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Incidence and relative risk of hearing disorders in professional musicians

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ABSTRACT

Background Hearing disorders have been associated with occupational exposure to music. Musicians may benefit from non-amplified and low-intensity music, but may also have high risks of music-induced hearing loss.

Aims To compare the incidence of hearing loss (HL) and its subentities in professional musicians with that in the general population.

Methods We performed a historical cohort study among insurants between 19 and 66 years who were employed subject to social insurance contributions. The study was conducted with data from three German statutory health insurance providers covering the years 2004–2008 with about 7 million insurants. Incidence rates with 95% CIs of HL and the subentities noise-induced hearing loss (NIHL), conductive HL, sensorineural HL, conductive and sensorineural HL, as well as tinnitus were estimated stratified by age, sex and federal state. A Cox regression analysis was conducted to estimate adjusted HRs and two-sided 95% CIs for HL and its subentities.

Results More than 3 million insurants were eligible, of whom 2227 were identified as professional musicians (0.07%). During the 4-year observation period, 283 697 cases of HL were seen, 238 of them among professional musicians (0.08%), leading to an unadjusted incidence rate ratio of 1.27. The adjusted hazard ratio of musicians was 1.45 (95% CI 1.28 to 1.65) for HL and 3.61 (95% CI 1.81 to 7.20) for NIHL.

Conclusions Professional musicians have a high risk of contracting hearing disorders. Use of already available prevention measures should reduce the incidence of HL in professional musicians.

INTRODUCTION

Background

Over the past 50 years, medical problems in professional musicians have been studied, with some emphasis on hearing.^{1–7} In particular, there have been several attempts to assess the risks of hearing loss (HL) in response to exposure to music, mainly in classical musicians^{8–12} and in rock/pop musicians.^{13–15} Noise-induced hearing loss (NIHL), plausibly interpreted as music-induced hearing loss when musicians are investigated, was seen in up to 58% of classical, and up to 49% of rock/pop, musicians.¹⁶ It should be noted that findings are based primarily on subclinical measures such as pure tone audiometry and in fewer cases, on reports on hearing problems such as hyperacusis, loss of hearing sensitivity and tinnitus (cf. Tables 1 and 2 in Zhao *et al* 2010¹⁶). Therefore, the clinical implications, particularly of

What this paper adds

- ▶ Professional musicians have an increased risk of hearing-related disorders, known to be associated with occupational exposure to high sound pressure levels.
- ▶ A large claims database was used to identify professional musicians and assess their risks of hearing-related disorders in comparison with the general population.
- ▶ A nearly fourfold higher adjusted HR for noise-induced hearing loss and a 57% higher adjusted HR for tinnitus was found for professional musicians in comparison with the general population.
- ▶ The new evidence underpins the need to implement strategies for hearing protection in professional musicians.

observed permanent or temporary shifts of hearing thresholds, have remained unclear.

NIHL seems to be provoked by both extrinsic and intrinsic factors.^{16, 17} For example, extrinsic factors include the number of years of exposure to high levels of sound and the position of the players in the orchestra on stage, in an orchestra pit, or near loud speakers,¹⁷ as well as the instruments being played.¹⁸ By contrast, more intrinsic factors related to individual differences in psychophysiological proneness to hearing disorders among musicians appear less well understood. Not surprisingly, previous studies on the size of the risk of hearing problems in professional musicians have been inconclusive.¹⁶ Moreover, the extent of damage and details of medical treatment are often not documented.¹⁷

Some studies have argued against a significant relationship between music exposure and hearing problems, with reservations based on methodological concerns. For example, Karlsson, Lundquist and Olaussen suggested that the sound exposure criteria for industrial noise are not valid when the relevant sound sources are acoustic instruments of a symphonic orchestra.¹⁹ Further problems arise from the fact that definitions of NIHL may vary from study to study, leaving open whether or not clinical implications can be drawn; also, some studies depend upon identifying a well-matched reference population.^{20, 21} These concerns notwithstanding, Zhao *et al*¹⁶ suggested that there could be



