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Exploring the interaction between emotional states and tinnitus severity before and after a sound therapy intervention

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ABSTRACT

This study examines the interaction between emotional states (anxiety and depression) and tinnitus severity in individuals undergoing a four-month sound therapy intervention. 43 participants (28 males and 15 females) of a study on four-month sound therapy of tinnitus were recruited and their tinnitus severity (Tinnitus Handicap Inventory, THI, and Tinnitus Functional Index, TFI) and emotional state (Hospitalary Anxiety and Depression Scale, HADS) were assessed before and after finishing the treatment. The participants, predominantly with moderate tinnitus, showed a significant reduction in tinnitus-related distress, with a mean reduction of approximately 30 points on both the THI and the TFI. Analysis revealed significant gender differences, with women experiencing higher baseline tinnitus distress but higher response to sound therapy. Emotional state assessments revealed moderate levels of anxiety and depression at baseline, which decreased significantly after therapy, particularly in women. Correlational analyses revealed a strong relationship between changes in emotional state and tinnitus severity, with reductions in anxiety and depression associated with improved tinnitus outcomes. The results highlight the complex relationship between emotional well-being and tinnitus severity and underline the potential of sound therapy to alleviate both emotional distress and tinnitus symptoms.

KEYWORDS

Tinnitus, tinnitus severity, tinnitus distress, emotional state, gender.

1 Introduction

Tinnitus is the perception of sound in the absence of an external source, affecting a substantial proportion of the adult population, with an approximate prevalence of 14% (Jarach et al., 2022). Psychiatric conditions, such as anxiety and depression, frequently coexist in individuals experiencing chronic tinnitus (Pattyn et al., 2016). Beyond being challenging and debilitating, these disorders have been demonstrated to elevate morbidity and the suicidity among tinnitus patients (Lewis, 2002).

The intricate relationship between tinnitus and emotional states has been extensively explored, revealing a bidirectional influence (Chen et al., 2023). Tinnitus can exacerbate pre-existing anxiety and depression, while these emotional states can, in turn, intensify the perception of tinnitus. The intensity of anxiety and depression has been linked to the severity of tinnitus, and as symptoms of depression improve, the prevalence of tinnitus may decrease (Hebert et al., 2012). Belli et al. (2008) identified in their study a notable increase in Beck Anxiety Inventory and Beck Depression Inventory scores among individuals with chronic tinnitus.

Recent research supports a model of tinnitus where reduced neuronal activity in a damaged cochlea leads to hyperactivity, mediated by diminished inhibition within the central nervous system (Vasilkov et al., 2023). Leong et al. (2020) demonstrated that sustained and executive attention processes were impaired in tinnitus compared to control participants. Tinnitus over-attention may be alleviated by therapies that divert attention away from auditory perception.

Reduced inhibition of attentional processes is associated with increased perception of tinnitus, as well as distress due to lack of concentration and/or memory, which can exacerbate mental health problems such as anxiety and depression. Eggermont and Roberts (2004) suggested that these emotional symptoms manifest in approximately 20% of tinnitus patients. Some studies have established correlations between emotional distress and tinnitus severity with anxiety and depression (Weidt et al., 2016). Møller, (2007) even proposed that emotional disturbance may precede tinnitus and predispose individuals to its development.

Individuals with tinnitus often experience sleep disturbances, particularly insomnia, which can lead to irritability, emotional problems, and difficulties with concentration and the sense of control (Brueggemann et al., 2022). Hebert et al. (2004) found a link between increased noise levels and elevated levels of the stress hormone cortisol. Additionally, emotional and behavioural

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responses in everyday life, particularly related to technology, can significantly impact the intensity and distress associated with tinnitus (Simoes et al., 2022).

Because there is no specific drug for tinnitus, sound therapy has emerged as a promising non-pharmacological intervention for the treatment of tinnitus. By employing masking, habituation, or cognitive-behavioural approaches, sound therapy aims to reduce tinnitus perception and associated distress (McKenna et al., 2014). However, the effectiveness of sound therapy in managing tinnitus distress among individuals with varying emotional states remains unclear.

