Hearing status among aircraft maintenance personnel in a Swedish Commercial Airline Company

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ABSTRACT

The aim was to study hearing loss in a population of aircraft technicians and mechanics and indentify predictors. Equivalent noise levels during a working day were measured and were 70-91 dB (A). Maximal noise level was 119 dB(A). A total of 336 aircraft maintenance personnel answered a self-administered work environment questionnaire (response rate 76%) and underwent audiometric test. The mean values for the hearing test at 3, 4, 6 kHz for the ear with the most hearing loss were compared with a Swedish population data base of persons not occupationally exposed to noise. At younger ages (-40 y) aircraft technicians and mechanics had more hearing loss compared to the reference group. Through multiple logistic regression analyses associations were found between age and hearing loss, and between exposure to solvents and reported annoyance due to hearing loss. In conclusion, aircraft technicians and mechanics may be exposed to equivalent noise levels above the Swedish occupational standard and have a higher age matched hearing threshold level at younger age compared to a reference group.

Introduction

Hearing loss is a problem at leisure activities and in many workplaces. In airline companies, hearing loss may have implications for safety communication between aircraft technician and mechanics, and cockpit during taxiing on platform. In addition to aging, occupational noise, genetic heredity, head injury, infections, certain drugs, high blood pressure and tobacco smoking (Lusk, 1997; Correa Filho et al., 2002; Ferrite & Santana, 2005; Uchida et al., 2005) are risk factors for hearing loss. Moreover, shooting and other impulse noise during leisure activities may also cause hearing loss (Nondahl et al., 2000), as well as non-impulse recreational noise as very loud toys, discos and exposure to electronically amplified music (Maassen et al 2001).

Hearing loss is well documented in many studies and there is an international, standardized database for hearing threshold levels as a function of age, ISO 7029 (International Organization for Standardization, 1984), describing hearing threshold levels for an otologically normal population. In ISO 1990 (International Organization for Standardization, 1990) populations in USA are described. In addition, there is a Swedish database with hearing threshold levels for a population without occupational noise exposure (Johansson & Arlinger, 2002).

In the aviation industry high noise levels are prevalent and the hearing ability of airline employees are usually followed by repeated audiometric tests. We have previously published data on hearing status and noise exposure in pilots and cabin crew (Lindgren 2008, Lindgren 2009). For both groups we concluded that they were exposed to equivalent noise levels below the occupational standard of 85 dBA, and they had normal age-matched hearing threshold levels. Another noise exposed group is the aircraft maintenance workers. Noise exposure occurs during maintenance work in hangar and on the platform during take-off and landing. However, there are still only a few studies on noise and hearing loss in aircraft maintenance workers.

A Chinese (Chen 1992) study investigated hearing loss in aircraft maintenance workers, airport firemen, airport policemen, airline ground staff, and airport civil servants. The prevalence of a high-frequency loss was 42%, with the highest prevalence in maintenance workers (65%) and firemen (55%). Hong (2001) identified risk factors as noise exposure level, years of noise exposure, non-occupational noise exposure, history of ear disease, ototoxic drug use, cigarette smoking, hypertension, and use of hearing protective device. Aircraft maintenance personnel may also be exposed to jet fuels and solvents and occupational exposures to organic solvents may have detrimental effect on hearing (Sliwinska-Kowalska 2007).. The combination of noise exposure and exposure to solvents may increase the risk of hearing loss. Subjects with noise and jet fuel exposure had an increase in hearing loss, even at fuel exposure estimates well below the threshold limit values (Kaufman 2005), and the effect of jet fuel appeared to be stronger at shorter duration of exposure. Kim (2005) studied the effect of occupational exposure to noise and organic solvents on hearing loss in male aviation industry workers. Pure tone audiometry from the workers biannual medical surveillance was used to assess hearing loss. Controlling for age, and compared to the unexposed, the relative risk of hearing loss was 8.1 in the both noise and solvents group, 4.3 in the only noise group and 2.6 in the solvents only group. Prasher (2005) compared aircraft maintenance workers to workers exposed to noise alone, to solvents alone, and to non-exposed.. There was a significant effect on pure tone thresholds for both noise and solvents+noise groups but the mean acoustic reflex thresholds showed a pattern of differences which differentiate noise from solvent and noise groups. The aim of the study was to investigate hearing thresholds and determine hearing loss in aircraft technicians and mechanics at a Swedish Airline Company, using reference data from a Swedish population data base of persons not occupationally exposed to noise, and to identify work related risk factors for hearing loss exposure to noise, occupation, years of employment and exposure to solvents.

