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Tinnitus, hyperacusis and their relation to hearing loss in professional symphony orchestra musicians

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Background: Musicians are exposed to loud sounds which can lead to hearing loss and hearing associated symptoms such as tinnitus and hyperacusis. Tinnitus and hyperacusis may be particular predominant in a population of musicians since musicians especially pay attention to audiologic symptoms. However, tinnitus and hyperacusis may or may not be associated with hearing loss. Purpose: To investigate the association between subjective hearing symptoms and objective hearing thresholds. Methods: Questionnaire data from 351 musicians from five symphony orchestras were used to estimate the frequency of subjective hearing loss, tinnitus and hyperacusis. Data from user operated Two Alternative Forced Choice Audiometry were available from 223 musicians and 199 of these included questionnaire data as well. Results: Subjective hearing loss was significantly ($p<0.001$) related to the hearing thresholds. Tinnitus was not related to the hearing thresholds in musicians. Subjects with hyperacusis were shown to have better hearing thresholds compared to musicians without hyperacusis. This was significant for the left ear after correction for age and gender ($p<0.02$). Conclusions: Auditory symptoms such as tinnitus and hyperacusis were not related to a reduced sensitivity in musicians. Hyperacusis was shown to be associated with a more sensitive hearing in musicians.

INTRODUCTION

Tinnitus can be described as an auditory phantom sensation where the experience is ringing in the ears when no external sound is present. Tinnitus is a common disorder in the population with an increasing prevalence with increasing age affecting

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approximately 12 % of all men aged 65-74 years. Tinnitus is more common in men than women (Lockwood *et al.* 2002).

Hyperacusis can be defined as an abnormal tolerance to environmental sounds or inappropriate response to sounds that are neither threatening nor uncomfortably loud to a normal person (Andersson *et al.* 2002; Baguley 2003). Subjects with hyperacusis as defined above usually have normal hearing and they avoid daily sounds such as forks and knives against a plate.

In a former study among 145 Danish symphony orchestra musicians 24% reported an experience of tinnitus lasting at least 5 minutes (Laitinen and Poulsen 2008). Musicians frequently experience tinnitus and the symptom of any tinnitus seems to be more frequent in musicians, at least in some studies compared to studies in the background population.

Musicians have frequently reported hyperacusis. In a Dutch investigation 79% out of 239 musicians reported to be sensitive to loud sounds varying from slight to severe (Jansen et al. 2009). 25% (31% men and 21% women) of musicians in a Danish study reported to have hyperacusis (Laitinen and Poulsen 2008).

In recent years there has been an increasing debate about the origin of especially tinnitus. If noise or ageing result in hair cell loss in the inner ear this could lead to de-afferentation of nerve fibers supporting the hair cells. It has been demonstrated that this de-afferentiation of nerve fibers leads to an altered tonotopic organisation of the primary auditory cortex. Thus there is some evidence for a central component of tinnitus as an analogy to phantom limb pain, where altered tonotopic organisations of somatosensoric areas are seen following amputations, which also lead to de-afferentiation of these brain areas (Eggermont and Roberts 2004). Tinnitus can occur as chronic or intermittent tinnitus in musicians after intensive exposure to sound.

Hearing loss can precede tinnitus and hyperacusis. Tinnitus and hyperacusis can be present in normal hearing subjects and the association between the hearing thresholds and the hearing associated symptoms was investigated in musicians in this study. Furthermore the relation between hearing associated symptoms and the exposure to loud sounds from music was investigated.

MATERIALS AND METHODS

Subjects

315 musicians out of 394 musicians (80%) employed in five symphony orchestras in Denmark answered a questionnaire about health problems. Questions included in this study were: Do you in your own opinion have hearing loss? Do you have or have had tinnitus? Have you developed overly sensitive hearing (hyperacusis)? 223 musicians (57%) took part in an audiometry study. 11 subjects were excluded from the audiometry study due to other causes of hearing loss than noise induced hearing loss. 199 musicians out of 394 musicians (51%) participated in both the questionnaire survey and the audiometry study.

Exposure

The entire equivalent lifetime sound exposure was estimated from the exposure time and the sound exposure level. The exposure time was estimated from responses from the questionnaire. The sound exposure was measured from 114 left and 114 right ear sound measurements from 54 different musicians in two different orchestras as previously described (Schmidt *et al.* 2011).

Material

For audiometry Tucker-Davis Technologies RM-2 processor under control from a personal computer was used. The system was calibrated to use Sennheiser HDA-200 headphones. The audiometry system was a user operated audiometry system based on the Two Alternative Forced Choice paradigm and a stimulus presenting method involving the Method of Maximum Likelihood and up-down methods (Schmidt *et al.* 2010). Audiometry was carried out at the workplaces in a quiet room.