Stimuli used in these treatments are often broadband sounds (Jastreboff, 2015), although other type of sounds, such as music (Argsttater et al., 2012), notched-music (Pantev et al., 2012), neuromodulation (Adamchic et al., 2012), or fractal tones (Tyler et al., 2017), have also been proposed. A new sound stimulus, customized to the hearing loss of the subject, named Enriched Acoustic Environment (Cuesta et al., 2022), has been proposed recently, able to provide tinnitus-related distress relief, clinically relevant and statistically significant, in roughly 90% of the subjects completing a four-month treatment with this therapy (Cuesta and Cobo, 2024). The tinnitus relief was assessed by measuring the score drop provided by tinnitus severity questionnaires along the treatment. However, the variations of the main emotional symptoms of tinnitus, anxiety and depression, were not assessed in these studies.

Therefore, the main objective of this article is to analyse the interaction between the variations of the emotional states (anxiety and depression) and the tinnitus severity scores in a sample of 43 patients who have been treated with the four-month EAE sound therapy.

2 Materials and methods

2.1 Subjects

A sample of 43 people with tinnitus were recruited through patient associations, and call launching for participation. The study was approved by the Research Ethics Committee of the European University of Madrid (protocol code CIPI/23.009, approved 30 January 2023). Participants with tinnitus lasting less than three months, a recent history of vertigo or surgery, objective tinnitus (somatosound) or diagnosed major depression, were excluded of the study. A comprehensive information sheet detailing the study was provided to all participants, who subsequently gave their informed consent. The mean (M) and standard deviation (SD) ages for all, male and female participants are summarized in Table 1.

2.2 Audiometric Assessment

Hearing levels (HL) were measured for all participants from 125 Hz to 8 kHz. Figure 1a shows the mean HL of the 43 participants for the right and left ears. Figures 1b and 1c display the corresponding HL curves for males and females, respectively. Shadowed areas around the HL values display the standard error of mean (SEM) at each frequency (SEM = SD/sqrt(N) N being the number of subjects). Therefore, the mean±SEM HL values plotted in Figure 1 represent the dispersion of the HL means of sample around of those of the population. Females exhibit larger hearing losses in the right ear.

Table 1 Gender and age of participants.

	All	Male	Female
N	43	28 (65%)	15 (35%)
Age (M) in years	52.6	51.8	54.4
Age (SD) in years	13.8	13.3	15.1