Study population and Methods

Study population

The study population consisted of all technicians and mechanics (maintenance personnel) employed in a Swedish airline company who had undergone voluntary audiometric test at the occupational health service in the years 2008 -2009. They were 327 males and 9 females, with a range of age of 22 to 67 years old. In total, there was 440 technicians and mechanics employed during this time period (76% participation rate). Due to the small

number of females, they were excluded from further analysis.
Technicians and mechanics were divided into 6 occupations: 1) technicians following the aircraft during in and out taxiing and working on platform and in hangar with aircraft, 2) mechanics working only in hangar with aircraft, 3) aircraft electricians, working only in hangar 4) mechanics working in hangar with sheet-metal work and riveting hammer, 5) supply work in hangar, 6) administration work. Work in hangar means work with stripping down and mounting parts of the aircraft. Both technicians and mechanics work in the same area with similar tasks but technicians have higher education with the responsibility of performed tasks. Administration work in hangar are usually performed by technicians and mechanics that have previously been working in hangar with the aircraft or on platform with in- or out taxiing aircraft.

Noise exposure

Exposure measurements were performed in 2009, using a Spark 706RC, noise dosimeter, (Larson Davis INC, UT 84601, USA). Equivalent personal exposure (Leq) dB (A) during a working day was measured during different working tasks. The microphone was placed at the technicians' and mechanics' right side within 100 mm of the typical ear where noise was normally received. Technicians and mechanics that follow the aircraft on platform use ear protection devices (earmuff) with communication, and Leq during work with short high noise exposures were also measured inside the earmuff. In total, exposure measurements were performed during two workdays on the platform, two workdays in the hangar and one workday while working in the hangar with riveting hammer. Furthermore, peak exposures were measured at certain situations, by noise analyzer Norsonic type 110, (Norsonic AS , Tranby, Lier, Norway).

Questionnaire
A self-administered questionnaire was mailed in November 2008-May 2009. The questionnaire was based on a standardized questionnaire developed by the company occupational health service, and have been used in the company for many years. The questionnaire contained one question on annoyance to hearing loss, asking "Do you have a problem hearing?" There were one question on work environmental items; "Are you bothered by any of the following factors in your work?", followed by a list of factors including "noise" and "solvents/chemicals". Another two questions asked about the psychosocial work environment: "Do you have too much to do at work?" and "Does your work demand too much of you, like too great responsibility, too difficult work tasks, unclear work tasks?" For each of these questions, there were four alternatives: "no, never", "no seldom", "yes, sometimes", and "yes, often". As high blood pressure may affect hearing, there was also one question asking "Have you ever had, or do you have, a high blood pressure?" (yes, no).

Audiometric test
The audiometric tests were carried out using Bekesy audiometer model BA2 (Interacoustics A/S, DK-5610 Assens, Denmark), calibrated annually according to international standards (IEC 60645 2001, ISO 389-1 1998). A sound-attenuating chamber was used with a background sound pressure levels not exceeding the maximum octave-band levels for audiometric test rooms (OSHA.). Threshold levels were determined according to the ascending method (Ivarsson 1988). The audiometric tests were performed at random times during the work shift.

Reference population
As a reference group a large database on hearing loss in males at different age, examined by the manual ascending method to determine hearing threshold levels, was used. The reference population consisted of 266 males randomly selected from the population census in one mid-Swedish county council (20-79 y), excluding subjects exposed to hearing damaging noise at work (Johansson & Arlinger, 2004).
Noise induced hearing loss initially appears as a threshold shift in the frequency region 3 to 6 kHz. Therefore, hearing ability of the high frequency pure-tone of 3, 4 and 6 kHz was used to evaluate hearing loss due to occupational noise exposure, as previously described (Quaranta A, 2001). In the evaluation, we calculated the mean value at 3, 4 and 6 kHz for the ear with the worst hearing ability, for each individual. This value is entitled HF PTA WE (High Frequency Pure Tone Average for the Worse Ear). The worse ear was used because it is a means of early detection of a developing hearing loss. The median of HF PTA WE at different age classes were plotted, and was compared with the percentile values for the reference population, stratified for males.

Audiometric tests and the questionnaire study were performed by the occupational health service, as integrated parts of its regular commission to follow the health of the employees. Information on age, date of employment, gender and audiometric test result was obtained from the medical records. Participation was voluntary and the aircraft technicians and mechanics gave their informed consent.