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Table 1 Characteristics of insurants eligible for the study cohort

| Variable | Musicians (N=2227) | Others (N=3 340 718) |
|-----------------------------|--------------------|----------------------|
| Sex | | |
| Male | 1257 (56.4) | 1 903 151 (57.0) |
| Female | 970 (43.6) | 1 437 567 (43.0) |
| Age at cohort entry (years) | | |
| Mean (SD) | 39.7 (11.56) | 39.7 (11.56) |
| Median (quartiles) | 40.0 (30.0; 48.0) | 40.0 (30.0; 48.0) |
| Population density | | |
| City | 1311 (58.9) | 1 276 648 (38.2) |
| Suburb | 658 (29.5) | 1 445 336 (43.3) |
| Rural surrounding area | 115 (5.2) | 352 331 (10.5) |
| Rural | 135 (6.1) | 250 684 (7.5) |
| Other/unknown | 8 (0.4) | 15 719 (0.5) |

Results are shown as number (%) unless stated otherwise. Percentages are based on N, the number of musicians and the number of non-musicians, respectively.

little doubt about music-induced hearing loss as a potential problem of professional musicianship.

In summary, assessments of professional musicians' risks of permanent damage of inner ear structures are compromised by a lack of comparable population data, and population-based studies are needed to assess musicians' proneness to hearing problems.

Here we present a large-scale epidemiological study to assess the risk of musicians contracting hearing-related disorders on the basis of insurance claims related to hospital admission and outpatient diagnoses. Specifically, we ask to what extent professional musicians have a higher incidence of hearing problems in comparison with the general population.

Objective

The objective of this study was to compare the incidence of HL and its subentities in professional musicians with that in the general population.

METHODS

Data source

The study was conducted with data from three German statutory health insurance providers (SHIs) covering the years

2004–2008 with about 7 million insurants. The database contains demographic information about each insurant as well as information on hospital admissions, outpatient visits to a doctor and outpatient prescriptions.²² Since outpatient visits to a doctor are reimbursed quarterly during the year, an algorithm was developed to allocate an exact date for outpatient diagnoses. All diagnoses, outpatient as well as inpatient, were coded according to the German modification of the International Classification of Diseases (ICD-10-GM). Analyses of the age and sex distribution, number of hospital admissions and drug use have shown the database to be representative for Germany.^{23 24} The use of health insurance data for scientific research is regulated by the Code of Social Law (SGB X). Informed consent was not required by law, since the study was based on pseudonymous data.

Study design

We performed a historical cohort study among insurants aged between 18 and 66 years who were employed subject to social insurance contributions and who were continuously insured for 12 months before cohort entry. Cohort entry was defined as the first date after 1 January 2005 on which the insurant had been continuously insured for more than 365 days, had his/her 19th to 66th birthday in the year of cohort entry and had had no diagnosis of hearing loss during the preceding 12 months. Cohort exit was defined as the first of the following dates: 31 December of the year in which the insurant had his/her 66th birthday, end of study period—that is, 31 December 2008, day of first diagnosis of HL and interruption or end of insurance, which was defined as the end date of the first insurance period after cohort entry. Re-entry after cohort exit was not possible.

Definition of professional musician

Registration with a given SHI is usually done through the employer who records key sociodemographic characteristics of the insurant, including his/her occupation. Freelance musicians are eligible to register themselves via a specific artists' social insurance agency (Künstlersozialkasse). Professional musicians were identified using the Standard Classification of Occupations, which is used by the Federal Employment Agency.²⁵ The corresponding code comprises rock/pop or classical instrumental musicians, singers, conductors and composers. A professional musician was defined as an insurant who had had

Table 2 Person-time, number of cases and incidence of hearing loss and its subentities

| Disease group | Occupational group | Person-time (in 100 000 person-years) | Cases (N) | Incidence (per 100 000 person-years) | IRR (95% CI) |
|--|--------------------|---------------------------------------|-----------|--------------------------------------|---------------------|
| Hearing loss | Musicians | 0.07 | 238 | 3621 | 1.27 (1.14 to 1.39) |
| | Others | 99.11 | 283 459 | 2860 | 1 (Ref.) |
| Noise-induced hearing loss | Musicians | 0.07 | 8 | 122 | 3.51 (2.82 to 4.21) |
| | Others | 99.11 | 3433 | 35 | 1 (Ref.) |
| Conductive hearing loss | Musicians | 0.07 | 12 | 183 | 1.12 (0.55;1.68) |
| | Others | 99.11 | 16 193 | 163 | 1 (Ref.) |
| Sensorineural hearing loss | Musicians | 0.07 | 42 | 639 | 0.91 (0.60 to 1.21) |
| | Others | 99.11 | 69 945 | 706 | 1 (Ref.) |
| Combined conductive and sensorineural hearing loss | Musicians | 0.07 | 2 | 30 | 0.51 (0.30 to 1.71) |
| | Others | 99.11 | 5944 | 60 | 1 (Ref.) |
| Tinnitus | Musicians | 0.07 | 148 | 2252 | 1.45 (1.29 to 1.61) |
| | Others | 99.11 | 153 737 | 1551 | 1 (Ref.) |

IRR, incidence rate ratio.

at least one insurance period in the study period from 1 January 2004 through 31 December 2008 coded as 'musician'.