The entire sound exposure of a musician was recorded with two miniature microphones (DPA-4063) positioned outside the entrance of the ear canal. Microphones were connected to a battery driven DPA-MPS6030 power supply and connected to a digital recorder (Olympus LS-10). The entire sound signal was analysed and compared to a reference calibration tone of 94 dB SPL recorded from B & K type 4231 sound calibrator.

Measurements

A full eight frequency audiogram from 0.25-8 kHz was recorded for all subjects. An average of the noise sensitive high frequencies 3, 4 and 6 kHz was used for the analysis.

Musicians from two different orchestras (Orchestra I and II) playing Niels W. Gade Ossian Ouverture, Sjostakovitj Violin Concerto No. 1 and Carl Nielsen Symphony No. 3. (Orchestra I) and Mahler Symphony No. 6 (Orchestra II) took part in the measurements. The A-weighted equivalent sound pressure level, L_{Aeq} was recorded for the different measured musicians as reported in Schmidt *et al.* 2011.

Statistics

Data from the audiometry was analysed with linear regression with an average of 3, 4 and 6 kHz as outcome variable and hearing symptoms as independent variables. Data from exposure studies were analysed with linear mixed models with the exposure as outcome variable and instrument type and repertoire as independent variables. Subjects were included as random effects. These analyses calculated separate exposure levels of the left and the right ear of the musician as previously reported in Schmidt *et al.* 2011. The sound exposures were then combined with questionnaire data about the total work time to obtain an estimate of the life time sound exposure.

RESULTS

35 % of the musicians among symphony orchestra musicians reported to suffer from tinnitus (Figure 1) and 30% of the musicians had experienced hyperacusis (Figure 2). Tinnitus and hyperacusis were frequent symptoms in all instrument groups.

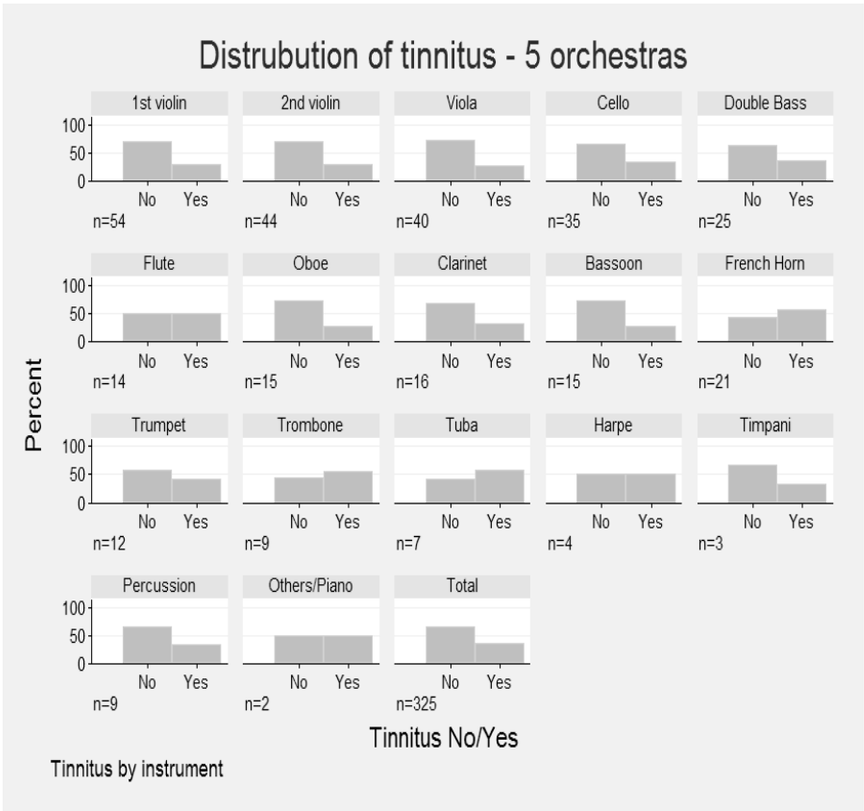

Fig. 1: Distribution of self reported tinnitus among musicians playing different instruments. Data are from five different symphony orchestras.

Subjective hearing loss was significantly ($p<0.001$) related to the hearing thresholds (Table 1). This association was dependent of age and indicated that hearing loss in musicians was increasing with age as expected. Tinnitus was not related to the hearing thresholds in musicians, However, a rather small but not significant p-values indicated a weak association if any between tinnitus and hearing loss. This weak association was related to age, as correction for age and gender ruled out this week association. It is well known that tinnitus is more frequent in older subjects. Subjects with hyperacusis were shown to have better hearing thresholds compared to musicians without hyperacusis. This was significant for the left ear after correction for age and gender ($p<0.02$). This indicated that musicians with hyperacusis were more sensitive compared to musicians without hyperacusis.

