Cognitive behavioural factors in tinnitus-related insomnia

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Abstract

Background: A significant proportion of individuals with distressing tinnitus also report insomnia. Limited but emerging evidence suggests tinnitus-related insomnia cannot be explained purely by the presence of tinnitus, and that that sleep-related cognitive behavioural processes may also play a key role in exacerbating tinnitus-related insomnia.

Objectives: This study aimed to assess whether sleep-related cognitions and behaviours believed to maintain insomnia disorder are present for individuals with tinnitus-related insomnia.

Methods: This between-groups study recruited 180 participants online for four groups: tinnitus-related insomnia (N=49), insomnia disorder without tinnitus (N=34), tinnitus sufferers who are good sleepers (N=38) and controls (N=59). They completed questionnaires assessing insomnia severity, sleep-related cognitions and behaviours, sleep quality, anxiety and depression. People with tinnitus completed a measure of tinnitus severity and rated the loudness of their tinnitus on a subjective measure.

Results: Linear regression found that group was a significant predictor of sleep-related thoughts, behaviours and quality. Pairwise-comparisons showed the tinnitus-related insomnia group had significantly greater insomnia-related thoughts and behaviours and significantly worse sleep quality than tinnitus good sleepers. No differences were seen between tinnitus-related insomnia and insomnia groups. The tinnitus-related insomnia group had significantly higher depression, anxiety and tinnitus distress than tinnitus good sleepers.

Conclusion: Findings suggest that tinnitus-related insomnia may be maintained by cognitive behavioural processes similar to those found in insomnia disorder, and such processes are more important than tinnitus severity when understanding sleep disturbance. People with tinnitus-related insomnia may benefit from treatments such as Cognitive Behavioural Therapy for insomnia.

1 Introduction

Tinnitus is defined by the experience of hearing sound, commonly ringing or buzzing, in the absence of external stimuli (Beukes et al., 2017). Estimates vary, some suggesting it may

affect 30% of the population (McCormack, Edmondson-Jones, Somerset, & Hall, 2016). Common impacts of distressing tinnitus include emotional distress, anxiety(Laurikainen, Johansson, Akaan-Penttila, & Haapaniemi, 2000), difficulties in sleep, relationships, work functioning and concentration (Asnis et al., 2018). A systematic review looking at the co-occurrence of depression and tinnitus suggested a 33% prevalence of depression amongst people who suffer with tinnitus (Salazar et al., 2019). It is likely that this co-occurrence is bidirectional, for example tinnitus fueling depression and depression possibly making tinnitus harder to cope with, thus making tinnitus worse. A UK survey estimated societal costs of £2.7bn annually (Stockdale et al., 2017).

Those suffering with tinnitus commonly complain of sleep disturbance (Hébert, Fullum, & Carrier, 2011; Miguel, Yaremchuk, Roth, & Peterson, 2014), though our understanding of the comorbidity rates of insomnia and tinnitus is incomplete. A review examining the relationship between the two disorders (Asnis et al., 2018) found that 15 of 16 studies included in the review used variable and often inadequate assessment techniques and criteria to define insomnia. Most reported prevalence of insomnia above 40% in their tinnitus sample (Asnis et al., 2018). The remaining study used diagnostic assessment (Miguel et al., 2014) and reported an insomnia prevalence of 27%. This review led to predictions that individuals who suffer with both disorders will experience greater tinnitus distress than those with only tinnitus and highlighted that higher tinnitus-related distress is associated with greater levels of anxiety and depression. Research has found that men who experience insomnia associated with tinnitus have higher depression scores than women, indicating potential gender differences to consider in treatment (Richter et al., 2021).

Our understanding about why sleep disturbance is common in tinnitus is limited. One hypothesis suggests insomnia in tinnitus be understood through the association between noise and difficulty sleeping (Izuhara et al., 2013). Izuhara and colleagues (2013) suggested that sleep disturbance associated with tinnitus could be similar to residents in a noisy neighborhood experiencing difficulties falling asleep, suggesting that tinnitus volume alone maintains insomnia. However, other research has indicated that interpretation of tinnitus causes greater distress than its volume alone (Basile, Fournier, Hutchins, & Hébert, 2013). A further study looked at the relationship between the loudness of tinnitus and insomnia (Aazh and Moore, 2019). The researchers found that the relationship was mediated by depression, tinnitus handicap and tinnitus annoyance as opposed to insomnia being directly related to the loudness of tinnitus. It remains unclear if the experience of tinnitus can be compared to an external sound, particularly as there are different types and possible causes of tinnitus.

Insomnia disorder is commonly comorbid with psychological disorders such as anxiety and depression (Harvey, 2001), however evidence indicates that it is not just a 'symptom' of other psychological disorders (Harvey, 2001). This is because it can treated independently from comorbidities and it can both precede and follow on from comorbidities. The cognitive model of insomnia (Harvey, 2002) outlines many processes that an individual experiences during the night and day which maintain insomnia. In summary, it proposes that insomnia arises from worry about sleep and the consequential impact on day-to-day life. This causes increased emotional and physiological arousal leading to selective attention and monitoring and distorted perceptions (i.e. underestimating sleep and functioning). Worries also lead to safety-seeking behaviours intended to reduce insomnia and its impact (e.g. cancelling plans) but which paradoxically exacerbate sleep difficulties. This leads to escalating anxiety and further insomnia.