Case definition

Cases were defined as cohort members with a diagnosis of HL—that is, an outpatient or hospital diagnosis with at least one of the following ICD-10-GM codes: H83.3 noise effects on inner ear, H90 conductive and sensorineural hearing loss or H93.1 tinnitus. Additionally, we defined four subentities of HL: NIHL if the ICD-10-GM code was H83.3, conductive HL if the codes H90.0 to H90.2 were used, sensorineural HL if the codes H90.3 to H90.5 were used, combined conductive and sensorineural HL if the code H90.6 was used and tinnitus if the code H93.1 was used.

Statistical analysis

We calculated incidence rates of HL, and incidence rates for the subentities NIHL, conductive HL, sensorineural HL, combined conductive and sensorineural HL and tinnitus stratified by age, sex and federal state. CIs for the incidence rates were estimated by the substitution method assuming a Poisson distribution for the number of events.²⁶

A Cox proportional hazards model was calculated to estimate adjusted HRs and two-sided 95% CIs for HL and its subentities, taking into account the differing observation periods between cohort members. The time scale for the Cox regression was the number of days each person was observed in cohort.

In the sensitivity analyses, adjustments were made for sex and age at cohort entry (continuous variables), for population density of place of residence (categorised as cities, concentrated surrounding areas, rural surrounding areas and rural areas), SHI and federal state.

All statistical analyses were done using SAS V.9.2 (SAS Institute Inc, Cary, North Carolina, USA) and the proportional hazards assumption was tested with the ASSESS option.

RESULTS

More than 3 million insured persons with employment subject to social insurance contributions were included in the cohort, of whom 2227 insured persons could be identified as professional musicians (0.07%). Table 1 summarises demographic and regional distribution information of professional musicians in comparison with all other professions. Age and sex distribution were

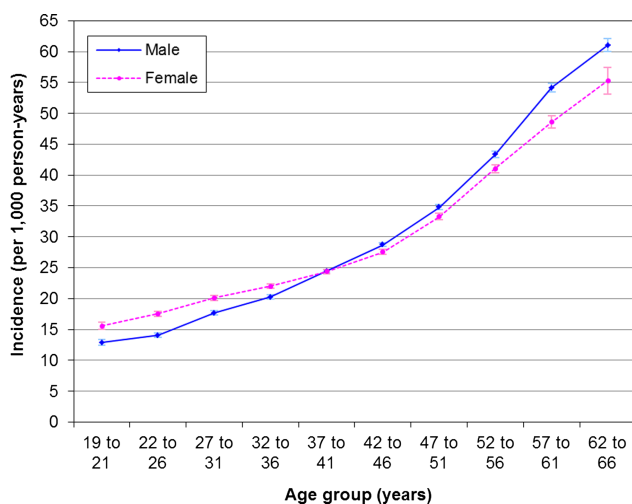


Figure 1 Incidence rate of hearing loss by sex and age.

similar; however, musicians were over-represented in Berlin (12.9% of the musician subcohort compared with 6.7% of the reference cohort). A higher percentage of musicians lived in cities (58.9% vs 38.2%) and only 11.2% lived in rural or rural surrounding areas compared with 18.1% of the reference cohort representing the general population.

During the study period, 283 697 cases of HL were newly diagnosed, 238 of them among professional musicians (0.08%), leading to an unadjusted incidence rate ratio of 1.27 (table 2). Musicians had a 3.51-fold higher incidence rate of NIHL and a 1.45 higher incidence rate of tinnitus than the general population. Unadjusted incidence rates for the other subentities were quite similar between musicians and the general population; all CIs overlapped. The seemingly protective effect for combined conductive and sensorineural HL was based on only two cases among musicians, leading to a broad, non-conclusive CI.

The incidence of HL was slightly higher for men (2990 vs 2678 per 100 000 person-years), but was not associated with population density. As expected, incidence rates increased with age. Up to the age of 36 years the incidence of HL was higher in women, but above that age it was higher for men (figure 1). The incidence of HL did not increase monotonically with age for any of its subentities (data not shown).