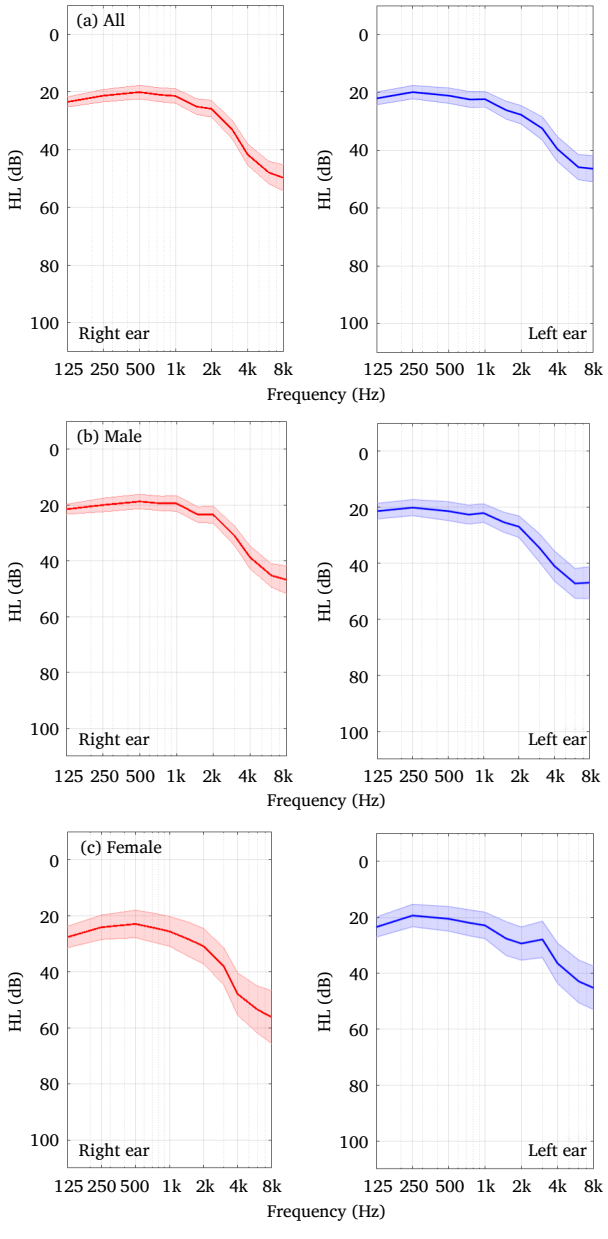

Figure 1 Average HL curves of (a) all, (b) male and (c) female participants.

2.3 Emotional States

The Hospital Anxiety and Depression Scale (HADS) (Zigmond and Snaith, 1983) was used to assess emotional state. Anxiety and depression were measured before starting sound therapy and during the four-month follow-up. The questionnaire consists of 14 items divided into two subscales: the Anxiety scale (HADS-A) and the Depression scale (HADS-D), which are presented alternately and in different order. Each item has four response options, scored from "0" (not at all) to "3" (very much). The HADS-A assesses symptoms of nervousness, restlessness, tension and

excessive worry. The HADS-D measures symptoms related to low mood, hopelessness or lack of interest in activities. The scores for each subscale are summed separately and the result corresponds to a score between 0 and 21 points, from minimum to maximum impact. A score equal or greater than 8 on either subscale indicates clinically significant impairment, while a value equal or greater than 11 is considered moderate to severe impairment. Anxiety and depression were measured before starting sound therapy and during the four-month follow-up.

2.4 Tinnitus Severity

Tinnitus severity was assessed using the Tinnitus Handicap Inventory (THI) (Newman *et al.*, 1998) and Tinnitus Functional Index (TFI) (Henry *et al.*, 2016) questionnaires. Validated Spanish versions of THI and TFI were used. Both were administered at the same time as HADS before sound therapy and during the four-month follow-up.

The THI consists of 25 questions and is divided into three subscales: functional, emotional and catastrophic. Each question has three possible responses: 'yes', 'some-times' and 'no', which are scored as 4, 2 and 0 points respectively. The final sum of all answers has a value between 0 and 100, from minimum to maximum discomfort. In general, the total THI score is used without subdivision into subscales. According to this questionnaire, the patient's disability can be classified into five categories (McCombe et al., 2001): 0-16 points, minimal disability; 18-36, mild disability; 38-56, moderate disability; 58-76, severe disability; 78-100, catastrophic disability.

On the other hand, the TFI consists of 25 questions and is divided into eight sub-scales: intrusion, emotions, cognition, auditory relationship, sleep, quality of life, energy and relaxation. Each of these questions is scored from 0 to 10, with 0 indicating "never" and 10 indicating "always". All responses are averaged and multiplied by 10 to give a score between 0 and 100, from minimum to maximum discomfort. Like the THI, the TFI score can be divided into five categories (Henry *et al.*, 2016): 0-17%, no effect; 18-31%, minor effect; 32-53%, moderate effect; 54-72%, major effect; 78-100%, very major effect.

2.5 Sound therapy

An Enriched Acoustic Environment (EAE) was used as sound therapy (Cobo *et al.*, 2021; Cuesta *et al.*, 2022). The EAE is a sound customized to the HL curves of the subject. Therefore, as hearing loss is one of the most probable causes of tinnitus, the EAE compensates for such losses so that, during the time of therapy, the subject hears with the same sensitivity to all frequencies. The EAE is implemented either as sequential or continuous sound (Cuesta and Cobo, 2024). When EAE is applied 1h/day along four months, 90% of participants completing the treatment get a tinnitus-relate distress relief which is clinically relevant and statistically significant (Cuesta and Cobo, 2024).

