International Journal of Otorhinolaryngology and Head and Neck Surgery
Hens M et al. Int J Otorhinolaryngol Head Neck Surg. 2024 Oct;10(5):506-516
http://www.ijorl.com
pISSN 2454-5929 | eISSN 2454-5937

DOI: https://dx.doi.org/10.18203/issn.2454-5929.ijohns20242706

Original Research Article

A study on impact of tinnitus masking on psychophysical and tinnitus tuning curve in participants with hearing impairment suffering from severe tinnitus

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Received: 06 July 2024
Revised: 11 August 2024
Accepted: 12 August 2024

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ABSTRACT

Background: Tinnitus can be treated by using different pedagogies of management approaches in which tinnitus masking has been acclaimed most evidence-based approach. Psychophysical tuning curve and tinnitus tuning curve explored as least interested procedures in tinnitus research. This noteworthy but nonspecific psychophysical domain may throw a light on need of the present research. Aim of the study was to find out the effect of tinnitus masking on Psychophysical tuning curve and tinnitus tuning curve.
Method: A total of 30 native Bengali speaking participants were included in this study, having mean age of 45.9 years and SD was 6.46. All the participants had unilateral subjective tinnitus with Mild to Moderately severe sensorineural hearing loss. Quasi-experimental research design was used. Dual channel audiometer (MAICO MA 53) with supra-aural TDH 39 headphone was used for psychoacoustic measurements of tinnitus (including pitch matching, loudness matching, minimum masking level etc.) and to provide tinnitus masking therapy. MATLAB version 9.5 was used to develop noise to assess PTC and TTC using Sennheiser HD 201 headphone routed through MAICO MA 53 audiometer via stereo jack and cable. Tinnitus masking therapy was carried out for 30 sessions by using regimen of MML +20 dB of masking level for 30 minutes duration for each session with matched pitch. PTC and TTC were measured before and 30 sessions-after tinnitus masking therapy. PTC was measured using 1000 Hz pure tone at 10 dBSLl as reference followed by four narrow band noise with centre frequency of 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz pertaining to 312 Hz band width as developed by MATLAB software. TTC was measured using the same noise with reference to matched tinnitus pitch. All the above-mentioned conditions forced choice procedure was carried out in dBHL frame work.
Results: Wilcoxon sign rank test was used at 95% confidence level to check the influence of tinnitus masking therapy on PTC and TTC measures. Significant changes were portrayed at 1000 Hz and 4000 Hz respectively in PTC measure and at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz respectively in TTC measures.
Conclusion: This study preliminarily provides information regarding influence on tinnitus pitch domains which has been psychoacoustically systematically measured as PTC and TTC. These two psychoacoustic signatures may be treated as prognostic biomarker of tinnitus management in future using replicable research using different methodology or using statistical basis of data mining. At that point conclusive remarks may not throw a clear indication based on the results found in this study.

Keyword: PTC, TTC, MML, Tinnitus masking therapy

INTRODUCTION

Tinnitus masking is nothing but suppression.[1] Physiology of suppression is basically to stimulate higher cortical pathway that is GABA and associated limbic structure to release the neuro-hormones like γ-aminobutyric acid (GABA) which can reduce the impact of annoyances and loudness level at outset with a huge impact. Masking of tinnitus or sound therapy is a widely used in tinnitus management that uses sound stimulation to help in reorganization of the cortex with or without masking tinnitus, and such therapy is thought to eliminate tinnitus completely.[1] When masking sounds presented at supra-threshold levels inhibit the scattered region of the tonotopic map, then residual inhibition occurs, briefly segregates the synchronous activity underlying the tinnitus sensation.[2]

Residual inhibition (RI) is the temporary suppression or eradication of tinnitus following acoustic stimulation.[3,4] The purpose of assessing for residual inhibition is to determine whether the use of tinnitus maskers would be an effective treatment course.[3,5] To test for residual inhibition the clinician is required to present tone at match tinnitus frequency at intensity10dB above the loudness match for one minute. Then the post-masking effects are classified into four categories. These categories are positive-complete i.e. the tinnitus is completely absent for more than one minute, positive-partial, that indicates the tinnitus is still present but softer at a lower perceived level than before for more than 1 minute, negative means there is no reported change in the tinnitus and finally, rebound which indicates the tinnitus is actually louder after the masking stimulus is presented. Minimum masking level (MML) is the minimum intensity level required to just cover or mask tinnitus.

