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The hypothetical relation between the degree of stress and auditory cortical evoked potentials in tinnitus sufferers

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A B S T R A C T

Tinnitus, known as" the ringing in the ears," is a heterogeneous auditory disorder. Many studies have shown that tinnitus perception and its correlations are not limited to the activity of a single brain area, but there are several networks involved in tinnitus generation, perception, and interpretation. One of the most important complications and comorbidity of tinnitus is tinnitus distress. Various studies have revealed that tinnitus distress is the product of multiple networks activity, namely the tinnitus distress network; some of them overlap with the perception and cognitive networks. Such an overlapping between the tinnitus perception network and the distress network brings to mind the role of stress on tinnitus perception. Moreover, tinnitus perception networks overlap the auditory perception network leading to the hypothesis that tinnitus distress might affect the functional status of the auditory cortex indexed by the auditory evoked potentials (AEPs), and consequently, the diversity in findings of studies concerning the AEPs in tinnitus sufferers could be interpreted by the amount of stress they have.

Introduction

Tinnitus is a phantom perception of sound that is heard in the ears or the head in the absence of any external sound source [1]. The prevalence of chronic tinnitus is estimated to be about 10% to 15% in the adult population. Such a condition could significantly affect the lifestyle of 6% to 25% of this population [2]. In such situations, tinnitus sufferers cannot adapt with their tinnitus and experience emotional and functional problems such as anxiety, depression, sleep disturbances, and lack of concentration, which is usually defined as tinnitus-related distress [3,4].

Different theories have been proposed to explain tinnitus generation mechanisms. The all are sharing the notion that peripheral lesions in the cochlea or auditory nerve initiate the hierarchical chain of neural events, inducing plastic changes in the central auditory system, increased synchrony between auditory cortex neurons, increased the spontaneous activity of neurons, reorganization of the tonotopic map and changes in temporal firing patterns [5,6]. Recent studies have demonstrated that tinnitus is correlated with increased activity in different regions of the brain that form the tinnitus network [7]. When tinnitus becomes chronic and persistent, other brain networks become involved. These include the auditory cortex as the perception network interconnected with the distress network, salience network, and memory mechanisms [3,7–9].

Tinnitus is an auditory perception of sound that evaluated subjectively by two parameters, namely tinnitus loudness and annoyance [16]. In many conditions, tinnitus sufferers express different levels of annoyance while having equal loudness levels that may be related to the involved brain networks. Several EEG and fMRI studies in tinnitus subjects showed increased activity in the stress network, including the ACC, amygdala, insula, and parahippocampus [17–19] and increased functional connectivity between the precuneus and the orbitofrontal and dorsolateral prefrontal cortices which are parts of attention, cognition and stress networks and form a global network for tinnitus [9,20].

One of the most common clinical methods for evaluation of brain activities is the electroencephalography (EEG) consisting of spontaneous and evoked responses. Spontaneous resting-state oscillations refer to the ongoing background brain activity [5]. Quantitative electroencephalography (qEEG) techniques are used to study the function of brain networks, and recently, they used widely in tinnitus research [8,9]. Brain auditory evoked oscillations or auditory evoked potentials (AEPs) study the brain response to an external sound stimulus [5]. These responses are vastly variant and originate from different regions in the auditory system, including the auditory brainstem responses, auditory middle, and long latencies responses, and also the 40 Hz steady-state responses. AEPs are assessed by their amplitudes, latencies, and phase in some occasions [10,11]. AEPs studies in tinnitus research revealed important alterations in their parameters; many of them are of contradictive results [5,12–14]. Most of the researches have focused on

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Table 1
The results of the comparison of the ASSR amplitudes in the two groups.

