Does Listening to Tinnitus Frequency-Filtered Music Relieve Tinnitus?

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Introduction

Tinnitus is a common disorder with prevalence rates of approximately 10% in the general population and 30% in the elderly population. It can have a number of serious negative effects, including psycho-emotional symptoms such as distraction, insomnia, and depression. Therefore, chronic and persistent tinnitus often requires active intervention. However, there is no established treatment for this intractable disease.

Recently, Okamoto, et al. [1] developed ‘tailor-made notched music training (TMNMT)’ and suggested that it could reverse the tinnitus-generating mechanism, “maladaptive plastic changes (tonotopic reorganization) in the auditory cortex” by restoring lateral inhibition. TMNMT involves listening to music with an octave band centred on the patient’s tinnitus frequency filtered out (notched), to augment lateral inhibition of the notched region. Theoretically, this could enhance lateral inhibition by stimulating the lateral frequency regions rather than the over-represented tinnitus frequency region [2,3]. The tonotopic reorganization model suggests that peripheral hearing loss reducing output from the damaged cochlear region may cause deterioration of lateral inhibition in the affected frequency areas and could subsequently enhance neural synchrony and hyperexcitability of the central auditory system, thus leading to develop tinnitus [4,5]. Pantev and colleagues [2,3] reported that TMNMT induced a reduction of auditory-evoked cortical activity corresponding to the tinnitus frequency, reflecting recovery of lateral inhibition. They also demonstrated behavioural and neural effects of TMNMT that did not depend on the filtered notch width (from 1/4 to 1 octave) or duration of...
tinnitus; and inability to cooperate with the research. Subjects were excluded if they received other treatments for tinnitus, including drugs, during the follow-up period, or if they withdrew consent to participate in the study.

Hearing and tinnitus assessment procedures

Hearing assessment was performed in a double-walled soundproof room. Pure tone air (250 Hz to 8 kHz) audiometry, tinnitus frequency, loudness and minimal masking level (MML) matching were performed. Assessments of the tinnitus characteristics were performed, i.e., the THI and VAS of subjective tinnitus loudness, daily awareness and annoyance of tinnitus.

The tinnitus pitch was decided in two-alternative forced choice procedure: two frequencies of pure tones (or narrow band sounds) were presented for patients to choose the most similar sound to their tinnitus. In the order of 500 Hz/4 kHz pair, then 250 Hz/500 Hz pair or 4 kHz/8 kHz pair and so on, patients repeated the forced selection procedure in half-octave steps. The above procedure was repeated three times until the final frequency was decided.

Outcome measures

We defined THI score as the principal outcome measure because the total THI score could more comprehensively represent tinnitus-related functional, emotional and everyday life handicaps than other variables such as loudness or awareness of tinnitus. As additional measures, matched tinnitus loudness, MML and VAS scores of subjective tinnitus loudness, daily awareness and annoyance were assessed. All variables were measured at the initial visit, and at 3 and 6 months (final follow-up). In addition, we calculated the incidences of improvement in THI score ≥50% and ≥20% in the experimental and control groups at 3 and 6 months.

Data analysis

The SPSS program (v. 22.0; IBM Corp., Armonk, NY, USA) was used for statistical analyses. The patients' initial demographic, hearing and tinnitus data and amount of improvement at 3 and 6 months (calculated as the difference between the initial and final values) in each variable were compared. Mann–Whitney U-test and chi-square test were applied for continuous and nominal variables, respectively. The amounts of improvement at 3 and 6 months were compared between the two groups using the paired t-test. p<0.05 was accepted as the statistical significance in all analyses.
Results

Ninety volunteers were initially enrolled in the study, with 41 and 33 continuing for 3 months, and 14 and 15 continuing for 6 months, in the experimental and control groups, respectively. We observed no significant difference in any initial demographic, hearing or tinnitus characteristic between the two groups (p>0.05) (Table 1). The total THI score improved significantly at 3 and 6 months in both groups. All VAS scores improved at 6 months in the experimental group, and at both 3 and 6 months in the control group. However, matched loudness and MML showed no improvement in either group (Fig. 1).