Tinnitus masking therapy (TMT) is an effective technique for reduction of tinnitus.[6] So use of TMT long term stabilized effects as it improves quality of life and it is one of the most employed therapeutic methods and one of the most beneficial for patients suffering from tinnitus.[7,8] Some therapies used tone to change the synchronized firing of neural assemblies near tinnitus pitch others changed the phase of sounds presented at tinnitus pitch and another paired tonal stimulation with vagus nerve stimulation.[9-11]

To directly compare masking of external sounds to tinnitus masking two procedures should be performed within the same individual using similar targets, that is, the external sound should be similar in pitch and intensity to the perceived tinnitus. A common method to determine the best masker frequency to mask an external sound is called psychophysical tuning curve (PTC).[12] PTC represents the level of a narrowband masker required to just mask a fixed signal as a function of the masker frequency.[13,12] For normal-hearing individuals, it is well known that the closer the frequency of the masker is to the target, the lower the masker level required to mask the target. The PTC has a V shape, and this pattern is thought to originate from cochlear mechanisms.[13] The PTC is a graphical representation of the frequency selectivity of hearing. It is the expression of the ability to detect one sound in the presence of another.

Fouriner et al measured PTC as well as the MML of tinnitus sound as a function of different frequency band. Narrow band noise was used to get the responses and provided a curve which represents the MML of tinnitus at different frequency region and the same narrow band noise was used to get the PTC in those cases with tinnitus. Thus, TTC has an impact on Tinnitus sufferers.[12] While understanding PTC in its finer aspect and with reference to its acoustic modelling.

A tinnitus tuning curve (TTC) is the level of a narrowband masker required to just mask the tinnitus as a function of the masker frequency.[13] Initially Feldman measured minimum masking using masker. The patient is given a noise band or tone for about 1-2 seconds at a low level and asked if he hears his own tinnitus. This level is changed until the tinnitus is just masked. This is completed for all the frequencies, 250 to 8 KHz. The resulting curves are then classified according to Feldman's system.[5]

There are six types of curves in the Feldman's system. Type 1, convergence, the patient's threshold curve and masking curve will slope together from low to high frequencies. They will meet at the frequency of the tinnitus and all frequencies above that. Type 2, divergence, the threshold and masking curves slope further apart from low to high frequencies. Type 3, congruence, the threshold and masking curves almost overlap each other for all frequencies. This type of tinnitus can be masked by any noise just above the threshold of the tinnitus.

Type 4, distance, the masking curve follows the threshold curve, but is at least 20 dB above the threshold. Type 4a, is the same as type 4, but the tinnitus can only be masked by pure tones. Finally, Type 5, persistence, is found when no sound at any level can mask tinnitus. This usually happens when the patient has a severe to profound hearing loss, but occasionally it occurs with those with moderate hearing loss.[5]

PTC is assumed to be unaltered with reference to influence of tinnitus but the same may be explored by conducting different studies. The PTC in subjects with tinnitus were significantly different from those of normal subjects and often had hypersensitive tails and some elevated tips. These shapes of tuning curves are consistent with cochlear lesions involving the loss of outer hair cells without damage to the inner hair cells or nerve fibres.[14] TTC might have altered with the tinnitus masking therapy procedures as this parameter has a robust influence on tinnitus. In this regard a need of a detailed study may produce evidence which may be the

food for thought in tinnitus action research. Tyler et al, investigated the benefit of maskers for patients with chronic, bothersome tinnitus.[15] Participants were included in two six-week long trials: with and without sound therapy. Neither group were counselled. Sounds aimed at reducing the tinnitus prominence were utilized in the Masking devices. Participants rated tinnitus annoyance, loudness, and background sounds acceptability with a numeric 0–100 interval scale and filled out the Tinnitus Primary Functions Questionnaire (TPFQ). This study demonstrated the use of partial masking, thus reassuring patients to pursue treatment with audiologists inclined towards providing the same.

