

Association Between Hospital-Diagnosed
Tinnitus and Suicide: A Nationwide Danish Longitudinal Study

Running title: Association Between Hospital-Diagnosed Tinnitus and Suicide

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Abstract

Objectives: Tinnitus is a source of significant distress among some people. Associations have been suggested between tinnitus and mental disorders, and with suicidal thoughts and attempts. However, whether this extends to suicide in the general population remains uncertain.

Methods: This is a retrospective cohort study including all individuals aged 15 years or older, using Danish nationwide, longitudinal, population-based register data from 1 January, 1990 through 31 December, 2021. The main outcome was death by suicide. Poisson regression models were used to estimate adjusted incidence rate ratios (IRR) with the 95% confidence intervals (CI).

Results: Among 7,438,007 individuals (49.8% males) observed over 144,050,344 person-years, 85,677 (57.7% males) were diagnosed with tinnitus. In all, 23,824 suicide deaths were identified, of which 225 had tinnitus. Suicide rates were 24.2 and 16.5 per 100,000 person-years for those with and without tinnitus, respectively, giving an adjusted IRR of 1.4 (95% CI 1.2-1.6). Suicide rates were adjusted for demographic characteristics, concomitant hearing loss, and co-existing mental disorders before tinnitus. Increased suicide rates were linked to a higher number of hospital contacts and to recent hospital contacts, suggesting dose-response and temporal associations.

Conclusions: The findings reveal an association between tinnitus and suicide, particularly among individuals with co-existing mental disorders. Dose-response and temporal associations were found between tinnitus and suicide. Concurrent hearing loss had no influence on the tinnitus-suicide association. Attention towards patients experiencing tinnitus related distress is warranted, especially those with pre-existing mental disorders.

Key words

cohort study, large population study, national registers, suicide, tinnitus

Highlights

- Associations between tinnitus and suicide have been found in selected populations
- This study investigates the association in a nationwide population over 31 years
- A higher suicide rate was reported among individuals diagnosed with tinnitus
- Dose-response and temporal associations were found between tinnitus and suicide
- High suicide rates were found among individuals with tinnitus and mental disorders

Introduction

Tinnitus may be defined as the perception of hearing sound without any external acoustic stimulation, often in the form of a ringing noise.[1] Tinnitus can sometimes be heard by an external observer (objective tinnitus), but most commonly it cannot be heard by others (subjective tinnitus).[2] According to the Central Gain model, a pathophysiological explanation for tinnitus is that certain areas of the central auditory system have become hyperactive in response to reduced neural activity from parts of the cochlea, which may be damaged with associated hearing loss.[2–4] The hypothesis of central hyperactivity also accounts for the frequent co-occurrence of hearing loss and hyperacusis (i.e. sensitivity to sounds) among individuals with tinnitus.[2] Given that there is no effective treatment for subjective tinnitus, symptom reduction is the highest achievable goal for the majority of cases.[5]

Based on a meta-analysis of studies published between 1972 and 2021, the global prevalences of any tinnitus and serious tinnitus have been estimated at 14.4% and 2.3% respectively.[6] In a representative survey study in 2021, 16.1% of Danes reported having tinnitus and the prevalence of tinnitus was found to have increased between 2010 and 2021.[7] Although validated questionnaires for assessing tinnitus severity, such as the Tinnitus Functional Index (TFI)[8] and the Tinnitus Handicap Inventory[9], exist, the definitions used for tinnitus lack consistency.[6] The aforementioned meta-analysis used six different definitions of tinnitus and five definitions for severe tinnitus.[6] Efforts have been made to grade tinnitus severity using the TFI,[10] paving a way to grade tinnitus more consistently in future studies.

Some individuals experience severe distress from having tinnitus but most do not pay much attention to it, suggesting the impact of tinnitus may be linked to psychological factors rather than physical ones.[11] Distress experienced in relation to tinnitus has been associated with mental disorders, such as depression, anxiety,[12,13] somatic symptom disorders,[14] and hearing

impairment.[15] Findings from qualitative studies suggest that tinnitus can be stressful because the disorder affects everyday life, leads to concentration difficulties and a perceived loss of control, and because of individuals being concerned about the cause.[16–18] The psychological impact of tinnitus, including phonophobia, hyperacusis, emotional distress and reduced quality of life, could potentially lead to or worsen mental disorders in susceptible individuals,[4] which, given the strong association between mental disorders and suicidal behavior,[19] might increase risk of suicide,[20] Currently, however, there is little evidence linking tinnitus to suicidal behavior. Pooling data from six studies, a 20% prevalence of suicidal ideation was reported for people with tinnitus,[20] which was higher than the 9% prevalence estimated for the general population.[21] Individuals in South Korea with self-reported tinnitus have been found to have elevated risk of suicidal ideation and suicide attempts when compared to individuals with no tinnitus.[22] However, US veterans with tinnitus were found to have a lower suicide rate when compared to controls with no tinnitus.[23] A population-based and comprehensive assessment of the association between tinnitus and suicide is lacking.[24]

The aims of this study were, first, to investigate whether people diagnosed with tinnitus have a higher suicide rate than people not diagnosed with tinnitus, and, second, to examine the role of co-existing disorders in relation to suicide risk. Based on the existing evidence, we hypothesized that there is an association between tinnitus and suicide.