2.6 Statistical Analysis

Descriptive statistics was used for providing average (mean and standard deviation) values of individual variables of participants. The Pearson method was applied to calculate correlations between tinnitus severity scores (THI and TFI) and emotional state (HADS-A, HADS-D) variables. One-way ANOVA tests were applied to assess the significance degree of correlations with $\alpha = 0.05$. Therefore, values $p<\alpha$ indicate statistically significant correlations.

3 Results

3.1 Emotional State

A correlation study was carried out between the emotional state (anxiety and de-pression), measured by the HADS-A and HADS-D questionnaires, and the severity of tinnitus, measured by the THI and TFI questionnaires, comparing the baseline with the end of sound therapy (after 4 months).

Table 2 displays mean (M) and standard deviation (SD) values of the emotional states of anxiety (HADS-A) and depression (HADS-D) for the 43 participants at the initial (i) and final (f) phases of the four-month therapy. The decrease in both the emotional states of anxiety (ΔHADS-A = HADS-A_i-HADS-A_f) and depression (ΔHADS-D = HADS-D_i-HADS-D_f) were also assessed. shows that initially all participants had a moderate level of anxiety (M = 9.9, SD = 4.2), with females having higher anxiety scores (M = 12.9, SD = 3.4) compared to males (M = 8.4, SD = 3.7). Throughout the study, there was a significant decrease in anxiety scores for all participants, males and females, at the final assessment, suggesting an overall positive trend in anxiety reduction. One-way ANOVA test applied to ΔHADS-A provided a $p<0.0001$, denoting statistically significant anxiety reduction. Interestingly, females showed a higher decrease in anxiety scores (M = 6.2, SD = 3.1) as compared with males (M = 2.4, SD = 4.1), suggesting potential gender differences in response to the intervention.

Table 2 Emotional state of the 43 participants.

		All	Male	Female
HADS-A_i	M	9.9	8.4	12.9
	SD	4.2	3.7	3.4
HADS-D_i	M	7.6	6.3	10.0
	SD	4.9	4.9	4.5
HADS-A_f	M	6.2	6.0	6.7
	SD	3.7	3.8	3.5
HADS-D_f	M	4.1	4.1	4.1
	SD	3.4	3.6	3.3
ΔHADS-$A_{(i-f)}$	M	3.7	2.4	6.2
	SD	4.2	4.1	3.1
ΔHADS-$D_{(i-f)}$	M	3.5	2.2	5.9
	SD	4.6	4.7	3.2

Examining the depression scale (HADS-D), initial assessments showed moderate levels of depression for all participants (M = 7.6, SD = 4.9), with higher scores for women (M = 10.0, SD = 4.5) compared to men (M = 6.3, SD = 4.7). Similar to anxiety, there was an overall decrease in depression scores for the two groups at the final assessment, indicating a positive trend in the reduction of depressive symptoms. This decrease was also statistically significant with $p<0.00001$. Again, women showed a higher decrease in depression scores (M = 5.9, SD = 3.2) as compared to men (M = 2.2, SD = 4.7).

Figure 2 shows the scatter plot of ΔHADS-A versus ΔHADS-D for the 43 participants. Both variables show a strong correlation ($r=0.79$, $p<1e-10$). Notice that some participants had negative values of ΔHADS-A and ΔHADS-D, indicating that their anxiety and/or depression scores increased along the four-month therapy.

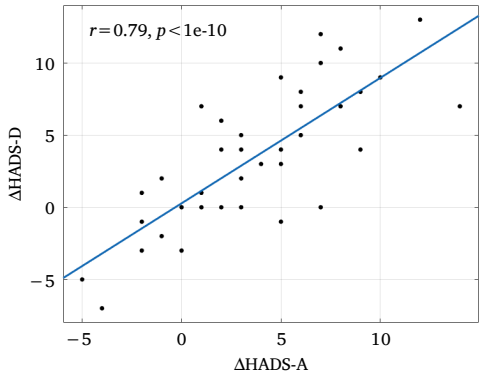

Figure 2 Scatter plot of ΔHADS-A versus ΔHADS-D for all participants.