Wang et al studied the effect of tinnitus sound matching degree on the efficacy of customized sound therapy in patients with chronic tinnitus.[1] The researchers aimed to compare as well as get a better understanding of the personalized sound therapy effect between tinnitus sound matching and nonmatching patients as well as therapy-related influencing aspects. The study included 100 patients with unilateral chronic tinnitus who were given personalized sound therapy. After 4 stages of tinnitus matching with the tinnitus assistant app (provided by Sound Ocean Company, Su Zhou, China), the participants were dichotomously divided into group A (matching) and group B (nonmatching) each consisting of 50 participants. Pre and post treatment data were collected at 6 months interval using tinnitus handicap inventory (THI), Hospital Anxiety and Depression Scale (HADS), and tinnitus loudness Visual Analog Scale (VAS). The study showed that the scores of both the groups were significantly decreased after treatment for all the four measurement tools HADS-A, HADS-D, THI, and VAS.

It also showed that there was marked increase in the performance of Group A as compared to Group B in HADS-A and THI scores, these may be attributed to the pre-treatment hearing loss of the tinnitus side ear; the lighter the degree of hearing loss, the better the improvement. No statistically significant differences were detected in HADS-D and VAS scores between the 2 groups, and also, these were not related to the degree of hearing loss.

No statistically significant effect was observed on improvement with regards to the differences in age, gender, and tinnitus duration. Tinnitus sound matching as well as nonmatching of the personalized sound therapy caused a significant effect on the participants. It further suggested those participants with tinnitus matching improved markedly as compared to nonmatching participants that THI and HADS-A scores of, and the customized sound therapy effect is negatively correlated with the severity of hearing loss.

Fournier et al suggested a novel technique for evaluating masking and residual inhibition of tinnitus.[16] These are also known as two well recognized psychoacoustic tinnitus measures. At two testing sites an acoustic sequence i.e., pulsed stimuli comprising of a fixed stimulus duration with inter-stimulus interval, was administered on 68 patients with tinnitus. Minimum masking level (MML) was measured by increasing the intensity of the stimulus until the tinnitus becomes inaudible. Following this, stimulus level further raised, until during the silence interval between the acoustic pulses the tinnitus appears suppressed. This level was referred to as minimum residual inhibition level (MRIL).

The study confirmed that with this novel approach, MML and MRIL can be easily and time efficiently gotten from an extensive assortment of patients exhibiting normal or different hearing loss configurations. From the above-mentioned references and assumptions an immense need was found to establish the different but important psychoacoustic biological signatures followed by assessing the influence of tinnitus masking on PTC and TTC. The present study aimed to find out the effect of tinnitus masking therapy on PTC and TTC in patients with hearing impairment along with chronic tinnitus.

METHODS

Quasi-experimental research design was applied in this study where repeated observation under experimental intervention (Tinnitus Masking Therapy) was carried out without assigning any control group. The study was carried out from for a period of 1year starting from April, 2022 till March, 2023 at AYJNISHD, RC, Kolkata, India. A total of 30 native Bengali speaking participants were included in this study with mean age of 45.9 years and SD 6.46.

Inclusion criteria

Study includes Male and female participants within the age range of 30-60 years. Subjective tinnitus in one ear, at least since last 3 months. Cut-off score of THI-B (Dutta et al, 2017) should not be less than 36. In this study mean THI-B score was 69.4 and SD was 8.393. Minimum academic qualification was class 10th pass. Should have mild to moderately severe sensorineural hearing loss (PTA should be within 60 dBHL). Mean PTA of the participants in this study was 43.3 dBHL and SD was 8.585.

Dual channel audiometer (MAICO MA 53) with supra-aural (TDH 39) headphone, B-41 bone vibrator was used for the pure tone audiometry. Participants with ‘A’ type tympanogram.

Normal middle ear function was determined with tympanometry and ENT evaluation. A calibrated Tympanometer (MAICO MA 44, ANSI S3.39) was used for tympanometry. Complete or partial one minute residual inhibition should be present.

Exclusion criteria

Study excludes participants who had academic and perceptual problem. Neurological/otological and psychological problems. HEINE MINI 3000 Otoscope was used for the examinations of the external auditory canal. Self-reported vertigo or balance problem. Binaural diplacusis and octave confusion. Phonophobia, misophonia and hyperacusis (by using LDL with mean 98.5 and SD 2.674 and subjective feelings). Tolerance problem in effective masking level. Dual channel audiometer (MAICO MA 53) with supra-aural (TDH 39) headphone was used for psychoacoustic measurements of tinnitus and Tinnitus Masking therapy. Prior to data collection this instrument was calibrated using ANSI S3.6-2004 specifications. High Definition (HD) headphone (Model- Sennheiser HD 201) was used for the psychophysical testing. MATLAB version 9.5 was used to make the masker noise. Stereo Audio jack was used to send the noise to audiometer from the personal computer (model Lenovo). A two-room audiometric setup was used. The test environment was met with ANSI S3.1-1999 specifications for the background noise. The current research was carried out through five following steps.