Methods

Study design and data sources

A cohort design was used to examine longitudinal, nationwide and retrospectively collected register data on all persons living in Denmark between 1 January, 1990 and 31 December, 2021. Danish

residents have a unique identification number, which is assigned at birth or upon first entry into Denmark.[25] This identification number is recorded in the Civil Registration System and in other administrative registers, hence, allowing for individual-level linkage of data across registers.[26] For our purpose, data from the Civil Registration System was linked to information on all hospital contacts from the National Patient Register[27] and the Psychiatric Central Research Register.[28] Hospital diagnoses were recorded according to the International Classification of Diseases (ICD), Eighth Revision (ICD-8)[29] until December 31, 1993, when it was replaced by the Tenth Revision (ICD-10),[30] as the Ninth Revision was never introduced in Denmark. Information on causes of death was retrieved from the Cause of Death Register[31] and data on sociodemographic variables were derived from other registers at Statistics Denmark.

Study population

All individuals aged 15 years or older who were recorded as residing in Denmark at some point between 1 January, 1990 through 31 December, 2021 were included.

Exposure

Individuals were considered as exposed if they had been diagnosed with tinnitus during a hospital contact. Information on inpatient contacts recorded from 1977 and visits to emergency departments and outpatient clinics from 1995 were screened for the diagnosis code of tinnitus (ICD-8: 78131; ICD-10: DH931). Individuals were considered exposed from the date of first diagnosis. Those diagnosed before 1990 were considered as exposed upon study entry. We included information on date of first and last diagnosis as well as number of hospital contacts for which tinnitus was recorded.

Other measures

Co-existing disorders were examined. In addition, the following ICD-codes were applied to identify

individuals recorded in the National Patient Register with a diagnosis of hearing loss (ICD-8: 38800, 38801, 38809, 38699, 38909, 38919, 38999; ICD-10: DH90, DH900, DH901, DH902, DH903, DH904, DH905, DH905A, DH905B, DH905C, DH905D, DH906, DH907, DH908, DH91, DH910, DH911, DH912, DH912A, DH918, DH919, DH938A, DH948A, DH80, DH800, DH801, DH802, DH808, DH809). The following ICD-codes were used to identify individuals recorded in the National Patient Register with a diagnosis of hyperacusis (ICD-10: DH932B). Information regarding dementia (ICD-8: 290.09-290.11, 290.18-290.19, 293.09-293.19; ICD-10: F00.0-00.9, F01.0-01.9, F02.0, F02.1-02.8, F03.9, G30.0-30.9, G31.0A, G31.0B, G31.8E, G31.8-31.9) was obtained from the National Patient Register and the Psychiatric Central Research Register. The latter register was also used to identify any mental disorder (ICD-8: 290-315; ICD-10: F00-F99), mood disorders (ICD-8: 296.x9 excluding 296.89, 298.09, 298.19, 300.49, 301.19; ICD-10: F30-F39), alcohol use disorder (ICD-8: 291, 303; ICD-10: F10), anxiety disorders (ICD-8: 300.x9 excluding 300.49, 305.x9, 305.68, 307.99; ICD-10: F40-F48), post-traumatic stress disorder (ICD-8: 309.81; ICD-10: DF43.1), autism (ICD-8: 299.0, 299.03; ICD-10: DF84.0, DF84.1, DF84.5), attention deficit hyperactivity disorder (ICD-8: 308.01; ICD-10: DF90, DF98.8), and personality disorders (ICD-8: 300. .19; 301.49; 301.59; 301.69; 301.79; 301.84; ICD-10: DF60). Given that some individuals with mental disorders, especially, depression, may only been seen in primary care, [32] information on redeemed antidepressant prescriptions was obtained from the National Prescription Registry using its Anatomical Therapeutic Chemical code (N06A).[33]

Outcome

The outcome was death by suicide, identified through ICD-codes (ICD-8: E950-E959; ICD-10: X60-X84, Y87.0) and derived from the Cause of Death Register.

Follow-up

The study population was followed between 1 January, 1990 and 31 December, 2021. In Denmark,

the first hospital-record of tinnitus was in 1984 and only few cases were recorded before 1990. Therefore, we opted to initiate the follow-up period from 1990. Individuals who turned 15 years or immigrated to Denmark were included on the dates of these respective events. The follow-up ended when individuals died (from any cause), emigrated, or on 31st December, 2021, whichever occurred first.

Statistical analysis

We calculated incidence rates (IR) of suicide among people with and without tinnitus per 100,000 person-years. Sex-and age standardized rates, overall and by calendar year, were calculated using indirect standardization and the entire population as a reference. The incidence rate ratios (IRR's) and their 95% confidence intervals (95% CI) were estimated using Poisson regression models to compare the suicide rate of those with tinnitus relative to the rate of those without tinnitus. The association was further examined according to: *number of hospital contacts for tinnitus* (no tinnitus; 1; 2; ≥ 3) and *time since first/last tinnitus diagnosis* (no tinnitus; ≤ 1 year; ≤ 3 years; ≤ 5 years; ≤ 7 years; > 7 years). Associations in combination with other disorders, i.e., *hearing loss, hyperacusis, dementia, any mental disorder regardless of their timing in relation to tinnitus, mood disorders, alcohol use disorder, and anxiety disorders*, were examined (no tinnitus, no other disorder; tinnitus, no other disorder; both disorders). The *temporal relationship* between onset of tinnitus and any mental disorder was also analyzed (none; tinnitus and no mental disorder; no tinnitus and mental disorder; tinnitus and mental disorder; mental disorders diagnosed before tinnitus; and mental disorders diagnosed at same time or later than tinnitus). We also examined the association in related to *prescribed antidepressant medication* (no tinnitus, no antidepressants; tinnitus, no antidepressants; tinnitus and antidepressants). The analyses were adjusted for: *calendar period* (1990-1999, 2000-2009, 2010-2021); *sex* (male, female); *age group* (15-49, 50-59, 60-69, 70-79, ≥ 80 years); *marital status* (never married, married/cohabiting, divorced/widowed); *socioeconomic*