There were no differences in the amounts of improvement in any variables between the two groups including THI scores: 12.0±13.4 vs. 16.7±15.1 and 14.8±12.4 vs. 18.5±14.5 at 3 and 6 months, respectively (Tables 2 and 3). The incidences of improvement in THI score ≥ 20% were 78.0% and 78.8% in the experimental and the control groups, respectively, at 3

Table 1. Initial demographic and audiologic profile of experimental and control groups

| Variables                  | Experimental group (No. of ears) | Control group (No. of ears) | p-value |
|----------------------------|---------------------------------|-----------------------------|---------|
| Age (yr)                   | 42.7±14.2 (41)                  | 42.2±12.3 (33)              | 0.205   |
| Sex (M:F, %)               | 75.6:24.4                       | 63.6:36.4                   | 0.280   |
| Duration of tinnitus (mo)  | 37.8±56.7 (39)                  | 29.2±53.9 (32)              | 0.525   |
| PTA low                    | 11.0±5.7 (41)                   | 9.2±8.2 (33)                | 0.470   |
| PTA mid                    | 12.8±7.6 (41)                   | 11.5±8.3 (33)               | 0.090   |
| PTA high                   | 35.2±18 (41)                    | 25.6±17.6 (33)              | 0.379   |

All continuous variables are expressed as mean ± standard deviation. MML, minimal masking level; PTA high, average of the scores at 250 Hz and 500 Hz; PTA mid, average of the scores at 1 kHz and 2 kHz; THI, Tinnitus Handicap Inventory; VAS, visual analogue scale

Fig. 1. Tinnitus-related variables after 3 and 6 months of TMNMT (n=41 and 33 at 3 months, n=14 and 15 at 6 months in the experimental and control groups, respectively). THI and all VAS scores had improved significantly at 6 months in both groups, whereas matched loudness and MML showed no changes in either group (paired t-test, *p<0.05). In, initial; MML, minimal masking level; THI, Tinnitus Handicap Inventory; TMNMT, tailor-made notched music training; VAS, visual analogue scale.
The developers of TMNMT, Okamoto and Pantev, reported that it could reduce the awareness and loudness of tinnitus, and thus help alleviate the suffering of patients. In addition, they reported normalisation of tinnitus-related auditory cortical evoked activity (N1m component of the auditory steady-state response (ASSR)) on magnetoencephalography after listening to notched music, even for only 5 days [2,6,8-10]. However, we do not agree that the sound-evoked N1m response is an adequate marker for tinnitus-related activity, because tinnitus develops in the resting state without any external auditory stimulation. Rather, an abnormally elevated auditory-evoked response reflects hyperacusis, which frequently shows elevated gain in the auditory system. They also suggested that TMNMT could reverse the tonotopic reorganization seen in the auditory cortices of tinnitus patients, where tinnitus frequency is overrepresented in comparison to other frequencies because of increased spontaneous activity of the corresponding neurons [2,3]. However, tonotopic reorganization following auditory input deficit occurs only when hearing loss is severe, which has not been the case in TMNMT studies.

**Discussion**

The incidences of improvement in THI score ≥50% were 31.7% and 51.5%, respectively, at 3 months and 30.8% and 46.7%, respectively, at 6 months (Fig. 2).