Ethical and technical consideration

It was done by the institute's ethical committee as well as the research advisory committee of West Bengal University of Health Sciences, Kolkata. All the Participants were familiarized with the procedure involved in collecting data. In addition, participants were assured that the scientific research might have no harmful effect during assessment and management process in this study. A written consent was obtained from all the participants before undergoing the study.

Preparation of the stimulus (Noise) to assess PTC and TTC

Using a software made by MATLAB version 9.5, four frequency narrow band noise were constituted. Band width of the noise was maintained at 320 Hz to minimize the beat frequency contour. With reference to the centre frequencies are 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. These noise bands were directed through the dual channel audiometer (MAICO MA 53) using the particular set up of audiometer where one channel is presenting the pure tone and the other one is in CD mode which delivered the noise from the dedicated laptop which was connected to the audiometer through a stereo jack. Noise and tone-based audiometry was carried out using forced choice technique underlying forward-backward masking procedures (tone presented without any silent interval).[12]

Assessment of tinnitus

After the audiological assessment (which include Pure tone audiometry, tympanometry, speech audiometry) by following ANSI S3.21 (2005) standards psychoacoustic measurement of tinnitus was conducted. TDH 39 headphone was used to measure pitch and loudness of the tinnitus. Uncomfortable level (UCL) was measured to assess whether there is hypercusis.

Psychoacoustic measurement

First a detailed tinnitus interview was taken then tinnitus handicap inventory-bangla (THI-B, Dutta et al, 2017) was used to assess the participant's perceived severity of tinnitus. Mean THI-B score of the participants was 69.4 and SD was 8.393 in this study.

Tinnitus matching

Psychoacoustic assessment was done for all the participants. Tinnitus pitch and loudness were matched using procedure given by Henry and Zaugg. Tinnitus was matched at contralateral ear. Participants were asked to tell the clinician which sound was similar to the sound presented by clinician through audiometer. Assessment of Tinnitus as well as Tinnitus Masking Therapy (TMT) was framed by incorporating the guidelines given by various authors. The details were furnished below.

Pitch matching

Pitch matching was a two-alternative forced choice. The test was started by presenting a few tones of different frequencies to make sure the participants can differentiate between them. The procedure was explained to the participants at the time when he/she was presented with two tones and he/she had to pick the one that sound closest to their tinnitus. For example, 1000 and 2000 Hz pulse tones was presented alternatively in the ear contralateral to the tinnitus ear at a comfortable level for the patient. A tone was presented to the participant and was asked to choose with another tone either one octave above or below that tone. The total procedure was repeated until the participants were able to match the tinnitus pitch. Narrow band noise, pure tone and/or broadband noise were used for participants based on the matched pitch during TMT.

Loudness matching

Loudness matching was done using procedure suggested by Goldstein and Shulman (1997). Loudness matching started at a level just below threshold and intensity was increased until the participant signals a match. In the ear contralateral to the tinnitus, the presenting tone slowly ascended by 5 dB steps. The participants were instructed to tell the clinician when the intensity was closest to the loudness that they experience in tinnitus. The procedure was repeated several times to ensure accuracy. The average of these response points has been recorded as matched level. The loudness and pitch of the tinnitus was matched in the contralateral ear using pure tones, narrow band noises or broadband noise.

Minimal masking level

Minimal masking level procedure was administered. Least amount of masking intensity needed to just mask the tinnitus in the ipsilateral ear was considered as minimal masking level. The participant was given their pitch matched noise, or tone for about 1-2 seconds at a low level and asked if he/she hears his/her own tinnitus. If the participant was able to hear the tinnitus, the intensity of the tone/noise was increased by 5 dB until the tinnitus was not heard.

Measurements of residual inhibition

Residual Inhibition test was administered and the level of the masking stimulus was adjusted to minimum masking level +20 dB and masking sound was presented for 1 minute in the tinnitus ear. The outcomes were measured in three ways; positive-complete, positive-partial, negative or rebound. Only positive-complete and positive-partial were taken into account among all of these categories.