Cognitive Behavioural Therapy for insomnia (CBTi) was developed as a brief psychological intervention for insomnia. Though it does not address all processes put forward in the cognitive model of insomnia (Harvey, 2002) it aims to target unhelpful thoughts and behaviours around sleep using psychoeducation, behavioural experiments, sleep restriction, stimulus control and cognitive restructuring (Pigeon et al., 2012). Research shows that specifically targeting distorted perception of sleep leads to reduced sleep-related anxiety (Tang & Harvey, 2004) whilst challenging insomnia-related thoughts and behaviours enables individuals to establish healthier sleep patterns and improve quality of life (Okajima, Komada, & Inoue, 2011). A high-quality meta-analysis of RCTs using CBTi in insomnia (Okajima et al., 2011) found it to be effective, with medium to large effect sizes. Improvement on measures of dysfunctional sleep-related cognitions was a significant change following CBTi, suggesting these are central to maintaining insomnia and crucial to target in treatment.

It is argued that the same cognitive and behavioural processes maintain insomnia, regardless of comorbidities such as chronic pain (Tang, Goodchild, & Salkovskis, 2012). CBTi is proven to successfully treat insomnia where such comorbidities exist (Jungquist et al., 2010). Of note, chronic pain shares many similarities with tinnitus (Moller, 2000); both being sensory perceptual disorders associated with hypersensitivity (Rauschecker, May, Maudoux, & Ploner, 2015) and related psychological difficulties (Rauschecker et al., 2015).

Evidence has shown that people with insomnia and people with tinnitus share similar sleep processes, including physiological characteristics of sleep disturbance (Burgos et al., 2005). Polysomnography (PSG), the 'gold standard' objective assessment for sleep disorders, has shown that tinnitus patients experience more awakenings and greater difficulty with sleep onset compared to healthy controls (Burgos et al., 2005). This finding is similar to that reported when comparing people with insomnia to healthy controls. A systematic review of studies of polysomnography applied to patients with tinnitus found that few have assessed tinnitus sufferers sleep using this technique, instead opting for self-report questionnaires (Teixeira, Granjeiro, De Oliveira & Júnior, 2017), highlighting the need for future studies to use polysomnography as an objective evaluation method.

Crönlein et al., (2016) assessed sleep and psychological difficulties in samples with and without tinnitus, using the Regensburg Insomnia Scale (RIS). People with tinnitus reported more difficulties with and greater worries about sleep, supporting the theory that insomnia in tinnitus may be maintained by the insomnia process outlined above. However, this study is limited by the use of the RIS, a brief outcome measure rather than a tool designed to assess insomnia-specific cognitions and behaviours. It also did not offer comparison with an insomnia group without tinnitus, and the authors suggested that anxiety and depression could be confounding factors that were not accounted for in their study.

Few tinnitus studies include measures of improved sleep as a primary or secondary outcome and few consider severity of sleep impairment in recruitment or analysis (Hesser, Weise, Westin, & Andersson, 2011). However, a clinic-based study evaluated outcomes from CBTi for tinnitus-related insomnia (Marks, McKenna, & Vogt, 2019) and found that 66.7% of participants showed reliable improvement on the Insomnia Severity Index (ISI). Participants reported reduced tinnitus severity and psychological distress. Though limited by the small sample size and lack of a control group, it was the first of its kind to evidence the efficacy of CBTi as a treatment for tinnitus-related insomnia. A more recent randomised controlled study looked at the benefits of CBTi for people with tinnitus-related insomnia and found it to be more

effective in reducing tinnitus distress and improving sleep quality compared with audiology-based care or a sleep support group (Marks, Hallsworth, Vogt, Klein & McKenna, 2022). These studies offer tentative evidence that tinnitus-related insomnia is maintained by cognitive and behavioural processes similar to those seen in insomnia without comorbidities or insomnia disorder (Harvey 2002).

In summary, evidences shows that the physiological characteristics of insomnia are similar in populations with and without tinnitus (Burgos et al., 2005), both experiencing decreaeed sleep efficiency, sleep time and a higher number of awakenings compared to healthy controls (Burgos et al., 2005). Limited evidence indicates that the psychological processes that may underpin the experience of insomnia in tinnitus could be equivalent to the psychological processes that underpin insomnia without tinnitus (Crönlein et al., 2016; Marks et al., 2019). An example of this would be dysfunctional sleep related cognitions, which are beliefs about people's expectations and attitudes about the causes and consequences of poor sleep e.g. "when I sleep poorly one night, I know it will disturb my sleep schedule for the whole week". Our understanding in this area is hampered by a lack of consistency across the field regarding the outcome measures used to assess sleep quality, the presence of insomnia, and sleep related thoughts and behaviours. It is vital to clarify how psychological factors are associated with tinnitus-related insomnia to improve understanding of patient experiences and effective treatment of tinnitus-related insomnia.