status (working, unemployed, disability pension, retired, other); *physical comorbidity* (based on previous findings linking chronic physical disorders to suicide[34] we included Charlson Comorbidity Index score of ≤ 1 ;[35] no, yes); and *history of mental disorder prior to tinnitus* (no, yes). All covariates (except sex) were included as time-varying and updated on the exact date of change or on a yearly basis. In preliminary analyses, evidence-supported covariates for potential confounders were added one at a time and only covariates with a significant impact were included. Missing data was examined as a separate category in preliminary analysis and merged with other categories if findings supported this. A p-value of < 0.05 was considered statistically significant.

We obtained an anonymized version of the dataset from Statistics Denmark and used SAS software (SAS Institute Inc; version 9.4)[36] for the analyses.

Ethical approval

The study was approved by the Danish Data Protection Agency (Capital Region of Copenhagen, approval no. P-2020-305). According to Danish legislation, individual informed consent is not required for register-based studies.

Results

A total of 7,438,007 individuals (49.8% males; median age, 45; interquartile range (IQR), 30-61 years) were observed over 144,050,344 person-years. In all, 85,677 individuals (57.7% males; median age; 56, IQR, 46-66 years) were diagnosed with tinnitus (Table 1). Individuals with tinnitus were observed over 33,500 person-years during 1990-1999, which increased to 639,016 person-years during 2010-2021 (Figure A1).

During the 32 years of follow-up, 23,824 individuals (70.4% males; median age, 53 years; IQR, 40-68 years) died by suicide, of which 225 (0.9% of all suicides; 77.3% males; median age, 63 years; IQR, 55-74 years) had been diagnosed with tinnitus. During 1990-1999, 18 individuals with tinnitus died by suicide, while 136 died by suicide during 2010-2021. The crude suicide rate among individuals with tinnitus was 24.2 per 100,000 person-years, while those with no tinnitus had a crude rate of 16.5. Although crude suicide rate ratios between males and females were not significantly different (IRR of males, 1.4; 95% CI 1.2-1.7 versus IRR of females, 1.3; 95% CI 1.0-1.7), the crude suicide rates were higher among males compared to females (males with and without tinnitus IR, 32.4 and 23.6, respectively versus females with and without tinnitus IR, 12.9 and 9.6, respectively) (Table A1).

When accounting for differences with respect to calendar period, sex, age groups, marital status, socioeconomic status, physical comorbidities, and history of mental disorder in adjusted analyses, the IRR was 1.4 (95% CI, 1.2-1.6) (Table 2). Suicide rates were significantly higher among individuals with physical comorbidities. However, the difference was less pronounced among individuals with no tinnitus compared to those with tinnitus (IR 31.2 for tinnitus and comorbidities versus 19.3 for tinnitus only, compared to IR 29.0 for comorbidities only versus IR 13.7 for no tinnitus and no comorbidities). When performing adjusting analyses, the difference in IRR of suicide was not significantly different between these groups. However, there was a significantly higher IRR in suicide among individuals with comorbidities and concurrent tinnitus compared to individuals with comorbidities only (IRR, 1.8; 95% CI 1.5-2.2 for tinnitus and comorbidities versus IRR, 1.4; 95% CI 1.3-1.4 for comorbidities only). Of individuals diagnosed with tinnitus at a hospital, the majority also had a diagnosis of hearing loss (66,812; 78%). Suicide rates did not differ between individuals with tinnitus only and those with both tinnitus and hearing loss (tinnitus only: IRR, 1.5; 95% CI, 1.2-1.9 versus tinnitus and hearing loss: IRR, 1.4; 95% CI, 1.2-1.6). However,

these suicide rates were higher than among individuals with hearing loss only (IRR, 1.0; 95% CI, 0.9-1.0). Among individuals with tinnitus, 1414 (1.7%) also had a hyperacusis diagnosis. The suicide rate did not differ between individuals with tinnitus only and those with both tinnitus and hyperacusis when compared to those with neither of these disorders (tinnitus only: IRR, 3.0; 95% CI, 1.1-8.1 versus tinnitus and hyperacusis: IRR, 1.4; 95% CI, 1.2-1.6). Similarly, no difference was found in relation to tinnitus and dementia (tinnitus only: IRR, 1.3; 95% CI, 1.1-1.5 versus tinnitus and dementia: IRR, 1.5; 95% CI, 0.5-4.6) (Table 2).