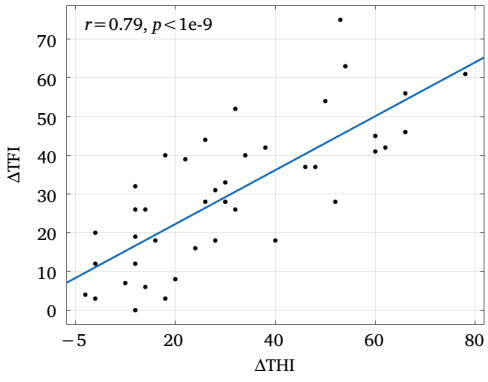

Figure 3 Scatter plot of ΔTHI versus ΔTFI for all participants.

3.2 *Tinnitus Severity*

Table 3 presents mean (M) and standard deviation (SD) values of tinnitus severity scores for baseline (i) and final (f) assessments of both THI and TFI. The decrease of both THI (ΔTHI = THI_i-THI_f) and TFI (ΔTFI = TFI_i-TFI_f) were also calculated. Table 3 shows that participants initially reported moderate levels of tinnitus-related disability, as indicated by the mean THI scores: 55.6 for all participants, 50.5 for men and 65.1 for women. Similarly, the mean TFI scores were 56.1 for all participants, 47.8 for males, and 71.7 for females. In both questionnaires, women scores were much higher than those of men, indicating a higher tinnitus-related distress in women.

Table 3 Tinnitus severity of the 43 participants.

		All	Male	Female
THI_i	M	55.6	50.5	65.1
	SD	23.9	21.1	26.6
TFI_i	M	56.1	47.8	71.7
	SD	22.6	21.4	19.5
THI_f	M	25.0	23.6	27.7
	SD	17.9	19.0	15.9
TFI_f	M	26.5	23.4	32.3
	SD	18.4	18.9	16.5
$\Delta THI_{(i-f)}$	M	30.5	26.9	37.4
	SD	20.0	18.9	20.6
$\Delta TFI_{(i-f)}$	M	29.6	24.4	39.4
	SD	18.1	16.0	18.1

Results show that participants decreased their tinnitus-related distress (ΔTHI = 30.5 and ΔTFI = 29.6) as an effect of the four-month sound therapy. This THI reduction was statistically significant (p<1e-11). This decrease was higher for women than for men.

Figure 3 shows the scatter plot of ΔTHI versus ΔTFI for all participants. Both variables are highly correlated (r = 0.79, p<1e-9).

3.3 *Correlation between changes in emotional state and tinnitus severity*

Table 4 shows the correlation coefficients between changes in emotional state, specifically anxiety (ΔHADS-A) and depression (ΔHADS-D), and in tinnitus severity as measured by the THI and TFI during the four-month sound therapy intervention. Coefficients were calculated using the Pearson correlation method, providing insight into the strength and direction of the relationships between these variables. Significance values (p) were also calculated for α = 0.05. As all p values are much smaller than α, correlations are significant.

Table 4 Tinnitus severity of the 43 participants.

	ΔTHI	ΔTFI
ΔHADS-A	0.51(p = 0.0005)	0.51(p = 0.0004)
ΔHADS-D	0.74(p = 1e-8)	0.71(p = 1e-7)

There is a moderate positive correlation between changes in anxiety (HADS-A) and tinnitus severity as measured by both the THI (r = 0.51) and the TFI (r = 0.51). Similarly, changes in depression (HADS-D) show a stronger positive correlation with tinnitus severity, with a correlation coefficient of 0.74 with THI and 0.71 with TFI. These results suggest that as anxiety and depression levels decrease over the course of four-month sound therapy, there is a corresponding tendency for tinnitus severity to improve. The p values indicate a highly significant relationship, highlighting the interrelated nature of emotional wellbeing and tinnitus outcomes within the context of the applied therapy. The highly significant correlation between emotional state and tinnitus severity variables is illustrated in the scatter plots of Figure 4.

Correlation between changes in emotional state (ΔHADS-A and ΔHADS-D) and tinnitus severity (ΔTHI and ΔTFI) during the four-month period of sound therapy was also analysed by gender, and the result is summarized in Table 5. Again, significance values (p) were also calculated for α = 0.05 and are included in Table 5.

