I/o) v5 [0.80 (0.78) dB SPL, N = 9] prescriptive formula [$\chi^2 (1) = 3.84, p = 0.045$]. Although, the median (SD) SNR 50 obtained from NAL-NL 2 [6.54(1.05) dB, N = 11] prescriptive formula was higher than DSL i/o v5 [5.75 (0.63) dB SPL, N = 9] prescriptive formula, the difference fails to reach significant [$\chi^2 (1) = 2.386, p = 0.122$] (Fig. 2).

Further, adjusted gain with respect to tinnitus pitch and SNR 50 were determined from the study participants classified based on the pitch of the tinnitus. The results of the Kruskal-Willis test revealed that median (SD) adjusted gain required to suppress tinnitus was high in the high pitched group [3.18 (2.63) dB SPL, N = 11] compared to that of the low pitched group [1.20 (0.62) dB SPL, N = 10], and their difference was found significant [χ^2

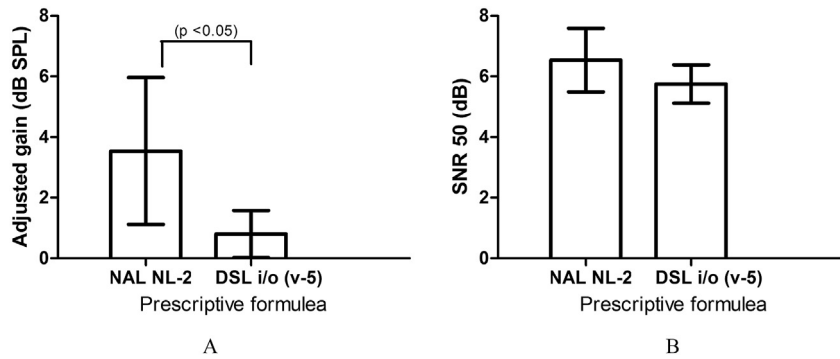


Fig. 2. Comparisons of adjusted gain and fitting formula for two prescriptive formulae.

(1) = 3.03, $p = 0.045$] (Figure- 3A). Though the median (SD) SNR 50 obtained in the high pitched tinnitus group [5.95 (0.84) dB, N = 11] was lower than the low pitched group [6.40 (1.04) dB, N = 10], this difference was failed to reach significance [$\chi^2(1) = 1.291, p = 0.255$] (Fig. 3 B).

It was found that both the fitting formula and pitch of the tinnitus had a significant effect on the adjusted gain. To determine how much gain adjustment was required between the two prescriptive formulae for the low and high pitched tinnitus groups a Mann Whitney U test was administered. The result revealed that in the low pitched tinnitus group, a significantly higher gain adjustment [$U = 3.23, p = 0.010$] was needed at tinnitus pitch when gain was set using NAL NL 2 prescriptive formula (Mdn = 1.83, SD = 1.16, N = 6) than DSL i/o prescriptive formula (Mdn = 0.50, SD = 0.25, N = 2). Similar result was obtained for the high pitch tinnitus group (Fig. 4), in which a significantly [$U = 2.34, p = 0.015$] higher gain adjustment at tinnitus pitch was required to suppress tinnitus by NAL NL2 prescriptive formula (Mdn = 5.60, SD = 1.81, N = 5) than DSL i/o prescriptive formula (Mdn = 1.16, SD = 0.75, N = 7).

3.2. Comparison of SNR 50 between soon after fitted with hearing aid and after short-term of hearing aid use

The grouping factor, the pitch was excluded as the majority of the participants reported habituation to perception after 30 days of hearing aid usage, and the pitch of the tinnitus was not assessed in them. The SNR 50 obtained after 30 days of hearing aid usage in the study participants who were grouped based on prescriptive formula was subjected to Mann Whitney U test. The results revealed that there was no significant difference between groups (made based on hearing aid fitting formulae) on SNR 50 [$U = 26.50, p = 0.076$]. Thus, the data on SNR 50 were combined irrespective of

the participant groups. Further SNR 50 obtained immediately after fitted with hearing aid after 30 days of hearing aid usage was compared using Wilcoxon signed-rank test. The results revealed that the SNR 50 (Mdn = 5.90, SD = 0.90, N = 20) after 30 days of hearing aid usage was significantly lower [$Z = 3.05, p = 0.002$] than that of SNR 50 obtained immediately after hearing aid fitting (Mdn = 6.16, SD = 0.95, N = 21) (Fig. 5). The SNR 50 obtained immediately after hearing aid fitting and that obtained 30 days of hearing aid use from each participant is represented in Table-2.