This study aimed to examine whether cognitive and behavioural factors believed to commonly maintain insomnia (Harvey, 2002) are equally important factors that contribute to insomnia in people who have tinnitus. It was hypothesized that levels of dysfunctional sleep-related cognitions, behaviours and sleep quality would be similar in individuals reporting insomnia, regardless of tinnitus presence, and greater than people who do not report insomnia (both with and without distressing tinnitus). As research has suggested that those with tinnitus and insomnia experience higher levels of anxiety, depression and tinnitus distress than individuals who have tinnitus without insomnia (Asnis et al., 2018) it was hypothesised that tinnitus distress, anxiety and depression will be significantly higher in tinnitus-related insomnia compared with tinnitus good sleepers. A final hypothesis was that subjective tinnitus volume will not differ significantly between tinnitus-related insomnia and tinnitus good sleepers, to add weight to the argument that it is not the noise of the tinnitus that keeps people who have insomnia awake.

2 Materials and Methods

2.1 Design

This cross-sectional study used a between-groups design in which four groups were compared: 1) tinnitus-related insomnia; 2) insomnia; 3) tinnitus good sleepers and 4) controls. All responses were collected via the online platform Qualtrics, questionnaires were presented in the same order to participants. Inclusion criteria was a minimum age of 18. Exclusion criteria were existing diagnosis of a sleep disorder other than insomnia, or belief that their insomnia was explained by a physical or mental health condition besides tinnitus. Recruitment was conducted via social media, with relevant charities agreeing to share the study on their websites.

2.2 Participants and Procedures

A total of 773 participants initiated the study, of which 266 did not consent, and 73 exited the survey before completion. Significantly more (N=253) met criteria for the controls and tinnitus-related insomnia group than planned and were prevented from taking part. One participant was excluded as they wrote "333" in all free-text boxes. The final sample consisted of 180 participants who had completed all questionnaires (all but the GAD-7 and PHQ-9 were counted as complete data sets). Participants were asked whether or not they had tinnitus and a further question to assess how much of a problem it was for them. Participants then completed The Insomnia Severity Index (ISI; Morin, 1993). This information was then used to sort participants into one of the four groups (Figure 1 in supplementary material shows the study flow). The final groups were as follows: insomnia (N=34); tinnitus-related insomnia (N=49); tinnitus good sleepers (N=38); and controls (N 59). See Table 1.1 for demographic characteristics of the sample.

2.3 Measurement

All participants completed the following self-report questionnaires:

2.3.1 The Insomnia Severity Index (ISI; Morin, 1993)

This 7-item measure was used to screen participants for insomnia. The measure uses a five-point Likert scale, ranging from 0 to 4 and offers a clinically-relevant tool for assessing insomnia. Participants were allocated to a certain group depending on their score on this measure. The ISI has good reliability and validity (Bastien, Vallières, & Morin, 2001). A score of 10 or above is deemed appropriate for identifying clinically-relevant insomnia in a community sample (Morin, Belleville, Bélanger, & Ivers, 2011). The ISI has been shown to have excellent internal consistency (Cronbach's α =0.75) when used to assess insomnia in a community sample (Morin et al., 2011).

2.3.2 The Pittsburgh Sleep Quality Index (PSQI) (Buysse et al., 1989)

This was used to assess participants sleep quality. The 18-item measure produces seven component scores and one overall global score relating to quality of sleep. Question 10 was omitted from administration as it does not contribute to the PSQI global score. This measure has acceptable internal consistency (Cronbach's α =0.75) (Hinz et al., 2017). Participants who entered time ranges, for example answering 9-11pm when asked what time they have usually gone to bed in the past month, were allocated a mid-point. This measure was used to assess sleep quality instead of the ISI as it includes both quantitative aspects of sleep, such as sleep duration, along with more subjective constructs, such as "restfulness" (Buysse et al., 1989).

2.3.3 Dysfunctional Beliefs and Attitudes about Sleep (DBAS-16) (Morin, Vallières, & Ivers, 2007)

The DBAS-16 was used to assess participants sleep related beliefs, many of which become the target of CBTi (Morin et al., 2007). Participants are asked to respond to statements relating to beliefs and attitudes about sleep on a Likert scale ranging from 0 (strongly disagree) to 10 (strongly agree). Examples of dysfunctional beliefs participants are asked to respond to are "without an adequate nights sleep, I can hardly function the next day" and "I am worried that I may lose control over my sleep abilities". The DBAS-16 has been shown to have acceptable validity and reliability (Cronbach's α= 0.77-0.79) (Morin et al., 2007).

2.3.4 Sleep Related Behaviours Questionnaire (SRBQ) (Ree and Harvey, 2004)

This measures the extent to which an individual engages in sleep-related safety behaviours thought to maintain insomnia. Participants respond to 32 statements about how often they engage in each behaviour, rating from 0 (almost never) to 4 (almost always). Examples of sleep related safety behaviours are "I catch up on sleep by napping" and "I try to stop all thinking when trying to sleep". The psychometric properties of the SRBQ have not been systematically evaluated (Lebrun, Gély-Nargeot, Maudarbocus, & Bayard, 2020). It has been shown to have good sensitivity to detect change in psychological therapy for insomnia (Harvey, Sharpley, Ree, Stinson, & Clark, 2007) so is the best available measure. Cronbach's α= .94 for this sample, indicating excellent internal consistency.