Adjusting for sex and age at cohort entry by performing a Cox regression analysis yielded a HR of 1.45 (95% CI 1.28 to 1.65) for HL in musicians (table 3). Men were at slightly higher risk of HL with a HR of 1.01 (95% CI 1.00 to 1.02). Inclusion of additional potential confounders (population density of place of residence, SHI and federal state) as well as an interaction term for age×sex into the statistical model did not change the HRs for HL in musicians.

Among professional musicians the HR was 3.61 (95% CI 1.81 to 7.20) for NIHL and 1.57 (95% CI 1.34 to 1.85) for tinnitus (table 3). The HR did not differ statistically significantly from unity for the other subentities of HL—that is, conductive and sensorineural HL and combined conductive and sensorineural HL.

DISCUSSION

It was hypothesised that professional musicians are exposed to a significant risk of contracting hearing disorders due to high levels of sound in their working environment. We found an almost fourfold higher adjusted HR for NIHL and a 57%

Table 3 HR estimates and corresponding 95% CIs for hearing loss, noise-induced hearing loss and tinnitus

| | HR | 95% Wald CI |
|----------------------------|-------|------------------|
| Hearing loss | | |
| Musician | 1.45 | (1.276 to 1.646) |
| Male sex | 1.01 | (1.002 to 1.017) |
| Age at cohort entry | 1.04 | (1.035 to 1.036) |
| Noise-induced hearing loss | | |
| Musician | 3.61 | (1.806 to 7.201) |
| Male sex | 2.10 | (1.947 to 2.273) |
| Age at cohort entry | 1.001 | (0.998 to 1.004) |
| Tinnitus | | |
| Musician | 1.57 | (1.337 to 1.845) |
| Male sex | 0.99 | (0.922 to 0.942) |
| Age at cohort entry | 1.02 | (1.021 to 1.022) |

higher adjusted HR for tinnitus for professional musicians in comparison with the general population. Case numbers were too small for conclusive results for the other subentities of HL—that is, conductive and sensorineural HL and combined conductive and sensorineural HL.

Zhao *et al*¹⁶ proposed that exposure to loud music might cause hearing symptoms, including temporary threshold shifts and tinnitus. The review by these authors, however, is primarily based on field studies using pure tone audiometry for the assessment of temporary and permanent hearing threshold shifts. Some reports have also described hearing problems such as hyperacusis or loss of hearing sensitivity, but interpretations were compromised owing to small population sizes and, in many cases, the absence of adequate reference groups.

To our knowledge this is the largest study comparing the risk of HL among professional musicians with that in the general population. The strengths of our study are the size of the database and its representativeness. There is no potential for selection bias due to selective non-response of potential study participants. All information was recorded prospectively so that recall bias was avoided.

Karlsson *et al*¹⁹ have pointed out that industrial noise may not be comparable with loud music. While chronic exposure to industrial noise has been clearly linked with hearing damage, including loss of hearing sensitivity, research on professional musicianship suggests *increases* of hearing sensitivity rather than *decreases*. For example, musicians have been shown to develop enhanced sensitivity to meaning in non-musical sound,²⁷ which might, to a certain extent, mask fundamental hearing deficits. Moreover, Zendel and Alain²⁸ found that musicians might receive benefit from their training such that age-related hearing loss is attenuated. However, these observations may not apply to specific subgroups. In light of our results, it might be that many musicians prone to HL do contract NIHL before age-related HL emerges. Our data suggest that in professional musicians the risks of music-induced HL outweigh by far the potential benefits for hearing ability as reported by Zendel and Alain.²⁸ Unfortunately, our data do not allow a distinction between different types of musicians (eg, those using acoustic vs electronic instruments).

Given the significant long-term risks to professional musicians of contracting hearing disorders, their management in educational settings seems appropriate.²⁹ This might entail, for example, increasing conductors' awareness of loud music while rehearsing and during concerts with large orchestras. Furthermore, musicians should be offered protection by in-ear devices and installation of sound-protecting shields between the sections of an orchestra. Some of these measures, such as in-ear sound protection, should also apply to professional musicians playing in rock bands, or when electric sound amplifiers are used. Some of these efforts may significantly reduce this risk for future generations. However, without internationally accepted policies to deal with the problem it is likely that musicians will continue to have a risk of contracting hearing disorders.

Strengths and limitations

Owing to the nature of secondary data, not all variables can be assessed in the desired detail. In particular, no information on the type of instrument, the kind of music, or the setting in which the musician worked is included in our claims database. The group of musicians defined by the occupational code is quite diverse, including instrumental musicians as well as singers, conductors and composers. Since certain subgroups of

musicians are more exposed to higher sound levels than others, we assume that this diversity will dilute the effects, leading to an underestimation of the risk.