Pre therapy PTC and TTC measurement

Measurement of PTC

Psychological tuning curve was measured in all 30 participants. Participants was introduced with a reference tone at 1K Hz and 10 dB SL. They were asked to indicate when the tone is no longer audible in the masking noise or when the noise was deemed uncomfortable. Noise and tone were presented in forward masking procedure. Noise was continuous for 5 seconds and tone was presenting intermittently.

Audiometer was set into single ear dual channel mode so that different frequency and intensity can be send to the single ear at a same time. In this dual channel setting one channel was presenting the reference tone for the psychoacoustic tuning curve and one channel was directed to present the noise from personal computer. Increment of noise was controlled by audiometer in 1 dB step and bandwidth was 320 HZ. In this study PTC was measured using the 1000 hHz 10 dBSL reference tone and using four frequency narrow band noise centre at 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz.

Measurement of TTC

Tinnitus tuning curve was measured also using the same narrow band noises which are used in PTC measurement. In TTC measurement participants were instructed to alert the experimenter when they no longer heard their tinnitus in the noise or when the sound level was deemed uncomfortable. If the tinnitus was not maskable for a specific masker frequency, the final value of the intensity of the audiometer or the loudest masker level tolerated were taken as the threshold. Increment of noise were in 1dB step.

Pre-counselling for TMT

Participants were counselled about what is tinnitus then what TMT is. They were instructed not to give attention towards the tinnitus sound or the noise & were given some hand writing task. They were administered with tinnitus masking at the level of MML+20 dB at matched-frequency to the tinnitus in the ipsilateral ear. Stimulus was selected as matched through psychoacoustic assessment.

The stimulus was generated by calibrated MAICO MA53 diagnostic pure tone audiometer with TDH 39 headphone. Intensity of masking stimulus was controlled by attenuator. Masking therapy were provided for 30 minutes and participants were given some writing tasks during the therapy time. Participants were given 30 sessions for this study.

Post therapy measurement of PTC and TTC

It was measured using same procedure as mentioned in pre-therapy measurement of PTC and TTC. Obtained data were tabulated in Microsoft office 2010 Excel data sheet based on variables under study for further statistical analysis. The data was subjected to Shapiro Wilk test for normality to check the normality of data. The results revealed the data was significantly deviating from normal distribution ($p<0.05$). Descriptive analysis such as mean, SD, median for value of age, THI-B score, LDL score, pure tone average (PTA) of all participants were measured.

Mean value of pre therapy PTC intensities in dBHL, pre therapy TTC intensities in dBHL, post therapy PTC intensities in dBHL, post therapy TTC intensities in dBHL of all 30 participants were measured). Inferential statistics such as Wilcoxon signed rank test, Nonparametric Wilcoxon Signed rank test was conducted to check the significant difference frequency wise comparison of PTC of pre and post TMT and frequency wise comparison of TTC of pre and post TMT.

The statistical significance i.e., p values were compared with 0.05 and/or 0.01 level of significance. Z values were also measured in same aspects. Cohen d was measured to find out the effect size. The whole statistical analysis was carried out using SPSS 20.

RESULTS

The purpose of the study was to find out the psychoacoustic effect of TMT. For this PTC and TTC was measured before and after the tinnitus masking therapy for 30 sessions.

Table 1: Participants' description on matched tinnitus pitch, loudness, MML and EML.