	Tinnitus Pitch	THI Score	The amplitude of ASSR in the left auditory region	The amplitude of ASSR in the right auditory region
Case 1 (female)	4	48	251	229
Case 2 (male)	6	54	131	367
Case 3 (female)	4	48	131	566
Case 4 (male)	6	70	44	88
Case 5 (male)	8	58	81	106
Case 6 (female)	6	90	52	90

auditory late latency response (ALLR) N1- P2 wave and 40 Hz auditory steady-state responses [5]. An overview of the past investigations shows different results about the amplitudes, latencies, and or phase of these potentials [5]. Various hypotheses were mentioned for these discrepancies, such as the degree of hearing loss, the heterogeneity of the tinnitus population, and the different methodological considerations [15]. Furthermore, some studies have mentioned the stress network and its probable effect on tinnitus distress [7–9], however, none of these studies have pointed to a probable effect of the degree of stress on the auditory evoked potentials measurable parameters like as amplitude or phase.

The hypothesis

In chronic and bothersome tinnitus, a global network is activated, some parts of it can be linked to the stress network. Therefore, it can be said that when the stress networks are seriously activated due to tinnitus distress, they might affect or modulate the neuronal activities of auditory cortex and tinnitus perception network. As a result, it can be assumed that the amount of stress can be a potential source of the diversity seen in the AEPs studies results in tinnitus sufferers.

Evaluation of the hypothesis

Different questionnaires are also used for the evaluation of tinnitus severity. One of them is the Tinnitus Handicap Inventory (THI) that is widely used to assess tinnitus-related self-reported handicap and seriousness, and it has high convergent validity with tinnitus stress [21]. The results of two studies have revealed significant positive correlations between THI scores and beta-band activity in the stress network and between the beta-band activity of the posterior cingulate cortex/precuneus regions and the scores of the THI [22,23]. The results of these studies indicate that higher THI scores, or tinnitus stress, are related to a greater degree of involvement of these areas. So it can be supposed that in tinnitus sufferers, the degree of stress network involvement varies from person to person leading to variable responses of cortical auditory evoked potentials in tinnitus sufferers.

Previous studies showed that the amount of stress changes the functional connectivity between stress and tinnitus perception networks. In one study, it was found that different brain networks interact with each other based on the degree of stress in tinnitus sufferers [4]. So, it seems logical that the auditory cortex neurons, the origin of the auditory evoked response and tinnitus perception network might be affected by the amount of stress.

Empirical data

We conducted a pilot study to test this hypothesis. Six chronic tinnitus sufferers (3 female) participated in this preliminary study. We used THI questionnaire to evaluate the degree of tinnitus distress. According to THI questionnaire scores, the tinnitus sufferers were divided into two sub-groups: the high-stress group with THI above 56 (3 subjects) and low-stress group with THI cut off less than 56 (3 subjects) [24,25]. All of the patients had mild sensorineural hearing loss in mid and high frequencies.

In this study, the amplitudes of 40 Hz auditory steady-state response were measured. The ASSR was recorded using a 32-electrodes EEG CAP, and two regions of interest were selected, they were the Left auditory (T3, C5, C3), and the right auditory (C4, T4, C6) regions. The ASSR stimuli were: 4 kHz carrier frequency that was almost corresponding to tinnitus pitch and was delivered in individually most comfortable level, with a modulation rate of 37 Hz, the modulation depth of 100%, and duration of 8129 ms [13]. The independent one sample T-test was used for statistical analysis. Table 1 shows the results of the comparison of ASSR amplitudes in the two groups.

The results of this pilot study showed that the amplitudes of ASSR in the tinnitus group with low distress are higher (better) than the tinnitus group with high distress (P-value < 0.05). Therefore, it seems that this hypothesis can be proved, while further studies on it are still highly recommended.

Conclusion

The hypothesis states that the amount of stress can be of potential importance in the study and interpretation of the auditory evoked potentials in the tinnitus population. However, such a hypothesis need more research to be proved.

Statement of ethics

The authors have no ethical conflicts to disclose.

Declaration of Competing Interest

None.

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