2.3.5 The Generalised Anxiety Disorder Assessment (GAD-7) (Spitzer, Kroenke, Williams, & Löwe, 2006)

This 7-item scale assesses anxiety symptoms over the past two weeks. Participants rate anxiety experiences from 0 (not at all) to 3 (nearly every day). Internal consistency of the GAD-7 is excellent (Cronbach's α = 0.92) and good test-retest reliability (α =0.83) (Spitzer et al., 2006). A score between 11 and 15 reflects moderate anxiety, above 15 indicates severe anxiety.

2.3.6 The Patient Health Questionnaire (PHQ-9) (Kroenke, Spitzer, & Williams, 2001)

This 9-item scale assesses depression symptoms over the past two weeks, with respondents rating how much they were bothered by symptoms from 0 (not at all) to 3 (nearly every day). The scale has good internal consistency (Cronbach's alpha = 0.89) and good test-retest reliability (α =0.84). A score between 10 and 14 reflects moderate depression, 15-19 indicates moderately severe depression and above 19 indicates severe depression.

2.3.7 Demographic information

A variety of demographic information was collected including age, gender, ethnicity and shift work, as this is known to impact on sleep and circadian rhythms (Boivin & Boudreau, 2014)

The following measures were *only* completed by those who identified as having tinnitus.

2.3.8 Tinnitus Handicap Inventory (THI) (Newman, Jacobson, & Spitzer, 1996)

This 25-item measure was used to assess the severity of impact of participants tinnitus on their daily lives. The THI requires participants to respond yes, no or maybe to statements about their tinnitus. The THI has been found to have high internal consistency (Cronbach's α = 0.92). This measure was chosen as it focuses less on sleep impairment than other tinnitus questionnaires, which reduced the risk of redundant questions.

2.3.9 Tinnitus-related distress

This was a single question that asked participants to rate how much of a problem their tinnitus was. Respondents chose between 'not a problem', 'minor problem', 'moderate problem', 'considerable problem' or 'severe problem'. Categories were informed by research looking at categories of tinnitus-related distress (Handscomb, 2006). This, along with the ISI, was used to inform which group participants were sorted into. This was used instead of the THI to insure the tinnitus groups both contained participants with at least moderate distress.

2.3.10 Tinnitus Visual Analogue Scale (VAS)

This assesses subjective loudness of tinnitus. Participants selected from 0 (I can't hear my tinnitus, even in quiet) to 100 (my tinnitus is louder than any other noise) where they would currently rate their tinnitus. A Cochrane review of CBT for Tinnitus (Martinez-Devesa, Perera, Theodoulou, & Waddell, 2010) found numeric visual analogue scales used in seven of the eight included studies, though variation in presentation was noted. Single item ratings, though limited, have been found to be more reliable than tinnitus loudness matching (Hall, Mehta, & Fackrell, 2017), this was included in addition to the THI due to literature suggesting tinnitus loudness may be independent from tinnitus distress.

2.4 Data analysis

Data was analysed using IBM SPSS v.25. Differences in participant demographics and general psychological characteristics (PHQ-9 and GAD-7) were explored across participant groups using one-way ANOVA for continuous variables and chi-squared tests for categorical variables. Differences in anxiety and depression were tested using a non-parametric Kruskal-Wallis H test as both variables were non-normally distributed, and no sensible transformations were identified.

ANCOVA's were planned *a priori* to test for differences between groups for insomnia-related cognitions, behaviours and sleep quality when controlling for depression and anxiety. However, the assumption of homogeneity of regression slopes was violated, so linear regression analysis was used to test for participant group differences (while controlling depression and anxiety). For each outcome, models were fitted in hierarchical blocks [Block 1: age and gender (female vs male); Block 2: anxiety and depression; Block 3: participant group (4 levels)] to test the incremental contribution of each set of variables to improvements in model fit (change in F-statistic and R^2). Ethnicity was excluded from all regression models as there were too few non-white participants to make meaningful inferences. Pairwise differences between groups were tested post hoc from a full model including all covariates, with a Bonferroni correction for multiple tests. Differences between the tinnitus-related insomnia and tinnitus good sleepers groups were explored using t-tests and Mann-Whitney U tests depending on the distribution of the outcome.

3 Results

3.1 Participant demographics

Demographic characteristics are presented in Table 1.1. Given small cell sizes for some variables, responses were collapsed such that there were two categories for each characteristic (e.g. Male vs Female, White vs non-White).

The tinnitus-related insomnia group were found to be significantly older than the insomnia and control groups ($F_{(3,176)} = 6.59$, $p < .001$). Significant differences were also observed for marital status, $X^2(3, N=176) = 10.7$, $p = .013$, and ethnicity, $X^2(3, N=176) = 14.7$, $p = .002$, whilst no differences were observed with regard to gender, education level and current employment. Table 1.2 presents summary scores across all measures. A Kruskal-Wallis H test showed significant differences between participant groups for both anxiety, $H(3) = 39.60$, $p < .001$ and depression, $H(3) = 71.7$, $p < .001$. Tinnitus-related insomnia and insomnia groups had significantly greater ($p < .01$ for all) levels of anxiety and depression compared to tinnitus good

sleepers and controls. Tinnitus-related insomnia compared with insomnia groups and controls compared with tinnitus good sleepers groups did not differ significantly.

After exclusions for missing data on the outcome or covariates, 174 participants were included in the regression analysis (34 in the insomnia group, 48 in the tinnitus-related insomnia group, 37 in the tinnitus good sleepers group, and 55 controls) (Table 1.3).