Participants	Type of tinnitus	Matched pitch of tinnitus (Hz)	Matched loudnessof tinnitus	MML (dBHL)	EML (dBHL)
1	Noise (NBN)	2000	60 dBHL	65	85
2	Noise (NBN)	4000	50 dBHL	55	75
3	Noise (NBN)	250	50 dBHL	60	80
4	Noise (NBN)	1000	55 dBHL	60	80
5	Noise (NBN)	4000	45 dBHL	55	75
6	Noise (NBN)	500	55 dBHL	60	80
7	Noise (NBN)	4000	50 dBHL	55	75
8	Noise (NBN)	4000	45 dBHL	50	70
9	Noise (NBN)	1500	45 dBHL	60	80
10	Noise (NBN)	500	50 dBHL	60	80
11	Noise (NBN)	4000	55 dBHL	60	80
12	Noise (NBN)	4000	65 dBHL	70	90
13	Noise (NBN)	1000	50 dBHL	60	80
14	Noise (NBN)	1500	50 dBHL	55	75
15	Noise (NBN)	4000	55 dBHL	60	80
16	Noise (NBN)	750	55 dBHL	60	80
17	Noise (NBN)	1000	35 dBHL	40	60
18	Noise (NBN)	1000	30 dBHL	40	60
19	Noise (NBN)	1500	35 dBHL	45	65
20	Noise (NBN)	1000	40 dBHL	45	65
21	Noise (NBN)	2000	50 dBHL	55	75
22	Noise (NBN)	1000	50 dBHL	55	75
23	Noise (NBN)	500	45 dBHL	50	70
24	Noise (NBN)	250	35 dBHL	45	65
25	Noise (NBN)	3000	55 dBHL	60	80
26	Noise (NBN)	1000	55 dBHL	65	85
27	Noise (NBN)	750	45 dBHL	50	70
28	Noise (NBN)	4000	45 dBHL	55	75
29	Noise (NBN)	1000	50 dBHL	55	75
30	Noise (NBN)	250	40 dBHL	45	65

Table 2: Individualistic PTC data of 500Hz, 1000Hz, 2000 Hz and 4000 Hz in dBHL of all participants in pre-TMT condition.

Participants	500 Hz (dBHL)	1000 Hz (dBHL)	2000 Hz (dBHL)	4000 Hz (dBHL)
1	76	60	84	>95
2	76	56	84	>95
3	78	66	98	>95
4	80	58	86	>95
5	78	56	74	86
6	88	76	96	>95
7	64	44	76	88
8	70	40	72	88
9	64	50	60	64
10	58	40	72	80
11	76	60	84	>95
12	76	56	84	>95
13	78	66	98	>95
14	80	58	86	>95
15	78	56	74	86
16	88	76	96	>95
17	64	44	76	88

Continued.

Participants	500 Hz (dBHL)	1000 Hz (dBHL)	2000 Hz (dBHL)	4000 Hz (dBHL)
18	70	40	72	88
19	64	50	60	64
20	58	40	72	80
21	68	50	78	>95
22	70	54	72	>95
23	74	54	86	>95
24	72	52	82	>95
25	84	66	86	>95
26	84	66	86	>95
27	72	52	82	>95
28	74	54	86	>95
29	70	54	72	>95
30	68	50	78	>95

Table 3: Mean, Median and SD of Pre therapy PTC intensities in DBHL of 30 participants.

Frequency (Hz)	Mean	Median	S.D.
500	73.33	74.00	7.849
1000	54.80	54.00	9.650
2000	80.40	82.00	9.719
4000	91.07	96.00	8.878

Table 4: Individualistic TTC data of 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz in dBHL of all participants in pre tinnitus masking therapy condition.

Participants	500 Hz (dBHL)	1000 Hz (dBHL)	2000 Hz (dBHL)	4000 Hz (dBHL)
1	68	70	72	>95
2	62	56	48	55
3	58	64	74	88
4	60	60	60	66
5	62	56	50	56
6	68	72	88	86
7	54	48	50	44
8	60	50	50	52
9	68	66	64	58
10	64	48	42	34
11	68	70	72	>95
12	62	56	48	55
13	58	64	74	88
14	60	60	60	66
15	62	56	50	56
16	68	72	88	86
17	54	48	50	44
18	60	50	50	52
19	68	66	64	58
20	64	48	42	34
21	66	60	58	>95
22	66	62	56	58
23	60	58	62	70
24	58	54	56	56
25	66	64	70	72
26	66	64	70	72
27	58	54	56	56
28	60	58	62	70
29	66	62	56	58
30	66	60	58	>95

Table 5: Mean, Median and SD of pre therapy TTC intensities of 30 participants.

Frequency	Mean	Median	S.D.
500	62.67	62.00	57.07
1000	59.20	60.00	54.93
2000	60.00	58.00	56.93
4000	65.77	58.00	61.07

Table 6: Individualistic PTC data of 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz in dBHL of all participants in post tinnitus masking therapy condition.

