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Accuracy of Tinnitus Pitch Matching Using a Web-Based Protocol

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Objectives: We investigated the accuracy of a web-based protocol for tinnitus frequency matching compared to that of tinnitus pitch matching performed by an audiologist using an audiometer in an anechoic chamber.

Methods: Twenty subjects underwent tinnitus frequency-matching in a random order using an audiometer in an anechoic chamber and using web-based software with a multiple-choice protocol in octave or half-octave steps from 250 Hz to 12,000 Hz and a slider in 25-Hz steps from 20 to 20,000 Hz. Octave challenge testing was performed. The participants were asked to indicate which protocol resulted in the closest match to their tinnitus frequency.

Results: The median tinnitus frequency was 6,000 Hz (range, 2,000 to 12,000 Hz) with use of the audiometer and self-directed multiple-choice protocol. With the slider, the median frequency was 5,925 Hz (range, 1,850 to 16,000 Hz). The patients with a tinnitus frequency higher than 12,000 Hz experienced a greater level of satisfaction when using the computer-based slider system. Five patients experienced octave confusion with self-directed multiple-choice tinnitus matching that was corrected accurately after the octave challenge step.

Conclusions: A web-based protocol for tinnitus frequency matching is as accurate as a standard audiometric protocol. An octave challenge test might be necessary for patient-directed tinnitus frequency matching.

Key Words: psychoacoustics, telemedicine, tinnitus.

INTRODUCTION

Subjective tinnitus is the perception of a phantom sound in one or both ears. Of the several introduced treatments, sound therapies are the most widely used option. Sound therapies have evolved from simple noise generators toward different engineered customized sound stimuli.¹ Since tinnitus is a subjective sensation, its quantification is mainly dependent on patient-directed answers. One of the standard measurements in the evaluation process is quantifying the tinnitus frequency. Since the tinnitus frequency is a physical measure and patients might have multiple types of sounds, the term “pitch-match frequency” has been described as the frequency of an acoustic stimulus that has been matched to the predominant pitch of the tinnitus.^{2,3} Pitch matching helps to classify cases as low-, middle- or high-frequency tinnitus and is the basis for some customized sound therapies that have shown promising results. The introduced customized sound therapies need to find the patient’s pitch-matched tinnitus frequency in order to engineer a tailored sound or music stimulus that will deliver targeted acoustic energy to the patients.^{1,4} The standard method for pitch matching

is to use an audiometer to present pure tones or narrowband noises and ask the patient whether his or her tinnitus has a higher or lower pitch.⁵

Attempts have been made to automate this process.^{5,6} With advancements in the treatment of tinnitus, the need for a simple patient-directed automated tinnitus assessment is urgent. In the current study, we aimed to evaluate the accuracy of a novel web-based protocol for tinnitus pitch matching in comparison to that of pitch matching by an audiologist using an audiometer in an anechoic chamber.

METHODS

Upon approval of the Institutional Review Board at University of California Irvine, 20 participants with tinnitus signed the informed consent form and were enrolled in the study through our tertiary care clinic. The participants were randomly assigned to start with audiometry or the web-based protocol. Tinnitus pitch matching with audiometry was performed for each participant with an audiometer (model GSI 16, Grason-Stadler, Eden Prairie, Minnesota) in a double-walled soundproof room with use of EarTone 3A insert earphones (Audiometrics,

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Find Your Tinnitus Pitch

Find your approximate tinnitus pitch



Instructions:

Click each circle to hear the individual sound. After clicking all of them, click the square under the letter that most closely resembles your tinnitus sound.

In this step, we are trying to find the approximate pitch of your tinnitus. You may not find the pitch that is exactly like yours, but click on the one that is closest.



Fig 1. Screenshot of tinnitus pitch matching with web-based multiple-choice protocol.

Oceanside, California). First, the participants were asked whether their tinnitus was a ringing or tonal sound, or a buzzing or hissing sound. Then, on the basis of their tinnitus type, pure tones or narrowband noise were presented at 10 to 20 dB above threshold. Starting with 1,000 Hz, the participants were asked whether the pitch of their tinnitus was higher or lower than the pitch of the tone. The test was continued in this manner to narrow down the tinnitus frequency to within an octave. Inter-octave frequencies were then presented the same way to determine a pitch match to the closest half-octave. Octave challenge testing was performed by presenting tones an octave higher and an octave lower to compensate for potential octave confusion and identify the final frequency match.

Tinnitus pitch matching with the web-based protocols was performed at a desktop computer with a Sound Blaster Audigy SE PCI Sound Card (Creative Labs, Jurong East, Singapore) in an examining room with AirDrives Interactive Stereo Earphones (range, 20 to 20,000 Hz; Mad Catz Inc, San Diego, California) with a multiple choice protocol and a slider protocol. Participants were asked whether their tinnitus

was a ringing or tonal sound, or a buzzing or hissing sound. Both protocols presented the sounds to both ears equally, regardless of the tinnitus lateralization. The multiple-choice protocol (Fig 1) followed an approach similar to the previously described “method of adjustment,”⁴ and participants were given a series of choices of different sound frequencies (250 Hz to 12,000 Hz in 5 to 9 steps). Pure tones were used for tonal or ringing tinnitus, and narrowband noise for hissing or buzzing tinnitus. After selection of the closest sound, octave challenge testing was performed. In the slider protocol (Fig 2), the participants used a scrolling slider to select the sound closest to their tinnitus. The slider frequency range was from 20 to 20,000 Hz in 25-Hz steps. After completing all steps, the participants were asked to indicate the most convenient method (audiometry versus multiple-choice versus slider) and the method that resulted in the closest pitch match. Nonparametric tests were used to evaluate the results (PASW 18.0, SPSS Inc, Chicago, Illinois).