There is also a potential for non-differential misclassification of the outcome. On the one hand, some diagnoses of HL might be incorrect; on the other, some cases of HL might not be diagnosed at all and therefore be missed in our study. It is unlikely that the observed large effects are fully explained by non-differential misclassification.

However, there is potential for detection bias. On the one hand, musicians might be reluctant to acknowledge hearing problems, because of fear of stigmatisation. For example, perfectionism (worry about the judgement of others) has been identified as one source of stress in professional orchestras.³⁰ On the other hand, it is possible, that fewer cases of HL are missed in professional musicians, who might be more sensitive to hearing problems than the general population. However, musicians do not show marked differences in health-related measures as compared with the general population.³¹ Williamson and Thompson³² suggested that although conservatoire students already experience health problems that are related to their musical performance and practice behaviours, they tend to seek medical advice from their teachers before turning to the general health system. Further studies suggest that there is a clear need for specialist interventions in health problems of professional musicians.³³ In health systems that are not well-prepared to deal with music-related disorders and health issues, it seems unlikely that professional musicians show strong inclinations to seek health advice for problems including those of hearing and auditory dysfunction.

NIHL may be caused by one-time acoustic trauma due to explosions, gunfire or firecrackers. NIHL may, however, also develop gradually by repeated exposure to loud noise. Risk factors for non-congenital sensorineural HL and conductive HL are age, chronic noise exposure, genetic factors and infections such as otitis media. Besides infections other diseases such as physical injury, Eustachian ear dysfunctions and otosclerosis may lead to conductive hearing loss. In addition, it is well known that some drugs (eg, aminoglycosides) are ototoxic and can lead to irreversible cochlear and vestibular dysfunction. However, none of these risk factors occurs sufficiently frequently to be a strong confounder. Therefore, in the main analysis we adjusted for age and sex only and additionally, in the sensitivity analyses, for federal state, population density of place of residence (to cover regional differences) and SHI (as a proxy for socio-economic status). Risk estimates remained virtually unchanged after these adjustments.

Given the number of professional musicians and the severity of the outcome, leading to occupational disability and severe loss of quality of life, hearing loss in professional musicians is of high public health importance.³⁴ Our data provide evidence of the need for prevention measures.

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Competing interests None.

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OCCUPATIONAL & ENVIRONMENTAL MEDICINE

Professional musicians run almost fourfold risk of noise induced deafness

And they are 57% more likely to have tinnitus than general public

[Incidence and relative risk of hearing disorders in professional musicians *Occup Environ Med*
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Professional musicians are almost four times as likely to develop noise induced hearing loss as the general public, reveals research published online in ***Occupational & Environmental Medicine***. And they are 57% more likely to develop tinnitus - incessant ringing in the ears - as a result of their job, the findings show.

Noise induced hearing loss can be caused by sudden very loud noise, such as an explosion or gunfire, but it may also develop gradually as a result of repeated exposure to loud noise, suggest the study authors. They base their findings on data from three statutory health insurance providers containing the details of seven million German citizens between 2004 and 2008. Among the three million people who were aged between 19 and 66, in employment, and making social insurance contributions to cover health and social care, some 2227 were professional musicians. During the four year study period, just under 284,000 cases of hearing loss were registered on the database, slightly more of them among men than women, overall.

In all, 238 (0.08%) cases were among professional musicians, who were more likely to live in cities. Hearing loss becomes more common with age, but after adjusting for this and other influential factors, such as sex and population density, professional musicians were still more likely to have noise induced hearing loss than the general public. They were almost four times as likely to have some level of deafness and 57% more likely to have tinnitus.

The authors point out that repeated long term exposure to industrial noise has been clearly linked to hearing damage, including an inability to hear the full range of sound. But published evidence suggests that long term exposure to music has the opposite effect and increases hearing sensitivity. "Our data suggest that in professional musicians the risks of music induced hearing loss outweigh the potential benefits for hearing ability, as reported by [other researchers]," write the authors. "Given the number of professional musicians and the severity of the outcome, leading to occupational disability and severe loss of quality of life, hearing loss in [this group] is of high public health importance," they add.

Professional musicians should be given protective in-ear devices, whether they are playing in rock bands or orchestras, and whenever sound amplifiers are used, in a bid to reduce the risk, they suggest. Sound shields should also be installed between different sections of an orchestra.