When compared to individuals with one hospital contact for tinnitus, those with three or more hospital contacts during the study period had a higher suicide rate (one contact: IRR, 1.3; 95% CI, 1.1-1.5 versus ≥ 3 contacts: IRR, 2.3; 95% CI, 1.6-3.3), thus, suggesting a dose-response association (Figure 1 and Table A2). Individuals who frequently visited the hospital for treatment, i.e., a potential proxy for severe cases of tinnitus, had a higher suicide rate compared with those with fewer hospital visits. Elevated rates of suicide were found for individuals within the first year of being diagnosed with tinnitus (IRR, 1.7; 95% CI, 1.2-2.5) as well as for those diagnosed more than seven years previously (IRR, 1.3; 95% CI, 1.1-1.6), when compared to those with no tinnitus. A higher suicide rate was also found for individuals who had been seen at hospital for tinnitus within the last year (IRR, 1.9; 95% CI, 1.4-2.6). When compared to those whose latest tinnitus-related hospital contact was more than seven years previously, there was a higher suicide rate among those with a contact within the last year (IRR, 1.6; CI 95%, 1.1-2.3; p-value 0.02). These findings suggest a temporal association between diagnosis of tinnitus and suicide in that the highest rate of suicide was found around the time of the first or recent contact for tinnitus versus later contacts or longer time since the hospital contact.

When compared to individuals with no disorders, those diagnosed with tinnitus and any mental disorder regardless of their timing in relation to tinnitus had an IRR for suicide of 10.1 (95% CI,

8.5-12.0), while those with tinnitus only had an IRR of 1.2 (95% CI, 1.0-1.5), and those with only mental disorders regardless of their timing in relation to tinnitus an IRR of 9.0 (95% CI, 8.8-9.3) (Table 3). In similar structured, but separate models, higher suicide rates were found among individuals with both tinnitus and mood disorders (IRR, 9.1; 95% CI, 7.3-11.4); alcohol use disorders (IRR, of 7.7; 95% CI, 5.7-10.4); and anxiety disorders (IRR, 4.0; 95% CI, 2.6-6.3) when compared to individuals without each of these disorders. As relatively few individuals had been with tinnitus and PTSD (n=7406 person-years), autism (n=1036 person-years), ADHD (n=2852 person-years), and personality disorders (n=1046 person-years), the suicide rates of individuals with tinnitus and these disorders could not be examined. Individuals with a mental disorder which was diagnosed prior to tinnitus had an IRR of suicide of 8.6 (95% CI, 6.9-10.8), while those diagnosed with a mental disorder at the same time or later than tinnitus had an IRR 13.3 (95% CI, 10.2-17.4) when compared to individuals with neither disorder. Individuals with tinnitus who were prescribed antidepressants had a higher rate of suicide (IRR, 5.5; 95% CI, 4.7-6.4) than those not prescribed antidepressants (IRR, 1.1; 95% CI, 0.8-1.4). However, this rate was comparable to those with no tinnitus who had been prescribed antidepressants (IRR, 5.8; 95% CI, 5.6-5.9).

Discussion

Using nationwide and longitudinal data, we found a significantly higher suicide rate among individuals diagnosed at hospital with tinnitus than those without such a diagnosis. Our findings indicate that patients with tinnitus who frequently visit hospitals face the highest risk of suicide. Moreover, the risk of suicide is highest for all tinnitus patients around the time of their hospital consultations and shortly after. Physical comorbidities were associated with a higher suicide rate, but tinnitus itself was also identified as an independent risk factor for suicide among these

individuals. Elevated rates of suicide were also found among individuals with mental disorders, in particular mood disorders and alcohol use disorders, regardless of their timing in relation to tinnitus.

The large cohort size and extended follow-up period in this study provide substantial support to the reliability and internal validity of these findings. By including individuals who were diagnosed with tinnitus by a specialist during a hospital contact, the diagnoses were likely to be based on careful assessment.

A tinnitus diagnosis was often accompanied by a hearing loss diagnosis, although the latter was not found to be an independent risk factor for suicide. Surprisingly, a hyperacusis diagnosis, despite its known negative impact on quality of life, did not affect suicide rates.[37] Given that hyperacusis often coincides with tinnitus,[38] the prevalence of hyperacusis among patients with tinnitus observed in our study was lower compared to the 9-15% frequency reported in other studies.[39] This discrepancy could potentially be due to underreporting of hyperacusis. Similarly, the rate of hospital-based tinnitus diagnoses was also lower compared to previous self-reported estimates,[7,22] but the incidence of tinnitus increased during the study period. No sex difference was found in suicide rate ratios but hospital presentations for tinnitus were more frequent among males than females. The higher prevalence of contacts due to tinnitus may be attributed males being more exposed to occupational noise [40] and more frequent use of headphones.[41] Given that medical documentation may be a requirement for compensation claims, this could also explain the sex difference.

Analogous to previous findings, a decline in the overall suicide rates was observed over the studied period in Denmark.[42,43] Suicide is related to multiple factors, with mental disorders as one of the strongest predictors. [19] Our findings align with this as the highest rates of suicide were found for those individuals who also had a diagnosis of mental disorder regardless of its timing in relation to tinnitus. Nevertheless, individuals diagnosed with tinnitus but seemingly not having a mental disorder were found to have an approximately 20% higher suicide rate when compared to those without tinnitus. When adjusting for mental disorders diagnosed prior to tinnitus, we found a significant association with suicide, which was further strengthened by the presence of dose response and temporal associations.

Tinnitus has been linked to lower quality of life,[16–18] increased psychological distress, and mental disorders.[4,11] A higher level of suicidal ideation has also been reported among individuals with tinnitus,[20,22,24] suicidal thoughts also being a risk factor for suicide.[19] Further, neuroplastic changes in areas of the brain related to stress, anxiety, and attention have been observed among tinnitus patients, suggesting potential pathophysiological mechanisms underlying symptoms which may accompany tinnitus.[4]

Our observations of a higher suicide rate among tinnitus patients, a dose-response relationship, and a temporal relationship between tinnitus and suicide in the general population contribute to this diverse body of evidence supporting a potential causal relationship between tinnitus and suicide. Future studies thoroughly examining the psychological, neurobiological, and social aspects of tinnitus patients could help substantiate the nature of this causation. Ideally, these studies should include patient cohorts from various settings, not just hospitals. Additionally, research that

investigates individual differences among tinnitus patients in terms of factors contributing to distress could facilitate development of targeted interventions.