The results of the pairwise differences between groups, which were tested post hoc from a full model can be seen in Table 1.4

3.2 Sleep-related cognitions

Results from a hierarchical regression model of sleep-related cognitions (DBAS-16 score) showed that the addition of anxiety and depression scores to predict sleep-related cognitions (DBAS-16 score) led to a statistically significant increase in R^2 (ΔR^2 = 0.44, F(2, 170) = 64.3 p<.001, as did the addition of group, ΔR^2 = 0.09, F(3, 169) = 10.5 p<.001. Post-hoc pairwise comparisons showed that the tinnitus-related insomnia group scored significantly higher on sleep-related cognitions compared to the tinnitus good sleepers, difference = 1.41, 95% CI [0.51, 2.23] and controls, difference = 1.45, 95% CI [0.60, 2.31]. The insomnia group scored significantly higher on sleep-related cognitions compared to the tinnitus good sleepers, difference = 1.46, 95% CI [0.53, 2.38] and controls, difference =1.49, 95% CI [0.62, 2.37]. The insomnia group had higher sleep-related cognitions than the tinnitus-related insomnia group, but this difference was not significant: difference = 0.04, 95% CI [-0.88, 0.80], nor was the difference between the tinnitus good sleepers and controls, difference = 0.04, 95% CI [-0.72, 0.80].

3.3 Sleep-related behaviours

Results from a hierarchical regression model of sleep-related behaviours (SRBQ scores) showed that the addition of anxiety and depression led to a statistically significant increase in R^2; ΔR^2 = 0.45, F(2, 172) = 71.6, p<.001, as did addition of participant group, ΔR^2 = 0.08, F(3, 171) = 9.56, p<.001. Post-hoc pairwise comparisons showed that the insomnia group scored highest on the SRBQ compared to other groups, with the difference between group means being significant for the tinnitus good sleepers, difference = 20.38, 95% CI [10.01, 30.74] and controls, difference = 16.10, 95% CI [6.31, 25.89]. Though the insomnia group scored higher on average than the tinnitus-related insomnia group, the difference between group means was not significant, difference = -9.20, 95% CI [-18.60, 0.21]. The tinnitus-related insomnia group scored significantly higher than the tinnitus good sleepers, difference = 11.18, 95% CI [1.13, 21.23] but not the controls, difference =6.90, 95% CI [-2.61, 16.42]. The tinnitus good sleepers group scored lower than the controls for sleep-related behaviours, but this difference was not significant, -4.28, 95% CI [-12.77, 4.22].

3.4 Overall sleep quality

Results from a hierarchical regression model of overall sleep quality scores (PSQI score) showed that the addition of anxiety and depression led to a statistically significant increase in R^2; ΔR = 0.47, F(2, 172) = 5.72, p<.001, as did addition of participant group, ΔR^2 = 0.19, F(3, 171) = 10.43, p<.001. Post-hoc pairwise comparisons showed that the tinnitus-related insomnia group had significantly worse sleep quality (indicated by higher score) compared to the tinnitus good sleepers, difference = 4.14, 95% CI [2.56, 5.73] and controls, difference = 3.44, 95% CI [1.94, 4.94]. The insomnia group scored significantly higher on sleep quality compared to the tinnitus good sleepers, difference = 5.18, 95% CI [3.54, 6.82] and controls, difference = 4.47. 95% CI

[2.93, 6.02]. The tinnitus-related insomnia group had better sleep quality than the insomnia group, but this difference was not significant, difference = -1.03, 95% CI [-2.52, 0.45], nor was the difference between the tinnitus good sleepers and controls, difference = -0.71, 95% CI [-2.05, 0.62].

3.5 Tinnitus loudness and tinnitus distress between tinnitus-related insomnia and tinnitus good sleeper groups

The tinnitus-related insomnia group had greater tinnitus distress (*M*=58.54, *SD*=23.04) compared to the tinnitus good sleepers' group (*M*=41.9, *SD*=21.62). This difference was significant (16.64, 95% CI [6.91, 26.28]). The tinnitus-related insomnia group experienced significantly louder subjective tinnitus volume compared to the tinnitus good sleepers' group (Median difference = 10, $U = 626$, $z = -2.61$, $p = 0.09$). As this was unexpected, post-hoc one-way ANCOVA explored whether sleep-related cognitions (DBAS-16) and behaviours (SRBQ) differed between the two groups when controlling for tinnitus loudness (VAS) and distress (THI). The tinnitus-related insomnia group had significantly greater insomnia cognitions, $F(1, 83) = 35$, $p < .001$, partial $\eta^2 = .3$, and behaviours, $F(1, 83) = 33.1$, $p < .001$, partial $\eta^2 = .29$, compared to tinnitus good sleepers when controlling for tinnitus distress and loudness, in line with the findings from the main analysis.