Statistical Analysis
For technicians and mechanics, the age-group median values for HF PTA WE were calculated. In the reference material, a 10-year window of the age-related data was used to calculate smooth percentile curves from the 10^{th} to the 90^{th} percentile. Johansson & Arlinger (2004) suggests that the 60^{th} percentile of the PTA distribution would be a reasonable criterion-value for evaluating the influence from noise exposure on a group level. This criterion is based on an assumption of normal distribution, with 50% of the population above the 50^{th} percentile, and empirical data showing that the standard deviation (SD) equals the 84^{th} percentile. Age-related curves for technicians and mechanics and reference material were compared.
The association between different factors and hearing problems was analyzed by a random effects multiple logistic regression using Statistical Package for Social Sciences (SPSS). Two types of outcomes were studied. In the first model measured hearing loss was dichotomized, defining subjects with HF PTA WE above 20 dB as cases and equal and below 20 dB as non cases. The first model included age (in years), total length of employment (in years), exposure to solvents (never, seldom, sometimes, often), and occupation. In the second model the question on annoyance due to hearing loss (never, seldom,

sometimes, often) was dichotomized, defining 'often' or 'sometimes' as cases and those with 'never' or 'seldom' as non-cases. The second model included age (in years), high blood pressure (yes, no), total length of employment (in years), exposure to solvents (never, seldom, sometimes, often), the two questions on psychosocial work environment (never, seldom, sometimes, often), and occupation. Due to colinearity between age and year of employment analyses were also performed including only one of these in the models.

For the logistic regression, odds ratios (OR) with 95% confidence interval (CI) were calculated, and a *P*-value of <0.05 was considered statistically significant.

Results

Noise exposure

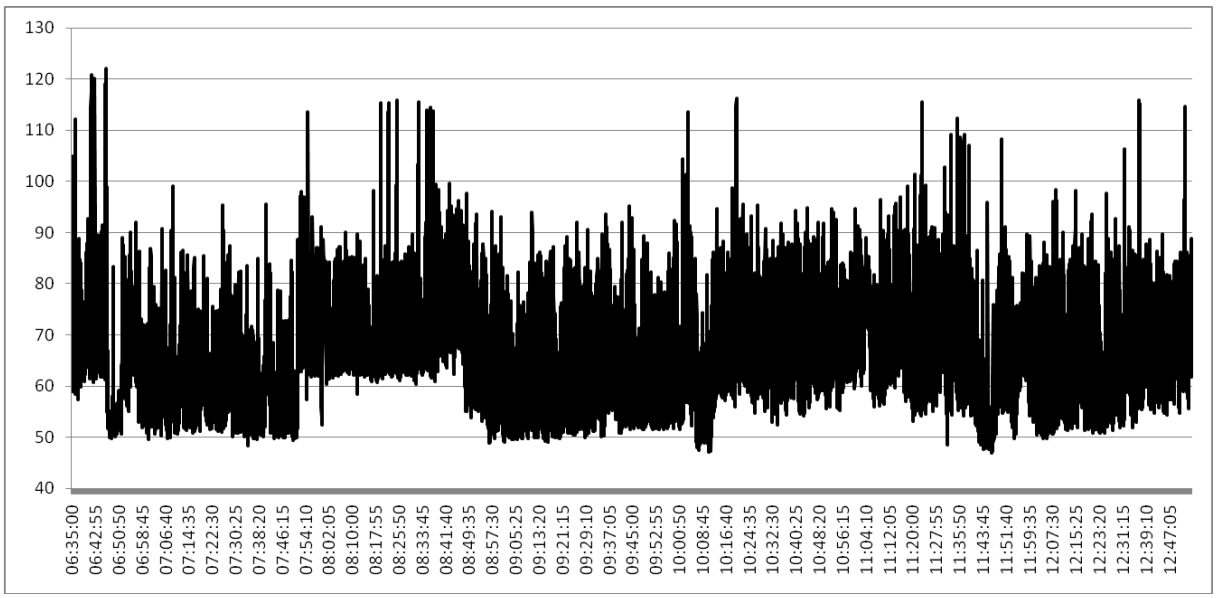
The noise exposure measurements showed that the Leq measured while working in hangar was between 70-91 dB (A), and following the aircraft on the platform was 81 dB(A), during an assumed 8-h workday (table I).

Table I. Equivalent noise levels measured inside and outside earmuff (ear protection device)

Type of work task	*Leq (8h) dB(A) Outside earmuff*	*Leq (during operation) dB(A) Inside earmuff*	*Maximum A-weighted pressure levels dB(A) Inside earmuff*
Following aircraft in and out from the gate	81	87	93
Working with riveting hammer in hangar	91	99	119
Working in hangar with strip down and mount parts of the aircraft	70	93*	104

Examples of exposure curves are given in figure 1. However, peak exposures could be very high. During the most noisy work tasks ear protection was usually used. The highest exposure levels occurred during sheet-metal work and while using riveting hammers in hangar, which happens 30 sec to 3 hours per working day. While working with riveting hammer, the highest maximum A-weighted sound pressure level inside the ear protection device was 119 dB (A). Other workers present in hangar are also affected by this noise, however they don´t usually wear the ear protection device. While following aircraft in and out from the gate noise exposure, inside earmuff, was 87 dB(A) during operation with a maximum A-weighted sound pressure level of 93 dB(A). or those who follow the aircraft on platform during in- out taxiing this task happens 8 to 12 times per working day.