Correlations between changes in emotional states and tinnitus severity for males are statistically significant for α=0.05. However, correlations for females are statistically significant only for ΔHADS-D with ΔTHI and ΔTFI. In terms of changes in depression (ΔHADS-D), a robust positive correlation is evident with ΔTHI and ΔTFI for both males (r = 0.72 and r = 0.70, respectively) and females (r = 0.79 and r = 0.58. respectively).

4 Discussion

The 43 participants in this study achieved tinnitus-related distress relief due to the four-month EAE therapy, with mean THI and TFI scores reduction of roughly 30 points. In a recent study with EAE therapy in 230 tinnitus participants (Cuesta and Cobo, 2023), participants reached some tinnitus relief, with an average THI

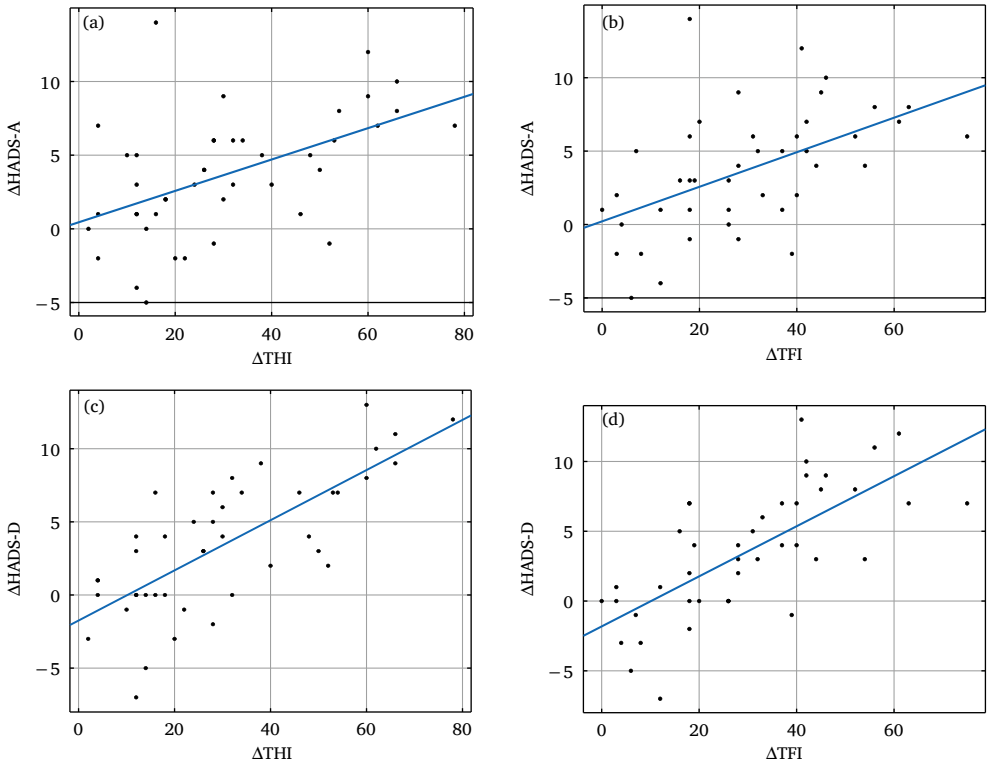

Figure 4 Scatter plots of changes in emotional state and tinnitus severity variables (a) ΔHADS-A versus ΔTHI (b) ΔHADS-A versus ΔTFI (c) ΔHADS-D versus ΔTHI, and (d) ΔHADS-D versus ΔTFI.

Table 5 Correlation between changes in emotional state and tinnitus severity by gender.

	Male	Female
ΔHADS-A vs ΔTHI	0.6 (p = 0.0008)	0.16 (p = 0.58)
ΔHADS-A vs ΔTFI	0.58 (p = 0.001)	0.04 (p = 0.89)
ΔHADS-D vs ΔTHI	0.72 (p = 0.00001)	0.79 (p = 0.0004)
ΔHADS-D vs ΔTFI	0.70 (p = 0.00002)	0.58 (p = 0.02)

score reduction of 24.3 points.