3.3. Outcome measures on tinnitus relief and hearing aid satisfaction

At baseline, all the participants had catastrophic tinnitus. After 30 days of hearing aid use, the results on THI revealed that 76% of the participants had experience habituation to perception. The remaining participants had a slight (10%), mild (10%), and moderate (4%) degree of tinnitus.

The score on each question of IOI-HA from each participant is represented in Table-3 The mean, and standard deviation for each question of IOI-HA was calculated from the study participants. It was found that mean residual activity was moderately difficult for study participant number 15. Besides, a data logging analysis of participant number 15 revealed an average hearing aid use of 4.4 h per day. All other participants reported they were highly satisfied with their hearing aid as evidenced by their mean scores on all domains of the IOI-HA. A data logging analysis revealed that participants used their hearing aid on average from 8.2 to 8.9 h per day.

4. Discussion

The results of the study revealed that in the low pitch tinnitus

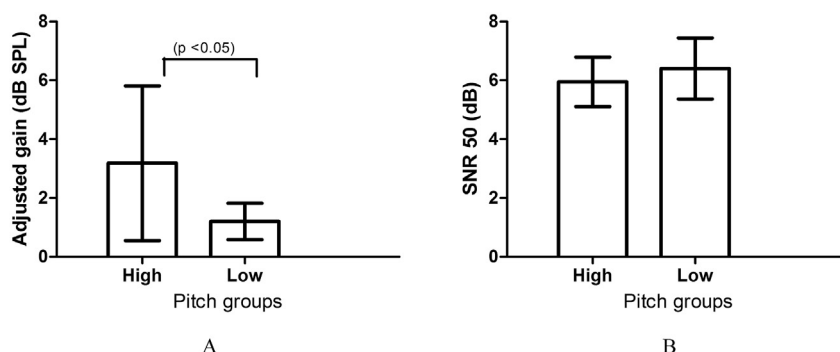


Fig. 3. Comparisons of A) adjusted the gain and B) SNR 50 in high and low pitched groups.

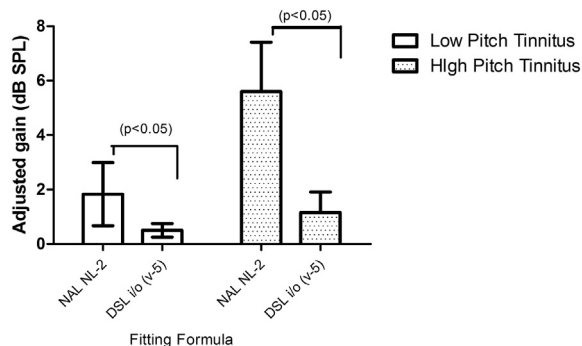


Fig. 4. Adjusted gain values for low and high pitched tinnitus groups with respect to prescriptive formulae.

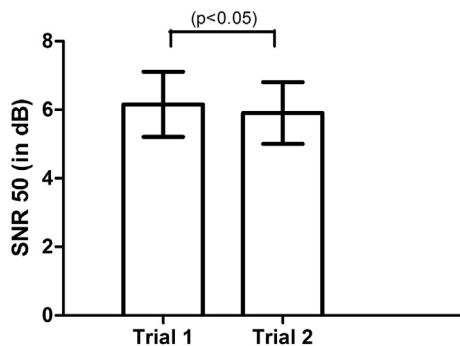


Fig. 5. Comparisons of SNR 50 for two trials.

Table-2 Individual participant data for SNR 50 over two trials.