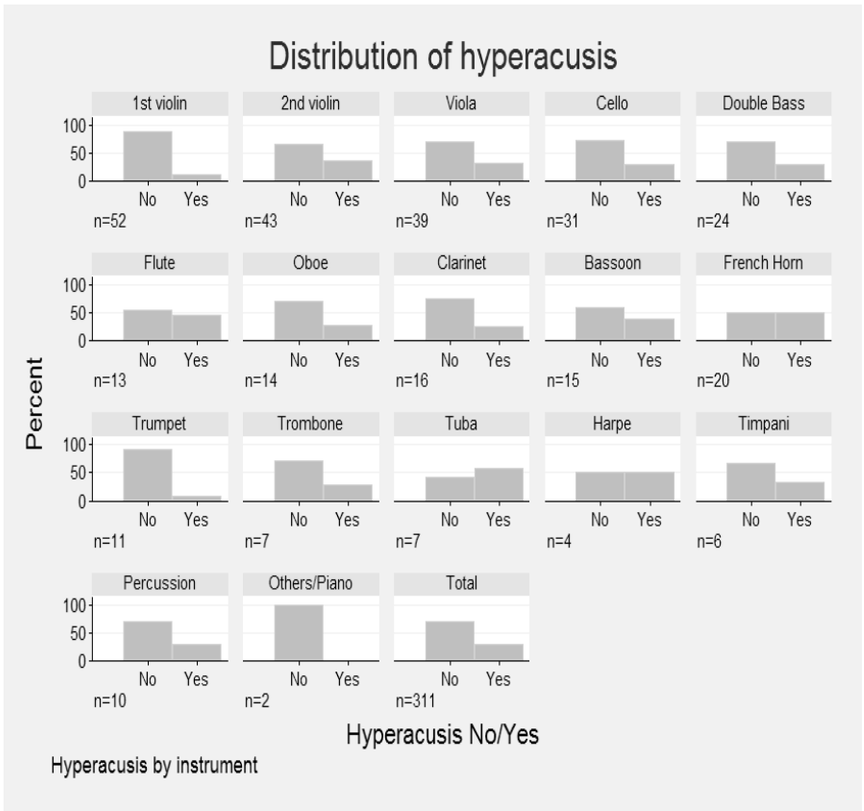

Fig. 2: Distribution of self reported hyperacusis among musicians playing different instruments. Data are from five different symphony orchestras.

The exposure of musicians depends on the instrument and has been measured previously in two orchestras (Schmidt *et al.* 2011). This study showed that brass players and in particular trumpet players were exposed to L_{Aeq} of approximately 95 dBA on both ears. In contrast double bass players were exposed to 85 dBA. High string players were asymmetrical exposed with typically L_{Aeq} of 92 dBA on the left ear and 87 dBA on the right ear (Schmidt *et al.* 2011).

Results from the sound measurements were used to estimate a likely exposure level of the musicians left and right ear in the different instrument groups as well as the musicians' life time exposure to sound. The results show that tinnitus and hyperacusis were not directly related to the size of the life time sound exposure in musicians. It is also evident from Figure 1 and 2 that tinnitus and hyperacusis occurs in all instrument groups including instrument groups with low exposure (cello and double bass).

Frequency	Related to	N	Coeffi-cient (dB)	Standard error (dB)	p-value<	95% CI. (dB)
3,4,6 kHz –left	Hearing loss	184	6.7	1.8	0.001	3.1 – 10.3
3,4,6 kHz –right	Hearing loss	183	6.2	1.7	0.001	2.9 – 9.5
3,4,6 kHz –left	Tinnitus	178	2.8	1.9	0.14 (n.s.)	-0.9 – 6.5
3,4,6 kHz –right	Tinnitus	178	2.6	1.7	0.12 (n.s.)	-0.7 – 5.9
3,4,6 kHz –left	Hyper-acusis	173	-3.1	1.9	0.10 (n.s.)	-6.9 – 0.7
3,4,6 kHz –right	Hyper-acusis	172	-1.3	1.7	0.46 (n.s.)	-4.6 – 2.1

Table 1: Mean 3, 4 and 6 kHz hearing thresholds from the left and the right ear compared to self reported hearing symptoms such as hearing loss, tinnitus and hyperacusis. A positive coefficient indicates that the hearing thresholds are higher for the subjects reporting hearing associated symptoms as listed in column "related to" compared to subjects without the symptom. A negative coefficient indicates a more sensitive hearing in subjects reporting a specific hearing symptom. Results are from linear regressions without correction for age and gender. n.s. = not significant.