4 Discussion

In line with hypotheses, this novel study found that individuals with tinnitus-related insomnia report the same level of dysfunctional sleep-related cognitions and behaviours as individuals with insomnia without tinnitus. For example, catastrophic cognitions about having inadequate sleep, which fuels anxiety and worry, hypervigilance to nighttime wakefulness and daytime sleepiness, and unhelpful behaviours such as spending too long in bed or taking day-time naps. These sleep-related cognitions and behaviours were significantly more prevalent in tinnitus-related insomnia than people with distressing tinnitus who sleep well and in people with neither insomnia nor distressing tinnitus. Such findings support the claim that cognitive behavioural processes hypothesised to contribute to the maintenance in insomnia (Harvey, 2002), also maintain insomnia in people with tinnitus. This aligns with recent findings from a RCT which found that CBTi targeting specifically sleep-related behaviours and cognitions (e.g. through time-in-bed restriction, psychoeducation about sleep, anxiety and worry management, etc) led to large, clinically significant improvements in sleep and tinnitus (Marks et al., 2022). Together, these studies suggest that insomnia in tinnitus patients may involve the same processes that are found in people who have insomnia without tinnitus. Of course, tinnitus may add an additional layer of complexity and challenge for the patient, but this similarity across groups indicates how tinnitus and insomnia patients can benefit from existing insomnia therapies.

One possible explanation could have been that anxiety and depression symptoms contributed to the impaired sleep and dysfunctional cognitive-behaviours related to sleep, as such symptoms were significantly higher both groups with insomnia. However, the fact that the differences in sleep remained after controlling for anxiety and depression demonstrates that sleep-related cognitive behavioural factors in fact explain unique variance in the experience of insomnia both with and without tinnitus.

This study offers new insight into possible maintaining factors for sleep difficulties reported by people with distressing tinnitus. The finding that people with tinnitus-related insomnia

reported greater levels of unhelpful sleep-related cognitions, behaviours and sleep quality than tinnitus good sleepers indicates that the factors differentiating these two groups relate to insomnia-relevant processes (cognitions and behaviours) rather than tinnitus-relevant processes. Furthermore, there were equivalent levels of sleep-related cognitions, behaviours and quality in the insomnia-only and tinnitus-related insomnia groups. This adds significant weight to the literature regarding shared cognitive-behavioural characteristics between the two experiences of insomnia, i.e. with and without tinnitus (Crönlein et al., 2016). Considering existing evidence in support of shared biological characteristics between insomnia and tinnitus-related insomnia (Burgos et al., 2005), these findings support a biopsychosocial model of tinnitus-related insomnia.

Unexpectedly, tinnitus subjective volume was louder for those with tinnitus-related insomnia than for those who sleep well, counter to evidence that tinnitus distress is not directly associated with tinnitus volume (Basile et al., 2013). Whilst this may represent a novel difference between people with tinnitus-related insomnia and those without insomnia further research is needed to draw firm conclusions and explain why this may be the case. The findings from the main analyses did not change when controlling for tinnitus severity and volume, supporting the argument that sleep-related cognitive behavioural factors maintain tinnitus related insomnia, and countering the hypothesis that tinnitus volume fuels insomnia (Izuhara et al., 2013; Aazh and Moore, 2019).

Another unexpected finding was a lack of significant difference in sleep-related behaviours between those with tinnitus-related insomnia and controls. One possible explanation may relate to the recruitment strategy whereby recruitment of tinnitus groups directly focused on sleep whilst recruitment of the control group took a broader approach, which may had led to a tinnitus sample with greater concerns about sleep than the controls.

4.1 Strengths

This is the first study that has compared insomnia related thoughts and behaviours reported by people with tinnitus to people with insomnia, people with tinnitus who sleep well and individuals without distressing tinnitus or insomnia. The use of multiple comparators is a key strength as it allows for clarification of similarities and differences across all groups and highlights how similar cognitive behavioural factors in tinnitus-related insomnia are to insomnia without tinnitus. The use of the ISI (Morin, 1993) to assess for the presence of insomnia, which is a validated outcome measure for insomnia research (Bastien, Vallières & Morin, 2001), is scarce within tinnitus literature (Asnis et al., 2018) and the robustness of measures collected across the sample is another strength.

4.2 Limitations

The possibility of participants having undiagnosed sleep disorders, besides insomnia is a limiting factor in this study. The researchers collected an outcome measure intended to screen for the possibility of undiagnosed sleep disorders (The Sleep Diagnostic Algorithm, Wilson, 2010) but it's briefness meant that no participants were excluded based on responses. Sleep disorders are diagnosed using thorough clinical assessments, which future research in this field should aim to include.

Some participants allocated to the insomnia or control group also reported tinnitus. This is because allocation of participants to groups was based on participant self-selection of tinnitus distress, rather than score on a tinnitus measure. Interestingly, there was a mismatch, with some self-reported 'mild' or 'no' tinnitus sufferers meeting criteria for moderate tinnitus on the THI. This could mean that sleep related cognitions and behaviours measured in the controls and insomnia groups are impacted

by the presence of tinnitus. This would limit the extent to which comparisons between the tinnitus related insomnia and insomnia groups can be drawn. Using the THI to sort participants into groups would have avoided this limitation. However, this would require every person in the study to complete the 25-item tinnitus questionnaire (THI). Along with increasing questionnaire burden, this could cause confusion for participants who say they experience no tinnitus as they would be asked to respond to statements such as "because of your tinnitus do you feel desperate?". As there are clearly pros and cons to each method of grouping criteria, future studies should consider the limitations of both methods prior to undertaking their study. The study is further limited by the questionnaires not being counterbalanced and solely using self-report measures and cut offs to classify people as having insomnia, tinnitus, or both. Future studies should consider more robust assessments, that are more in line with the clinical diagnostic process for each condition and administered in a randomised way. Additionally, the field would benefit from future studies using consistent standardised measures to compare outcomes more easily.