Participants	500 Hz (dBHL)	1000 Hz (dBHL)	2000 Hz (dBHL)	4000 Hz (dBHL)
1	76	60	84	>95
2	76	56	84	>95
3	78	66	98	>95
4	80	58	86	>95
5	78	56	74	86
6	88	76	96	>95
7	64	44	76	88
8	70	40	72	88
9	64	50	60	64
10	58	40	72	80
11	76	60	84	>95
12	76	56	84	>95
13	78	66	98	>95
14	80	58	86	>95
15	78	56	74	86
16	88	76	96	>95
17	64	44	76	88
18	70	40	72	88
19	64	50	60	64
20	58	40	72	80
21	68	50	78	>95
22	70	54	72	>95
23	74	54	86	>95
24	72	52	82	>95
25	84	66	86	>95
26	84	66	86	>95
27	72	52	82	>95
28	74	54	86	>95
29	70	54	72	>95
30	68	50	78	>95

Table 7: Mean, Median and SD of post tinnitus masking therapy PTC intensities of 30 participants.

Frequency (Hz)	Mean	Median	SD
500	73.73	76.00	7.961
1000	56.53	56.00	7.736
2000	79.73	80.00	11.335
4000	90.13	96.00	10.878

Table 8: Frequency wise comparison of PTC of pre and post tinnitus masking therapy using Wilcoxon signed rank test.

Frequency (Hz)	P value (Wilcoxon signed rank)	Z value	Effect size
500	0.767	0.297	0.054
1000	0.03*	2.131	0.389
2000	0.467	0.728	0.133
4000	0.026*	2.220	0.405

Table 9: Individualistic TTC data of 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz in dBHL of all participants in post tinnitus masking therapy condition.

Participants	500 Hz (dBHL)	1000 Hz (dBHL)	2000 Hz (dBHL)	4000 Hz (dBHL)
1	60	68	68	>95
2	54	38	44	42
3	56	62	74	72
4	58	54	60	62
5	62	54	48	58
6	60	64	72	72
7	56	52	60	52
8	50	58	50	46
9	62	62	58	50
10	50	36	34	40
11	60	68	68	>95
12	54	38	44	46
13	56	62	74	60
14	58	54	60	58
15	62	54	48	66
16	60	64	72	66
17	56	52	60	58
18	50	58	50	60
19	62	62	58	46
20	50	36	34	>95
21	56	52	52	50
22	58	50	52	40
23	54	60	62	>95
24	58	54	60	46
25	62	60	60	60
26	62	60	60	58
27	58	54	60	66
28	54	60	62	66
29	58	50	52	58
30	56	52	52	60

Table 10: Mean, Median and SD of Post tinnitus masking therapy TTC intensities of 30 participants.

Frequency (Hz)	Mean	Median	S.D.
500	57.07	58.00	3.850
1000	54.93	54.00	8.721
2000	56.93	60.00	10.422
4000	61.07	58.00	17.001

Table 11: Frequency wise comparison of TTC of pre and post Tinnitus Masking Therapy using Wilcoxon signed rank test and Cohen d.

Frequency (Hz)	P value (wilco)	Z value	Effect size (Cohen)
500	0.000*	4.304	0.786
1000	0.003*	3.022	0.552
2000	0.012*	2.501	0.457
4000	0.003*	2.938	0.536

*Indicates significant at P<0.05, **Indicates significant at P<0.01.

Table 1 showed tinnitus was matched at noise level of all the participants. Most of the participants were male. Table 2 revealed the intensities of four narrow band noise which masked the 1000 Hz 10 DBSL tone to measure the PTC in pre tinnitus masking therapy condition of 30 participants. During the measurement the last limit of the

intensity of audiometer was used to mask. In 4000 Hz narrow band noise highest limit of noise intensity was 95 dBHL.

Table 3 revealed the mean, median and SD of the intensities of 4 centre frequency of the PTC values in pre therapy condition. Table 4 revealed the intensities of four narrow band noise which masked the minimum masking level to measure the TTC in pre and post tinnitus masking condition of 30 participants. Table 5 depicted the mean, median and SD of the intensities of 4 centre frequency of the PTC values in pre therapy condition. Table 6 revealed the intensities of four narrow band noise which masked the 1000 Hz 10 dBs tone to measure the PTC in post tinnitus masking therapy condition of 30 participants.