Sl.no	SNR50 Trial No-1	SNR50 Trial No-2
1.	5.00	5.00
2.	7.00	6.00
3.	8.00	8.00
4.	6.00	4.50
5.	6.00	5.00
6.	5.00	6.00
7.	6.50	6.00
8.	8.00	7.50
9.	5.00	3.00
10.	6.00	6.00
11.	6.50	6.00
12.	5.50	6.50
13.	6.50	6.50
14.	6.00	5.50
15.	5.50	5.50
16.	6.50	6.50
17.	7.00	6.50
18.	6.00	6.00
19.	5.00	4.50
20.	7.50	7.00

group (<5 kHz) the adjusted gain required was lesser than the high pitch tinnitus group (>5 kHz). The tinnitus could be effectively masked by the amplified speech sound because of the frequency response of the aid. Also, the low-level environmental sounds or ambient noise and the presence of internal noise in hearing aid might have effectively masked the tinnitus. The observed results are by the research reports of Moffat et al. (2009), McNeil et al. (2012) and Shekhawat et al. (2013a,b) who have reported maximal suppression of low pitch tinnitus via hearing aids. Also, at high pitched tinnitus group, a more gain was required to suppress

tinnitus especially if the tinnitus pitch falls above low pass frequency of hearing aid. It was surprising that high pitched tinnitus group had reported reduced tinnitus percept even though increment available was limited to increase the gain in hearing aid at tinnitus pitch above 6.05 kHz. This is because an SPL generated in the single channel would be lesser in loudness than combined 14 channels. The loudness generated from wideband channels would have suppressed tinnitus.

It was observed that those individuals with low pitch tinnitus group who were fitted with hearing aid using NAL-NL 2 required 1.83 dB extra gain above prescriptive formula at tinnitus pitch. In contrast, DSL (I/o) v5 required an additional gain of 0.50 dB. The gain adjustment for DSL (I/o) v5 prescriptive formula was 1.3 dB lower than NAL-NL 2. The reason could be higher gain prescribed with DSL (I/o) v5 than NAL-NL 2 within the frequency region of tinnitus pitch less than 5 kHz. On average, DSL (I/o)v5 prescribe a 10 dB more gain than NAL-NL 2 and specifically within frequency region from 500 to 4000 Hz, a gain of 7 dB more prescribed with DSL (I/o)v5 than NAL-NL 2 (Ching et al., 2010). In individuals with high-frequency tinnitus, the adjusted gain at tinnitus pitch required was 5.6 dB and 1.16 dB for NAL-NL 2 and DSL (I/o) v5, respectively. For tinnitus suppression, a significant 4 dB less gain was required by DSL (I/o)v5 than NAL-NL 2. The reason could be that, for frequencies above 4000 Hz, DSL (I/o)v5 prescribe more gain than NAL-NL 2. The observed result is in agreeance with the Byrne et al. (2001) who reported that > 4 kHz, an approximately 5–12 more gain prescribed by DSL (I/o) than NAL-NL 2. This gain difference between fitting formulae at frequencies above 4 kHz required less gain to suppress tinnitus in the DSL (I/o) v5 group than NAL- NL 2 group. The relatively increased loudness delivered by DSL (I/o) v5 masks the tinnitus at a lesser gain than that required for the participants of the study.

The study implies tinnitus pitch and prescribing adjusted gain in the hearing-aid prescriptive formula are essential factors in tinnitus suppression as also observed in the research reports of Wise (2003). However, the study participants of Wise (2003) preferred to use DSL (I/o)v5 for suppressing tinnitus and for the perception of speech NAL-NL 2 was chosen. Wise (2003) evaluated speech perception in noise using words. In contrast, this study utilized sentences for evaluating speech in noise. Hence, the redundancy cues in sentences might have caused similar speech recognition in noise while using either prescriptive formula. The study compared SNR 50 immediately fitted with hearing aid and after 30 days of hearing aid usage. A significant reduction in the level required to obtain 50% recognition in noise was noted after 30 days of using a hearing aid. The findings of the study also revealed that the noise level required obtaining 50% recognition of speech was unaffected by either the prescriptive formula or pitch of the tinnitus. It suggests that auditory stimulation for the short-term lead to spontaneous learning of the new acoustic information. Speech intensity level study participants would be exposed to in their daily routine conversation. Moreover, at this level of presentation, acclimatization is more likely, which is in accordance with the research report of Munro and Lutman (2003) who documented the greatest acclimatization at 69 dB SPL.