The strong correlation between THI and TFI, both at baseline and after the EAE treatment, confirms that both questionnaires provide almost identical results as evaluators of the tinnitus severity (Fernández et al., 2023). Good correlation coefficients are also observed between tinnitus severity (THI and TFI) and anxiety and depression scale (HADS-A and HADS-D) variables confirming the feedback between them: tinnitus produces emotional troubles which increase the tinnitus distress (Mazurek et al., 2012).

Both the initial values of THI and TFI scores as well as the mean scores falling due to the EAE therapy showed significant gender differences (see Table 3). Women of this cohort had higher baseline tinnitus-related distress but responded better to the EAE treatment. Previous studies suggested that the sex of tinnitus-affected subjects should be considered as distinctive factor in the assessment and treatment of tinnitus (Sharma et al., 2018; Cederroth and Schlee, 2022; Cuesta and Cobo, 2023). It seems that significantly more males report tinnitus, although females tend to report a greater emotional reaction to their tinnitus, in accordance with our results. This can be due to that tinnitus-related distress is more associated with personality factors in men but with emotional factors in women.

Similarly, the mean values of the emotional state variables (HADS-A and HADS-D) differed both at baseline as well as at the end of treatment (see Table 2). Again, women begun with higher average anxiety and depression but decreased more their emotional scales after the EAE treatment. Corresponding with previous studies investigating the relationship between tinnitus distress and emotional states, our results indicate that women consistently report higher levels of anxiety and depression (Fioretti et al., 2020; Niemann et al., 2020). These findings support previous outcomes by the World Health Organization ("Depression and other common mental disorders: global health estimates." Licence: CC BY-NC-SA 3.0 IGO, 2017) recognizing higher rates of anxiety and depression in women compared to men.

In relation to hearing loss, other studies refer also gender differences (Cederroth and Schlee, 2022). In our study, the dispersion of hearing thresholds, as well as the asymmetry of hearing losses in both ears, was higher in women. This differs of the results of a recent study, where males showed hearing thresholds higher than females (Cuesta and Cobo, 2023).

On the other hand, our results confirm previous research suggesting that women often derive greater benefit from acoustic stimulation treatments (Partyka et al., 2021). Moreover, Van der Wal et al. (2020) found that female patients responded more favourably to high-definition transcranial direct current stimulation and orofacial therapy whereas male participants showed greater improvement with a combined treatment approach involving tinnitus retraining therapy (TRT) and cognitive-behavioural therapy (CBT). However, the question of gender differences in response to different treatments remains open and requires further research.

4.1 Limitations

Two main limitations of this study are the modest size of the

sample and the un-matched sizes of men and women subgroups. We are aware that the results of this study should be confirmed with a larger sample with balanced male and female participants. A study without these limitations (164 tinnitus patients with matched male/female participants) is currently being carried in China and Shanghai Hospitals (Huang et al., 2024), aiming to test the Acceptance and Commitment Therapy (ACT) combined with a tailored sound therapy, customised to the pitch and loudness of the tinnitus subject. This paper contains the results of an observational study combining sound counselling with EAE sound therapy, personalised to the hearing condition of the tinnitus participants.

5 Conclusions

This study aimed to explore the complex interaction between emotional states, specifically anxiety and depression, and the severity of tinnitus symptoms in 43 individuals undergoing sound therapy for tinnitus over a four-month period. The research revealed a remarkable average reduction of 30 points in tinnitus-related distress scores (THI and TFI) within the sample studied. Gender differences were evident, with women showing a more pronounced response to sound therapy than their male counterparts, despite initially higher levels of tinnitus distress.

Initial assessments using HADS revealed moderate levels of anxiety and depression, both of which showed significant reductions following treatment, particularly in women. Correlational analyses revealed a robust relationship between changes in emotional states and improved outcomes in tinnitus severity. These findings under-score the relationship between emotional wellbeing and tinnitus symptom severity and highlight the potential of sound therapy to simultaneously reduce distress and alleviate symptoms.

The observed gender differences in treatment response highlight the need for further research to elucidate the subtleties of individual differences. Such findings could inform the development of personalized treatment approaches tailored to the individual needs of each patient.

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Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Conflicts of Interest

The authors declare no conflict of interest.

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