Table 7 revealed the mean, median and SD of the intensities of 4 centre frequency of the PTC values of post therapy condition. Table 8 depicted the result which showed that the difference of PTC between pre and post therapy in four frequencies where we can say there is no significant changes in PTC at 500 Hz and 2000 Hz. Table 9 revealed the intensities of four narrow band noise which masked the MML to measure TTC in pre & post tinnitus masking condition of 30 participants. Table 10 depicted the mean, median and SD of the intensities of 4 centre frequency of the PTC values in post therapy condition. Table 11 depicted the statistical comparison of pre and post therapy TTC. In comparison of TTC significant changes have seen in post therapy measurements in all four frequency regions.

DISCUSSION

PTC has an impact on tinnitus patient and the curve of MML of tinnitus at different frequency range was named as tinnitus TTC.[12] PTC (in this present study PTC values were depicted descriptively on table no 2, 3, 6, and 7) as well as the MML of tinnitus sound was also measured as a function of different frequency band. It's found that the PTC of participants with tinnitus is significantly different from the normal participants and participants with sensorineural hearing loss.[17] In this study comparison of PTC in pre and post tinnitus masking therapy (table 8) revealed that among four frequency regions, two frequency regions such as 1000Hz and 4000Hz had significant change at 95%confidence level. There was a lack of strong evidence to support this finding which may be the food for thought for the further research. Another study measured PTC and TEN test in participants with and without tinnitus.[18] Dead region was not found or no such significant different in PTC in tinnitus participants but threshold was changed significantly between two groups and in the table 8 same type of findings were replicated. Tinnitus related activity may share common properties with stimulus induced activity. For a masker centered at the tinnitus frequency, the tinnitus was more difficult to mask than the mimicking tone in most of the noise.[12] Study found frequency modulated tone as a masker had an effect to suppress the tinnitus though the long term effects of the modulated sounds on tinnitus and the underlying mechanisms remain to be investigated.[19] It is also found that tinnitus and its suppression in residual inhibition depend on processes that span the region of hearing impairment and not on mechanisms that enhance cortical representations for sound frequencies at the audiometric edge.[20] This information may be further studied before coming into any conclusive remarks at this point of time.

Masking of tinnitus and pure tone was measured using several maskers and it was found that masking of tinnitus sound is different from the masking of pure tone. This type of masking using several maskers was same like the PTC. TTCs may provide useful information (in this present study TTC values were depicted descriptively on table no. 4,5,9,10) to support its evidence in the dominant tinnitus pitch in some participants with hearing impairment having chronic subjective tinnitus. Frequency specific change has been well measured using TTC 12 and this might be a protocol in tinnitus pitch matching in future.

This finding may have some backup based on limited research in this arena. In this condition, studies found that in addition to a traditional masking approach using unmodulated pure tones and white noise, modulated sounds should be used for tinnitus suppression because they may be more effective in reducing hyperactive neural activities associated with tinnitus.[19] The recent observations were found in a research that inferred a significant effect to suppress the tinnitus in both tinnitus sound matched and non-matched participants.[21] This study may support that tinnitus masking therapy had an obvious impact on frequency regions too.

CONCLUSION

From the statistical comparison of PTC and TTC data in pre and post therapy condition it can be concluded that there is no such impact of tinnitus masking on PTC but a strong effect can be noticed in TTC. Use of tinnitus masking helps in suppression of tinnitus perception. In present study only changes of loudness and pitch was measured. Post TTC measurements revealed that masking had an effect on other frequency region irrespective of tinnitus frequency and changes of loudness. TTC measurement can provide finer description of tinnitus characteristics though it should be further explored. This study preliminarily provides information regarding influence on tinnitus pitch domains which has been psychoacoustically and systematically measured as PTC and TTC.

These two psychoacoustic signatures may be treated as prognostic biomarker of tinnitus management in future using replicable research using different methodology or using statistical basis of data mining. At that point no conclusive remarks may be highlighted at this present moment due to participation of limited number of participants and conduction of therapy sessions. Study

can be done in correlation with any objective test, electrophysiological test & can be done to check the lesion with reference to the tinnitus perception using different types of maskers. It can also be conducted to check tinnitus and treatment efficacy with reference to multi-frequency PTC and TTC.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Hens M, Chatterjee I, Shatapathy P, Kumar S. A study on impact of tinnitus masking on psychophysical and tinnitus tuning curve in participants with hearing impairment suffering from severe tinnitus. Int J Otorhinolaryngol Head Neck Surg 2024;10:506-16.