Clinical Implications

Our findings suggest that physicians and other healthcare professionals involved in diagnosis and treatment of mental disorders or tinnitus should be aware of patients' level of psychological distress experienced in relation to tinnitus, especially in those with pre-existing mental disorders and those who visit hospitals repeatedly due to tinnitus. For individuals seeking hospital care for tinnitus, they may be at their highest risk of suicide at the time of their consultation or shortly thereafter. Hence, it is crucial to provide them with appropriate support during this critical period. A clinical assessment could help with determining the impact that a patient's tinnitus is having on their general quality of life. We suggest using the TFI[8] and the grading hereof [10] due to its ability to detect differences in tinnitus severity following treatment.[44] According to international guidelines, therapeutic such as approaches amplification devices (i.e., hearing aids), supportive counselling and cognitive behavioral therapy are recommended to alleviate levels of psychological distress related to tinnitus.[45] These interventions can be accessed through relevant professionals, some whom also offer online therapy. Additionally, various sound masking devices and sound therapy options, particularly for improving sleep, are widely available and can also help in reducing distress from tinnitus.[45] These measures could potentially reduce the risk of an adverse outcome like suicide.

Strengths and Limitations

Strengths of this study include longitudinal and register-based data, a large cohort followed over more than three decades, complete coverage of the entire Danish population, and no loss to follow-

up. Furthermore, uniformly and prospectively collected individual-level data minimized any selection bias. By adjusting for relevant, potential confounders, our IRR estimates gained precision. The National Patient Registry has been evaluated as valid, which increases the reliability of our findings.[46]

There are some potential limitations. First, tinnitus cases and individuals with hearing loss might have gone undetected, such as those with outpatient contacts before 1995, those only treated at hearing centers or primary care, and those who did not seek medical advice. Second, although a measure on severity of tinnitus, such as the TFI, would have been preferred, only information about tinnitus diagnoses was available for this study. Third, not all individuals with mental disorders might have been identified despite including data from both primary and secondary health care. Fourth, although the suicide registration in Denmark has been evaluated as good,[47] we cannot exclude the possibility that some deaths were missed. Fifth, we would have preferred to include information related to work environment, perceived severity and psychological distress, but this was not available.

Conclusions

In this nationwide cohort study, we found a significant association between hospital-diagnosed tinnitus and suicide, further supported by dose-response and temporal associations. Among individuals with tinnitus, those with mental comorbidities, especially mood disorders and alcohol use disorders, were found to have the highest risk of suicide. Concomitant hearing loss had seemingly no influence on the association between tinnitus and suicide. While tinnitus may be a causal factor for suicide, further research is needed to substantiate this. Future studies could adopt a comprehensive approach, considering multiple aspects of tinnitus, and use a scale to assess tinnitus severity.

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None.

Author contributions

All authors had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: MM, SU, TO, AE.

Acquisition, analysis, or interpretation of data: MM, SU, TO, KH, AE.

Drafting of the manuscript: MM.

Critical revision of the manuscript for important intellectual content: SU, KH, TO, and AE.

Statistical analysis: MM, AE.

Administrative, technical, or material support: TO and AE.

Supervision: AE.

Proof reading: KH.

All authors revised the manuscript, contributed to the interpretation of the results, and approved the final version of the study.

Institutional Review Board approval

The study was approved by the Danish Data Protection Agency (Capital Region of Copenhagen, approval no. P-2020-305). According to Danish legislation, individual informed consent is not required for register-based studies.

Data sharing statement

Data are not available due to Danish data protection regulations as the dataset contains information that could compromise the privacy of research participants.

Financial disclosures/conflicts of interest

All authors have completed the Unified Competing Interest form

https://www.icmje.org/coi_disclosure.pdf and declare that Keith Hawton is a member of the

National Suicide Prevention Strategy for England Advisory Group. All other authors declare no conflicts of interest and no financial relationships with commercial interests.

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Table 1 Crude Incidence Rates of Suicide Among Individuals With and Without Hospital-diagnosed Tinnitus.