RESULTS

The female-to-male ratio of the participants was 7 to 13. Nine patients had bilateral tinnitus, 6 had

Find Your Tinnitus Pitch

Find your approximate tinnitus pitch



Instructions:

Click the Play button above and to the right to get started, then adjust the slider until you find the approximate pitch of your tinnitus. Once you find the sound that most closely resembles your tinnitus, please hit “Next” below.

In this step, we are trying to find the approximate pitch of your tinnitus. The slider has a wider range of sounds than the letters on previous slides.



Fig 2. Screenshot of tinnitus pitch matching with web-based slider protocol.

tinnitus in the left ear, and 5 in the right ear. There was no statistical difference regarding the tinnitus frequency between genders or ear sides. The participants' ages ranged between 30 and 77 years (median, 53.5 years). The median tinnitus frequency was 6,000 Hz (range, 2,000 to 12,000 Hz) with the audiometer and the multiple-choice self-directed protocol. Using the multiple-choice protocol, 5 participants (25%) experienced octave confusion at the first step (matched to a frequency one octave below or above), but accurately matched their tinnitus frequency after the octave challenge step. A Spearman's rank order correlation was run to determine the relationship between frequencies. With the multiple-choice protocol, all participants had the same tinnitus frequency as with audiometry ($r_s = 1.00$; $p < 0.001$). With the slider, the median frequency was 5,925 Hz (range, 1,850 to 16,000 Hz). There was a strong positive correlation between slider and audiometry tinnitus frequencies ($r_s = 0.97$; $p < 0.001$). There was a high level of internal consistency of the responses to all tests (Cronbach's alpha, 0.98).

Eight participants (40%) preferred the web-based tests to audiometry, and the rest had no preference. Forty-five percent (9 of 20) indicated that the multiple-choice protocol had the closest match to their tinnitus frequency. Other responses included a preference for the slider protocol in 40% (8 of 20), a preference for audiometry in 10% (2 of 20), and an equal preference for all 3 tests in 5% (1 of 20). Of those who did not select audiometry (18 of 20), 67% preferred the multiple choices, and 33% the slider. Among the participants with a tinnitus frequency of 12,000 Hz by audiometry (4 of 20), 3 chose a higher frequency using the slider — 12,100, 14,100, and 16,000 Hz — and all indicated the slider protocol as the most accurate.

DISCUSSION

Our findings revealed that a web-based protocol for tinnitus pitch matching could be as accurate as a standard audiometry protocol. Most of the commercially available audiometers and some of the computer-assisted methods have a presentation limit of 12,000 Hz, and therefore, the tinnitus frequency of patients with high-pitched tinnitus might not be accurately assessed.⁷ The current study mainly focused on whether the web-based protocols could be utilized as a replacement for routine audiometry. The GSI 16 audiometer, utilized in the current study, is widely used throughout the United States. It normally presents sounds with frequencies between 125 Hz and 12,000 Hz. Although optional accessories are available that will increase its range to 20,000 Hz, those accessories require additional calibrations and

are not part of the routine audiometric methods.

The secondary aim of the current study was to discover the simplicity and acceptability of the web-based protocols in comparison to the routine audiometric methods. The slider had originally been designed for patients who could not match their tinnitus with the available frequencies in a multiple-choice protocol and therefore included a broader range of frequencies. Although the best way to compare the three methods would have been to calibrate the audiometer to present a broader range of frequencies up to 20,000 Hz, it would not be a comparison of the currently used audiometric method. Additionally, we presented the sounds binaurally in the web-based protocols. Although this practice was against previous recommendations,^{1,4} our aim was to simplify the automated pitch matching process. Our findings showed that the results of the two protocols were nearly identical.

Patients with very high-frequency tinnitus preferred the web-based slider. Patients may inaccurately identify their tinnitus frequency as one octave higher or lower than it is; therefore, an octave challenge test is necessary for patient-directed tinnitus pitch matching.⁸ Other studies have also introduced automated tests for tinnitus quantification. Henry et al⁵⁻⁸ have been developing and using an automated process for tinnitus psychoacoustic assessment that consists of hardware and software for evaluation of tinnitus loudness match, pitch match, minimum masking level, and residual inhibition. In comparison, the web-based system we introduced is currently designed to quantify only tinnitus frequency, but is easily available over the web and could be performed with minimal equipment. Although the web-based method could be limited by the user's computer skills, any automated test will be limited by users' knowledge of the process.

Occurrence of octave confusion during tinnitus pitch matching is controversial. Some authors have acknowledged that patients with tinnitus often confuse their tinnitus frequency with octaves below or above the true frequency.⁹⁻¹¹ We included an octave challenge test in our protocols to prevent this phenomenon, and octave confusion occurred in 25% of our participants. Therefore, it would be appropriately cautious to always test for octave confusion in performing web-based tinnitus pitch matching.

The findings of the current study should be interpreted with consideration of its limitations. The validity of the matches could not be evaluated, since there is no way to directly measure a phantom sensation. This study was also limited by a small sample size. Future studies with larger sample sizes and

repeated measures are required to further evaluate web-based protocols for tinnitus pitch matching.

CONCLUSIONS

We attempted to introduce a new, simple, cost-effective, and reliable method to quantify tinnitus frequency. A web-based tinnitus matching protocol is

as effective as a standard protocol using an audiometer in identifying a patient's tinnitus frequency. A slider-based matching system is more effective for high frequencies and for those who might not find the exact match of their tinnitus frequency using the standard protocol. An octave test is a necessary element of web-based tinnitus pitch matching. Most patients preferred the web-based tinnitus matching.

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