DISCUSSION

An association between sound exposure and the occurrence of tinnitus and hyperacusis could not be directly demonstrated. Tinnitus is however, described as a symptom which can be seen as part of a Temporary Threshold Shift (TTS). This might be an explanation why 35% of the musicians reported tinnitus and 30% reported to suffer from hyperacusis. The findings were consistent with previous studies (Woolford 1984; Laitinen and Poulsen 2008). Some studies, however, reported more frequent occurrence of especially tinnitus (Jansen *et al.* 2009). 25% of the population in a recent study reported tinnitus (Shargorodsky *et al.* 2010). A prevalence of hyperacusis in the general population has been estimated to 8.6% (Andersson *et al.* 2002). Thus musicians report frequently tinnitus and hyperacusis compared to the background population.

The different studies on classical musicians did not investigate the association between hearing loss and hearing associated symptoms, but a few studies on pop-rock musicians did. Slightly poorer high frequency hearing thresholds have been reported in subjects complaining about tinnitus and hyperacusis in a group of pop-musicians in contrast to the findings presented here (Axelsson and Lindgren 1981). In contrast Kähari *et al.* (2003) reported better hearing at 1.5 and 2 kHz in the right ear and 4 kHz in the left ear for musicians with tinnitus compared to musicians without tinnitus. Musicians with hyperacusis did not show different thresholds from subjects without hyperacusis except at 2 kHz in the right ear (Kähäri *et al.* 2003). Consistent with the findings in the present study no association between self-reported hearing symptoms and the measured hearing thresholds in a group of pop-rock musicians could be found (Schmuziger *et al.* 2006).

Tinnitus may be a result of intermittent high exposure to sound and therefore a result of auditory stress due to fatigue of the auditory system. This fatigue will often result in temporary hearing loss as well as a part of TTS. TTS is most likely not associated to permanent threshold shifts (PTS) as the underlying mechanism leading to PTS is completely different from TTS. An association between tinnitus and PTS in the 3, 4 and 6 kHz area could therefore not be demonstrated in the present study (Table 1). On the other hand, hyperacusis seems to be related to the more sensitive musicians with the lowest hearing thresholds. Hyperacusis might be a symptom of auditory fatigue as well in absolutely normal hearing musicians.

CONCLUSIONS

Tinnitus and hyperacusis were frequently reported among musicians. 35% of all musicians complained of tinnitus and 30% complained of hyperacusis. The symptoms were present among all instrument groups.

Auditory symptoms such as tinnitus and hyperacusis were not related to a reduced sensitivity in musicians. Hyperacusis was shown to be associated to a more sensitive hearing in musicians especially on the left ear when analyses were corrected for the effect of age and gender.

Musicians with the sensation of hearing loss had reduced hearing thresholds compared to musicians unaware of hearing loss.

Tinnitus and hyperacusis were not related to an individual life time sound exposure as no relationship between high sound exposure and increased incidence of tinnitus and hyperacusis could be confirmed. Tinnitus and hyperacusis were reported in musicians with high as well as low sound exposure.

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Distortion Product Otoacoustic Emissions (DPOAE) after exposure to noise and music of equal energy

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Exposure to intense noise and music can result in Temporary Threshold Shifts (TTS). Previous investigations suggest that music and noise may induce TTS differently and that the magnitude of TTS after noise exposure is larger compared to music exposure. Listening to music may induce unknown effects in the medial olivocochlear bundle which may suppress the size of the TTS. Ten normal hearing listeners were exposed for 10 minutes to 100 dB SPL familiar and unfamiliar music or noise on separate days. During the exposure of music or noise the test subjects focused entirely on the auditory stimulus. In a parallel experiment, the subjects had non-auditory attention on a puzzle task (the Tower of Hanoi). The order of the experiments was randomized. Pre- and post-exposure Distortion Product Otoacoustic Emissions (DPOAE) were measured at 2, 3 and 4 kHz. DPOAE response was suppressed on both ears immediately after noise exposure and on the left or the right ear after familiar and unfamiliar music exposure, respectively. Auditory attention compared to non-auditory attention resulted in higher DPOAE suppression on the left ear. In conclusion, music and noise with equal energy suppressed DPOAE responses on both ears but with noticeable differences between ears.

INTRODUCTION

Temporary hearing loss in conjunction with excessive exposure to sound is described as Temporary Threshold Shift (TTS). Musicians would be expected to experience incidences of TTS quite often since they are exposed to loud sound (Schmidt *et al.* 2011). The duration of the TTS is correlated to the magnitude and the length of the sound exposure (Clark 1991).

TTS can occur after exposure to music and industrial noise, but the magnitude of TTS have been reported to be much smaller and TTS duration shorter after exposure

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