	People with tinnitus			People with no tinnitus		
	No. (%)	Person-years (%)	IR	No. (%)	Person-years (%)	IR
Total	225 (100.0)	929,518 (100.0)	24.2	23,599 (100.0)	143,120,827 (100.0)	16.5
Calendar period						
1990-1999	18 (8)	33,500 (3.6)	53.7	9856 (41.8)	43,055,400 (30.1)	22.9
2000-2009	71 (31.6)	257,002 (27.7)	27.6	6760 (28.6)	43,871,271 (30.7)	15.4
2010-2021	136 (60.4)	639,016 (68.7)	21.3	6983 (29.6)	56,194,156 (39.2)	12.4
Sex						
Male	175 (77.8)	540,900 (58.2)	32.4	16,607 (70.4)	70,339,571 (49.1)	23.6
Female	50 (22.2)	388,619 (41.2)	12.9	6992 (29.6)	72,781,255 (50.9)	9.6
Age group						
15-39	30 (13.3)	201,560 (21.7)	14.9	10,194 (43.2)	82,185,062 (57.4)	12.4
40-54	50 (22.2)	200,961 (21.6)	24.9	4582 (19.4)	22,655,354 (15.8)	20.2
55-64	66 (29.3)	247,257 (26.6)	26.7	3471 (14.7)	18,303,842 (12.8)	19.0
65-79	47 (20.9)	191,049 (20.5)	24.6	3063 (13.0)	12,893,971 (9.0)	23.8
80+	32 (14.2)	88,961 (9.6)	36.1	2289 (9.7)	7,082,598 (4.9)	32.3
Marital status						
Never married	30 (13.3)	93,704 (10.1)	32.0	6054 (25.6)	25,951,984 (18.1)	23.3
Married/cohabiting	123 (54.7)	646,782 (69.6)	19.0	11,011 (46.6)	97,953,190 (68.4)	11.2
Divorced/widowed	72 (32)	189,014 (20.3)	38.1	6556 (27.8)	19,215,652 (13.4)	34.1
Socioeconomic status						
Working	31 (13.8)	351,750 (37.8)	8.4	4776 (20.2)	77,323,391 (54.0)	6.2
Unemployed	12 (5.3)	53,827 (5.8)	22.8	1981 (8.4)	9,300,477 (6.5)	21.3
Disability pension	44 (19.6)	88,660 (9.5)	50.1	3928 (16.6)	7,381,828 (5.2)	53.2
Retired	111 (49.3)	407,608 (43.9)	27.2	7379 (31.3)	29,441,456 (20.6)	25.1
Other ^a	26 (11.6)	27,673 (3.0)	94.0	5535 (23.5)	19,673,704 (13.7)	28.1
Physical comorbidity						
No	110 (48.9)	569,458 (61.3)	19.3	16,051 (68.0)	117,085,570 (81.8)	13.7
Yes	115 (51.1)	360,060 (38.7)	31.2	7,548 (32.0)	26,035,256 (18.2)	29.0
History of mental disorder prior to tinnitus						
No	146 (64.9)	839,977 (90.4)	17.4	12,683 (53.7)	131,566,095 (91.9)	9.6
Yes	79 (35.1)	89,542 (9.6)	88.2	10,916 (46.3)	11,554,731 (8.1)	94.5

Abbreviations: IR: incidence rate per 100,000 person-years.

^a The category of 'other' included individuals in education, other types of socioeconomic status, and missing information. Data on socioeconomic status was not available for the years 1990-1991, which was coded as missing.

Table 2 Suicide Rates by Tinnitus, Hearing Loss, Hyperacusis, and Dementia.

	No. suicides/ No. individuals	Person-years	IR	Unadjusted IRR (95% CI)	Basic adjusted IRR ^a (95% CI)	Fully adjusted IRR ^a (95% CI)
No tinnitus	23,599/7,352,330	143,120,826	16.5	1.0 (ref)	1.0 (ref)	1.0 (ref)
Tinnitus	225/85,677	929,518	24.0	1.5 (1.3-1.7)	1.3 (1.2-1.5)	1.4 (1.2-1.6)
Hearing loss						
None	22,413/6,817,713	137,925,452	16.3	1.0 (ref)	1.0 (ref)	1.0 (ref)
Tinnitus, no hearing loss	60/18,865	244,739	24.5	1.5 (1.2-1.9)	1.4 (1.1-1.9)	1.5 (1.2-1.9)
No tinnitus, hearing loss	1186/534,617	5,195,374	22.8	1.4 (1.3-1.5)	1.1 (1.0-1.1)	1.0 (0.9-1.0)
Tinnitus and hearing loss	165/66,812	684,779	24.1	1.5 (1.3-1.7)	1.3 (1.1-1.5)	1.4 (1.2-1.6)
Hyperacusis						
None	23,599/7,351,696	143,117,941	16.5	1.0 (ref)	1.0 (ref)	1.0 (ref)
Tinnitus, no hyperacusis	221/84,263	921,768	24.0	1.5 (1.3-1.7)	1.3 (1.2-1.5)	1.4 (1.2-1.6)
No tinnitus, hyperacusis	0/634	2885	-	-	-	-
Tinnitus and hyperacusis	4/1414	7750	51.6	3.1 (1.2-8.3)	4.2 (1.6-11.2)	3.0 (1.1-8.1)
Tinnitus and dementia						
None	23,326/7,244,711	142,634,046	16.4	1.0 (ref)	1.0 (ref)	1.0 (ref)
Tinnitus, no dementia	<225/84,099	922,436	24.0	1.5 (1.3-1.7)	1.3 (1.2-1.5)	1.3 (1.1-1.5)
No tinnitus, dementia	273/107,619	486,780	56.1	3.4 (3.0-3.9)	2.4 (2.1-2.7)	1.7 (1.5-1.9)
Tinnitus and dementia	<5/1578	7083	42.4	2.6 (0.8-8.0)	1.9 (0.6-5.8)	1.5 (0.5-4.6)

Abbreviations: IR: incidence rate per 100,000 person-years; IRR incidence rate ratio.

^a Basic adjusted IRR was adjusted for calendar period, sex, and age group. Fully adjusted IRR was adjusted, in addition to those mentioned for the basic model, for marital status, socioeconomic status, physical comorbidity, and history of mental disorder prior to tinnitus. The model examining tinnitus and dementia was not adjusted for history of mental disorders prior to tinnitus.

Table 3 Suicide rates by tinnitus, mental disorders and prescribed antidepressant medication.