This study is limited by the samples lack of ethnic diversity. The study did not collect any information about participants socio-economic status, which may mean we are missing information about the prevalence of tinnitus and insomnia in different fractions of society. A large proportion of the sample reported to have further education experience, which can improve cognitive flexibility and lead to better coping strategies. Future studies should set out an a-priori strategy to recruit a more diverse sample, and to set hypotheses around potential differences between groups, such as gender differences (Richter et al., 2021). This will allow conclusions to be more representative of society and could lead to new insights into risk and protective factors.

4.3 Conclusions and clinical implications

This study demonstrates that insomnia-related cognitive and behavioural processes are very similar in people with insomnia both with and without associated tinnitus, and that these are different from people with tinnitus who sleep well. The study replicates findings that people with both tinnitus and insomnia report greater anxiety, depression and tinnitus-related distress than tinnitus sufferers without insomnia (Asnis et al., 2018) but shows that such insomnia related cognitions and behaviours remain important even when such differences are accounted for. This suggests that difficulties with sleep reported by many tinnitus sufferers can be understood by recognising that they are engaging in key sleep-related thoughts and behaviours that are stopping them from sleeping, as reported by people with insomnia and explained by the Cognitive Behavioural model of insomnia (Harvey, 2002).

CBTi has been shown to work with insomnia co-occurring with other physical health problems, such as chronic pain (Jungquist et al., 2010; Tang et al., 2012) and evidence has indicated it is also effective in tinnitus-related insomnia (Marks et al., 2019; Marks et al., 2022). The findings from this study supports emerging evidence that people presenting with tinnitus-related insomnia could benefit from treatments already shown to work effectively on people with insomnia disorder, such as CBTi, targeting sleep-related cognitions and behaviours.

5 Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

6 Author Contributions

EM and GB designed the study. GB collected the data for the study, analysed the data and wrote the manuscript. EM contributed substantially to the reviewing and editing of the manuscript. EM supervised the study. Both authors contributed to the reviewing of the article and approved it for submission.

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9 Supplementary Material

Supplementary Material should be uploaded separately on submission, if there are Supplementary Figures, please include the caption in the same file as the figure. Supplementary Material templates can be found in the Frontiers Word Templates file.

Please see the Supplementary Material section of the Author guidelines for details on the different file types accepted.

10 Data Availability Statement

The fully anonymised data supporting the conclusions of this article will be made available to any qualified researcher on request.

11 Ethics Statement

The study received ethical approval from The University of Bath. Participants provided their informed consent and were provided with debrief information following participation. This included websites for further support.

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12 Tables

Table 1.1

Demographic characteristics of participants in study exploring cognitive-behavioural factors in tinnitus-related insomnia

Demographics	**Insomnia**	**Tinnitus-related insomnia**	**Tinnitus good sleepers**	**Controls**	**P-value**
Age (N=180) M (SD)	34.97[b] (15.29)	48.86[a] (11.39)	43.08[a] (16.27)	41.53[b] (14.19)	<.001
Gender (N=178)					
Male	13 (38.2)	21 (42.9)	17 (44.7)	14 (24.6)	0.14
Female	21 (61.8)	28 (57.1)	21 (55.3)	43 (75.4)	
Marital Status (N=176)					
Married/living with partner	13 (38.2)	25 (52.1)	24 (63.2)	40 (71.4)	0.013
Not married/unpartnered	21 (61.8)	23 (47.9)	14 (36.8)	16 (28.6)	
Ethnicity (N=176)					
White	25 (73.5)	47 (97.9)	35 (92.1)	52 (92.9)	0.002
Non-white	9 (26.5)	1 (2.1)	3 (7.9)	4 (7.1)	
Education (N=176)					
Tertiary/further	22 (64.7)	34 (70.8)	29 (76.3)	44 (78.6)	0.49
Less than tertiary/other	12 (35.3)	14 (29.2)	9 (23.7)	12 (21.4)	
Employment (N=176)					
Full-time	15 (44.1)	24 (50.0)	19 (50.0)	29 (51.8)	0.92
Not full-time	19 (55.9)	24 (50.0)	19 (50.0)	27 (48.2)	
Shift /night work (N=176)					

Yes	3 (8.8)	6 (12.5)	4 (10.5)	2 (3.6)	0.40
No	31 (91.2)	42 (87.5)	34 (89.5)	54 (96.4)	

P-values are derived from chi-squared tests for categorical variables and t-tests for continuous variables. Values in cells are expressed as n (%) unless otherwise specified. a, b values sharing super scripts do not differ (p>.05)

Table 1.2 *Summary of measures completed across groups in study exploring cognitive-behavioural factors in tinnitus-related insomnia*