**Table 2.** Amount of improvement in tinnitus-related variables after 3 months of treatment

| Variables                  | Experimental group (No. of ears) | Control group (No. of ears) | p-value |
|----------------------------|----------------------------------|----------------------------|---------|
| Matched loudness (dB HL)  | 3.2 ± 13.3 (34)                  | 0.5 ± 11.2 (23)            | 0.832   |
| MML (dB SL)                | -1.7 ± 10.1 (33)                 | -0.1 ± 15.7 (23)           | 0.217   |
| VAS loudness               | 0.8 ± 1.7 (41)                   | 1.2 ± 5.8 (33)             | 0.485   |
| VAS awareness (%)          | 22.4 ± 30.7 (41)                 | 27.3 ± 29.6 (33)           | 0.248   |
| VAS annoyance              | 1.1 ± 1.9 (41)                   | 1.5 ± 2.6 (33)             | 0.582   |
| THI score                  | 12.0 ± 13.4 (41)                 | 16.7 ± 15.1 (33)           | 0.578   |

**Table 3.** Amount of improvement in tinnitus-related variables after 6 months of treatment

| Variables                  | Experimental group (No. of ears) | Control group (No. of ears) | p-value |
|----------------------------|----------------------------------|----------------------------|---------|
| Matched loudness (dB HL)  | 2.4 ± 19.2 (14)                  | -5.2 ± 8.2 (7)             | 0.607   |
| MML (dB SL)                | -3.6 ± 12.6 (14)                 | 0.9 ± 10.3 (8)             | 0.274   |
| VAS loudness               | 1.4 ± 1.6 (13)                   | 1.5 ± 1.9 (15)             | 0.542   |
| VAS awareness (%)          | 25.5 ± 32.6 (13)                 | 23.7 ± 34.1 (15)           | 0.871   |
| VAS annoyance              | 1.9 ± 2.1 (13)                   | 1.6 ± 1.7 (15)             | 0.757   |
| THI score                  | 14.8 ± 12.4 (13)                 | 18.5 ± 14.5 (15)           | 0.533   |

All variables are expressed as mean ± standard deviation. MML, minimal masking level; THI, Tinnitus Handicap Inventory; VAS, visual analogue scale.

**Fig. 2.** Incidences of ≥20% (A) and ≥50% (B) reductions in THI score at 3 and 6 months of TMNMT (n=41 and 33 at 3 months, n=14 and 15 at 6 months in the experimental and control groups, respectively). The incidence rates of THI improvement were higher in the control group at both 3 and 6 months. THI, Tinnitus Handicap Inventory; TMNMT, tailor-made notched music training.
been clearly demonstrated in tinnitus patients [11]. Furthermore, the recovery of tonotopic reorganization does not explain the effect of TMNMT, because sufficient hearing function is required to listen to the notched music, so patients with tinnitus associated with severe or profound hearing loss (a prerequisite for tonotopic reorganization) would not be good candidates for TMNMT.

Table 4 presents a summary of randomized, controlled double-blind studies on the tinnitus-relieving effect of TMNMT, including the present study. Taken together, there is no strong evidence to support the effectiveness of TMNMT, except in the reports by the developer’s group. They reported a greater improvement of VAS loudness by TMNMT compared to the control in one study with only eight participants, but showed no difference in a subsequent study, although there were positive effects on other variables such as a tinnitus questionnaire score and VAS awareness [3,12]. The study by Atipas, et al. [7] and our study assessed the effects of TMNMT more comprehensively and showed negative results for all measured variables; in particular, the indices of tinnitus loudness (matched tinnitus loudness, MML, or VAS score) were not significantly improved by TMNMT compared to the controls. There are clear discrepancies in results between Pantev’s group and other groups.

In conclusion, the mechanism of tinnitus-frequency filtered music therapy (TMNMT) is unproven (recovery of tonotopic reorganization), and the developers’ studies used an inadequate neurological marker for tinnitus activity (N1m component of ASSR). Moreover, the results were inconsistent even in their own studies, and there is no reliable evidence of the effectiveness of TMNMT for the treatment of tinnitus. Music therapy, a unique form of sound therapy, appears to have a potential to relieve tinnitus; however, higher-quality research is needed to develop a more effective methodology that addresses optimized stimulation parameters and duration of treatment, and the best responding tinnitus populations.

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Conflicts of interest
The authors have no financial conflicts of interest.

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