	No. suicides/ No. individuals	Person-years	IR	Unadjusted IRR (95% CI)	Basic adjusted IRR ^a (95% CI)	Fully adjusted IRR* (95% CI)
Tinnitus and any mental dis^b						
None	12,693/6,438,701	131,566,096	9.6	1.0 (ref)	1.0 (ref)	1.0 (ref)
Tinnitus, no mental dis	92/71,237	799,008	11.5	1.2 (<1.0-1.5)	1.2 (<1.0-1.5)	1.2 (1.0-1.5)
No tinnitus, mental dis	10,916/913,629	11,554,731	94.4	9.8 (9.5-10.1)	11.9 (11.6-12.2)	9.0 (8.8-9.3)
Tinnitus and mental dis	133/14,440	130,510	101.9	10.6 (9.0-12.5)	12.7 (10.7-15.1)	10.1 (8.5-12.0)
Tinnitus and mood dis						
None	17,915/7,013,458	139,023,078	12.9	1.0 (ref)	1.0 (ref)	1.0 (ref)
Tinnitus, no mood dis	145/79,475	873,709	16.6	1.3 (1.1-1.5)	1.3 (1.1-1.5)	1.3 (1.1-1.5)
No tinnitus, mood dis	5684/338,872	4,097,748	138.7	10.8 (10.4-11.1)	13.5 (13.1-13.9)	9.3 (9.0-9.6)
Tinnitus and mood dis	80/6202	55,809	143.3	11.1 (9.0-13.9)	13.1 (10.5-16.3)	9.1 (7.3-11.4)
Tinnitus and alcohol use dis						
None	20,215/7,222,456	141,266,718	14.3	1.0 (ref)	1.0 (ref)	1.0 (ref)
Tinnitus, no alcohol use dis	182/83,659	910,245	20.0	1.4 (1.2-1.6)	1.3 (1.1-1.5)	1.3 (1.1-1.5)
No tinnitus, alcohol use dis	3384/129,874	1,854,108	182.5	12.8 (12.3-13.2)	11.5 (11.0-11.9)	6.0 (5.8-6.3)
Tinnitus and alcohol use dis	43/2018	19,274	223.1	15.6 (11.6-21.0)	14.1 (10.5-19.1)	7.7 (5.7-10.4)
Tinnitus and anxiety dis						
None	22,407/7,220,784	141,481,144	15.8	1.0 (ref)	1.0 (ref)	1.0 (ref)
Tinnitus, no anxiety dis	206/83,204	906,489	22.7	1.4 (1.3-1.6)	1.3 (1.1-1.5)	1.3 (1.1-1.5)
No tinnitus, anxiety dis	1192/131,546	1,639,682	72.7	4.6 (4.3-4.9)	6.5 (6.1-6.9)	3.7 (3.5-4.0)
Tinnitus and anxiety dis	19/2473	23,030	82.5	5.2 (3.3-8.2)	6.5 (4.5-10.2)	4.0 (2.6-6.3)
Time of mental dis						
None	12,683/6,438,701	131,566,096	9.6	1.0 (ref)	1.0 (ref)	1.0 (ref)
Tinnitus, no mental dis	92/71,237	799,008	11.5	1.2 (<1.0-1.5)	1.2 (<1.0-1.5)	1.2 (1.0-1.5)
No tinnitus, mental dis	10,916/913,629	11,554,731	94.5	9.8 (9.6-10.1)	11.6 (11.6-12.2)	9.0 (8.8-9.3)
Mental dis before tinnitus	79/9444	90,036	87.8	9.1 (7.3-11.4)	11.1 (8.9-13.8)	8.6 (6.9-10.8)
Mental dis at same time or later than tinnitus	54/4996	40,474	133.4	13.8 (10.6-18.1)	16.1 (12.3-21.1)	13.3 (10.2-17.4)
Prescribed antidepressants						
None	13,911/5,627,819	123,340,268	11.3	1.0 (ref)	1.0 (ref)	1.0 (ref)
Tinnitus, no antidepressants	56/48,481	595,405	9.4	0.8 (0.6-1.1)	1.0 (0.8-1.3)	1.1 (0.8-1.4)
No tinnitus, antidepressants	9608/1,724,511	19,780,559	48.6	4.3 (4.2-4.4)	6.9 (6.7-7.1)	5.8 (5.6-5.9)
Tinnitus and antidepressants	169/37,196	334,113	50.6	4.5 (3.8-5.2)	6.6 (5.6-7.6)	5.5 (4.7-6.4)
Tinnitus and comorbidity						
None	16,051/4,647,130	117,085,570	13.7	1.0 (ref)	1.0 (ref)	1.0 (ref)
Tinnitus, no comorbidity	110/38,509	9569,458	19.3	1.4 (1.2-1.7)	1.4 (1.2-1.7)	1.5 (1.2-1.8)
No tinnitus, comorbidity	7548/2,704,566	26,035,255	29.0	2.1 (2.1-2.2)	1.9 (1.8-2.0)	1.4 (1.3-1.4)

Tinnitus and comorbidity	115/45,754	360,059	31.9	2.3 (1.9-2.8)	2.2 (1.8-2.6)	1.8 (1.5-2.2)
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Abbreviations: IR: incidence rate per 100,000 person-years; IRR: incidence rate ratio per 100,000 person-years; dis: disorder.