Interestingly, the finding showed that after 30 days of using their hearing aid, about 76% of the study participants reported habituation of perception. The remaining participants had a slight (10%), mild (10%) degree of tinnitus. Additionally, 96% (N = 19) of participants who have reported maximum satisfaction from hearing aid on IOI-HA. This high score could reflect that the hearing aid fitting alleviated speech perception problems, suppresses the tinnitus and creates motivation thereby improving quality of life. Thus, the participants of the study have used hearing aid consistently. To document empirically data-logging information revealed

Table-3

Represents each participant data, average score and standard deviation of each question on IOI-HA.

Participants	Use	Benefit	Residual activity	Satisfaction	Residual participant restriction	Impact	Quality of life.
1	5.00	4.00	4.00	4.00	3.00	4.00	5.00
2	4.00	4.00	5.00	5.00	4.00	5.00	5.00
3	4.00	5.00	3.00	4.00	3.00	4.00	5.00
4	4.00	4.00	4.00	5.00	4.00	4.00	5.00
5	4.00	4.00	3.00	4.00	4.00	5.00	4.00
6	4.00	3.00	3.00	4.00	4.00	4.00	5.00
7	5.00	3.00	3.00	5.00	3.00	4.00	5.00
8	4.00	4.00	3.00	4.00	5.00	4.00	5.00
9	5.00	4.00	3.00	5.00	3.00	5.00	5.00
10	3.00	5.00	3.00	4.00	5.00	4.00	5.00
11	5.00	4.00	4.00	5.00	4.00	5.00	5.00
12	4.00	4.00	3.00	4.00	5.00	4.00	4.00
13	5.00	4.00	3.00	5.00	3.00	5.00	5.00
14	5.00	4.00	4.00	4.00	5.00	4.00	5.00
15	3.00	3.00	3.00	4.00	3.00	2.00	2.00
16	5.00	5.00	4.00	4.00	4.00	4.00	5.00
17	4.00	4.00	3.00	5.00	5.00	4.00	4.00
18	5.00	4.00	4.00	5.00	4.00	4.00	5.00
19	4.00	3.00	5.00	5.00	5.00	4.00	5.00
20	4.00	4.00	4.00	4.00	4.00	4.00	5.00
Mean	4.02	4.01	3.55	4.45	4.00	4.30	4.85
SD	0.59	0.60	0.68	0.51	0.79	0.47	0.36

that participants had used their devices on an average of 8.2 and 8.9 h per day. Also, However, 4% (N= 1) of the population had a moderate degree of tinnitus and reported moderate satisfaction from amplification. On data logging information it was observed that though the participant has used their hearing aid on average of 6.4 and 7 h per day, they often reported trouble while sleeping, paying attention and disturbs in the perception of speech especially when more than two people are involved during the conversation. Moreover, the pitch of the tinnitus was high, i.e., 11900 and falls above the low pass frequency response of the hearing aid.

5. Conclusion

In the low pitch tinnitus group, the significantly lesser gain adjustment was noted in DSL (I/o) v5 (0.5) than NAL-NL 2 (1.83). Similarly, for the high pitch tinnitus group, gain adjustment required was significantly less using DSL (I/o) v5 (1.16 dB) compared to NAL-NL 2 (5.6 dB). Additionally, speech perception in noise was unaffected by the adjusted gain at tinnitus pitch using either NAL NL 2 or DSL (I/o) v5 prescriptive formulae. Thus, it is advised to adjust the gain at tinnitus pitch using DSL (I/o) v5 for managing tinnitus and speech perception. Interestingly, with the short-term hearing aid use, SNR 50 was obtained at reduced SNR level. Chronic tinnitus was dramatically reduced, and study participants reported benefits in tinnitus suppression and demonstrated improved speech perception.

6. Implication

Adjusting the gain at tinnitus pitch is helpful for individuals who have an aidable hearing loss with chronic tinnitus. Such a setting in the hearing aid is sufficient to manage tinnitus and improves speech perception. Ascertaining gain matched at tinnitus pitch would help to reduce the frequency of switching over of programs in hearing aid based on listening conditions.

Conflicts of interest

The authors have no financial conflicts of interest.

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Appendix A. Supplementary data

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