	Insomnia group (N=34)	Tinnitus-related insomnia group (N=48)	Tinnitus good sleeper groups (N=37)	Controls (N=55)
ISI- Mean (SD), range	15.68 (3.54), 10-23	16.63 (4.05), 10-25	4.39 (2.71), 0-9	4.37 (2.65), 0-9
DBAS-16 - Mean (SD), range	5.77 (1.48), 1.81-8.06	5.85 (1.51), 2.81-9.63	3.51 (1.52), 0.63-6.50	3.21 (1.48), 0.38-6.69
SRBQ - Mean (SD), range	64.74 (17.87), 27-91	55.24 (17.56), 12-86	30.87 (13.80), 4-59	33.75 (19.44), 0-83
PSQI - Mean (SD), range	11 (2.98), 5-16	10.67 (2.75), 4-17	4.58 (2.14), 2-11	5.07 (2.43), 1-11
GAD-7 - Mean (SD), range	10.71(5.32), 0-21	9.50 (6.00), 0-21	5.62 (4.68), 0-17	4.79 (3.82), 0-19
PHQ-9 - Mean (SD), range	12.15 (5.92), 3-25	12.29 (6.79), 1-26	4.77 (4.77), 0-20	4.04 (4.14), 0-23
THI - Mean (SD), range	26.33 (13.59), 6-48	58.16 (22.95), 10-98	41.9 (21.62), 6-88	19.50 (16.55), 16-92
VAS - Mean (SD), range	41.17 (18.93), 11-66	70.51(19.82), 25-100	60.45 (19.60), 15-100	43.61 (19.16), 1-74

ISI Insomnia Severity Index; DBAS-16 Dysfunctional Beliefs and Attitudes about Sleep; SRBQ Sleep Related Behaviours Questionnaire; PSQI The Pittsburg Sleep Quality Index; GAD-7 The Generalised Anxiety Disorder Assessment; PHQ-9 The Patient Health Questionnaire; THI Tinnitus Handicap Inventory; VAS Tinnitus Visual Analogue Scale

Table 1.3

F-statistics, R-squared, and change in R-squared values derived from hierarchical linear regression models predicting sleep-related cognitions (DBAS-16) / behaviours (SRBQ) / sleep quality (PSIQ) from age, gender, anxiety, depression and group

Model	**Block**	**Variables**	**F**	**df**	**P**	**R^2**	**ΔR^2**
DBAS-16	1	Age, gender	0.28	2	0.76	0.00	--
(n=172)	2	Anxiety, Depression	64.3	2	<.001	0.44	0.44
	3	Group	10.5	3	<.001	0.53	0.09
SRBQ	1	Age, gender	0.78	2	0.17	0.02	---
(n=174)	2	Anxiety, Depression	71.6	2	<.001	0.47	0.45
	3	Group	9.56	3	<.001	0.55	0.08
PSQI	1	Age, gender	.08	2	0.93	0.00	-
(n=174)	2	Anxiety, Depression	5.72	2	<.001	0.47	0.47
	3	Group	10.43	3	<.001	0.66	0.19

df, degrees of freedom

DBAS-16 Dysfunctional Beliefs and Attitudes about Sleep; SRBQ Sleep Related Behaviours Questionnaire; PSQI The Pittsburg Sleep Quality Index

Table 1.4 *Effect estimates, adjusted 95% confidence intervals, and adjusted and unadjusted p-values*

Model	Comparison	Estimate	95% CI	P_{adj}	P_{unadj}
DBAS-16	Tinnitus Related Insomnia– Insomnia	-0.04	-0.88 - 0.80	1.00	0.90
	Tinnitus Related Insomnia – Tinnitus Good Sleepers	1.41	0.51 - 2.23	<.001	<.001
	Tinnitus Related Insomnia– Controls	1.45	0.60 -2.31	<.001	<.001
	Insomnia - Tinnitus Good Sleepers	1.46	0.53-2.38	<.001	<.001
	Insomnia – Controls	1.49	0.62-2.37	<.001	<.001
	Tinnitus Good Sleepers – Controls	0.04	-0.72-0.80	1.00	0.90
SRBQ	Tinnitus Related Insomnia– Insomnia	-9.20	-18.60 - 0.21	0.06	0.01
	Tinnitus Related Insomnia – Tinnitus Good Sleepers	11.18	1.13-21.23	0.02	<.001
	Tinnitus Related Insomnia– Controls	6.90	-2.61-16.42	0.33	0.08
	Insomnia - Tinnitus Good Sleepers	20.38	10.01-30.74	<.001	<.001
	Insomnia – Controls	16.10	6.31-25.89	<.001	<.001
	Tinnitus Good Sleepers – Controls	-4.28	-12.77- 4.22	1.00	0.18
PSQI	Tinnitus Related Insomnia– Insomnia	-1.03	-2.52- 0.45	0.40	0.07
	Tinnitus Related Insomnia – Tinnitus Good Sleepers	4.15	2.56- 5.73	<.001	<.001
	Tinnitus Related Insomnia– Controls	3.44	1.94- 4.94	<.001	<.001
	Insomnia - Tinnitus Good Sleepers	5.18	3.54-6.82	<.001	<.001
	Insomnia – Controls	4.47	2.93-6.02	<.001	<.001
	Tinnitus Good Sleepers - Controls	-0.71	-2.05-0.62	0.97	0.16

Note. Model is adjusted for age, gender, anxiety and depression. P_{adj} are adjusted using the Bonferonni method; P_{unadj} are not corrected for multiple comparisons.

DBAS-16 Dysfunctional Beliefs and Attitudes about Sleep; SRBQ Sleep Related Behaviours Questionnaire; PSQI The Pittsburg Sleep Quality Index