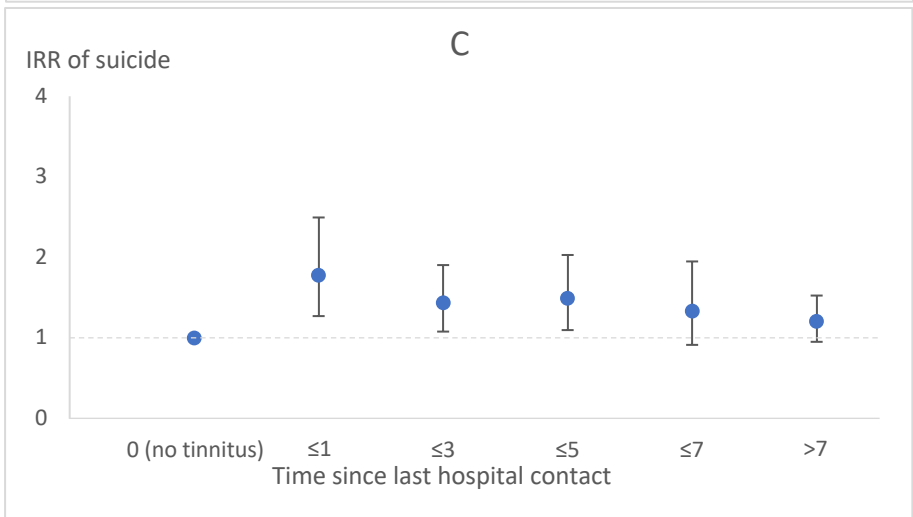
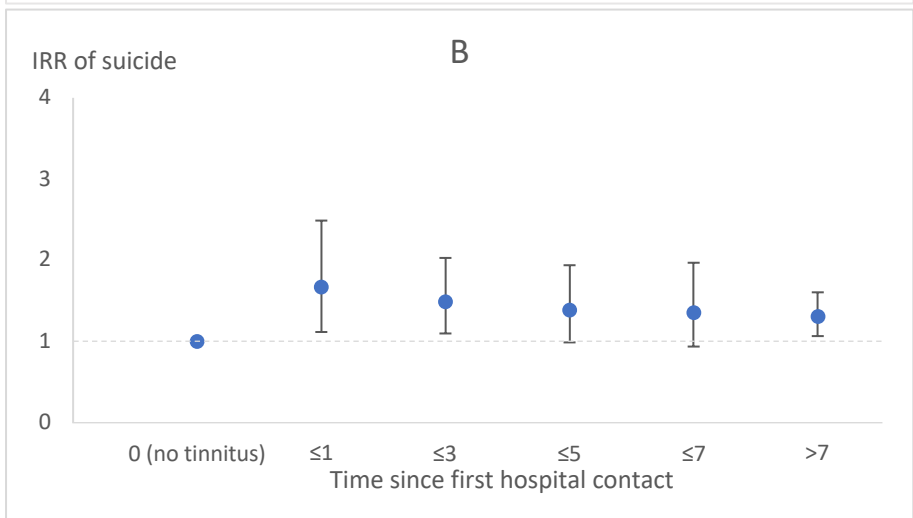
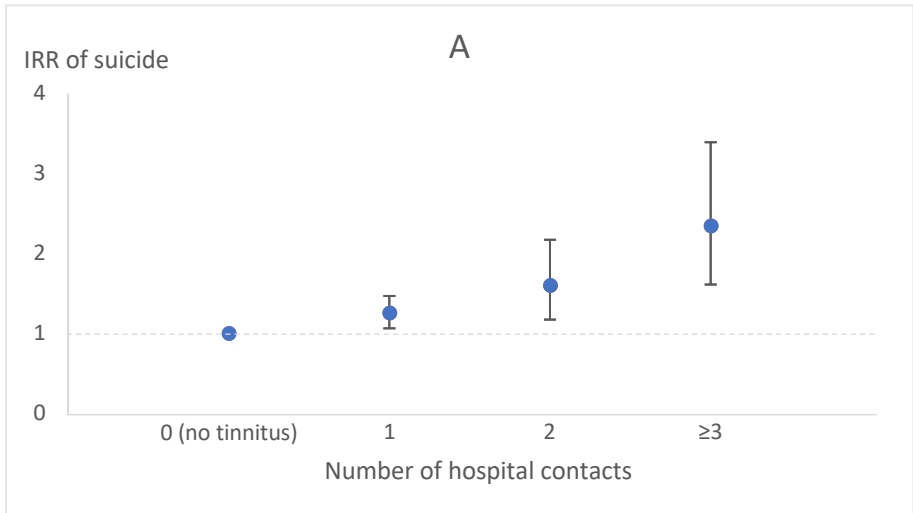
^a Basic adjusted IRR was adjusted for calendar period, sex, and age group. Fully adjusted IRR was adjusted, in addition to those mentioned for the basic model, for marital status, socioeconomic status, and physical comorbidity.

^b Mental disorders in this table include diagnoses regardless of the timing of diagnosis in relation to tinnitus.

Figure captions

Figure 1 parts A-C. Incidence rate ratio (IRR) of suicide by number of hospital contacts (A), time since first tinnitus diagnosis (B), and time since last tinnitus diagnosis (C).*

* IRRs were adjusted for calendar period, sex, and age group, marital status, socioeconomic status, and physical comorbidity, and history of mental disorder prior to tinnitus.



^a IRRs were adjusted for calendar period, sex, and age group, marital status, socioeconomic status, and physical comorbidity, and history of mental disorder prior to tinnitus.