Figure 1. Leq exposure of noise in hangar working with riveting hammer and sheet-metal, measured outside earmuff. This corresponds to 92 dB(A) during 8 hours working day.



Hearing loss and annoyance due to hearing loss

Mean age of the employees was 47 y (SD=10.2). Mechanics not working with riveting hammer and those working with supply work in hanger were somewhat younger (mean age 43 and 38 years, respectively). Number of workers in each age group is given in table 2. The prevalence of hearing loss more than 20 dB in worst ear was 41% and 34% reported annoyance due to hearing loss (sometimes or often). The prevalence of exposure to solvents was 31% (often). High blood pressure was reported by 17% (sometimes or often). In total, 77% reported work stress (sometimes or often), and 35% reported too high work demands, table 3.

Table 2. Number of workers in each age group

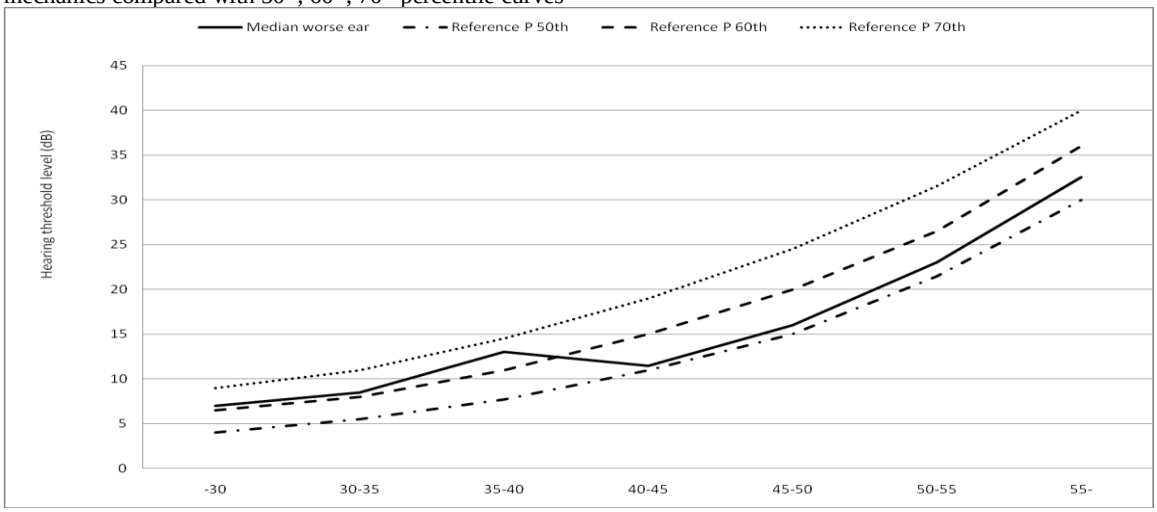
-30 years old	16
30-34	36
35-39	16
40-44	54
45-49	51
50-54	67
55-	75

Table 3. Measured hearing loss and responses to specific items in the questionnaire, cross occupations, (%).

	Technicians	*Mechanics*	*Mechanics working with riveting hammer and sheet-metal in hangar*	*Aircraft electrician*	*Supply work in hangar*	*Administration work in hangar*
More than 20 dB(A) hearing loss in worst ear	44	38	44	39	17	50
Annoyed due to hearing loss	37	26	38	36	17	41
Exposure to solvents	41	38	56	8	0	3
High blood pressure	11	16	39	27	0	17
Too much work to do	79	74	64	73	0	87
Too high work demands	36	29	33	9	33	51

When considering the total result for all age classes, younger technicians and mechanics had more hearing loss in worse ear compared to the reference group and the older maintenance personnel had a better hearing ability than the referents, with average median values being above and below, respectively, the 60th percentiles for the reference material (figure 2).

Figure 2. Mean values of HF PTA WE (3, 4 & 6 kHz) in different age for male (female excluded) aircraft technicians and mechanics compared with 50th, 60th, 70th percentile curves



In the multiple logistic regression analysis we found significant relationships between more than 20dB (A) hearing loss in worst ear and age. We also found significant relationships between annoyance due to hearing loss and exposure to solvents, when adjusting for occupation, total length of employment, high blood pressure and psychosocial working environment, table III and IV. Models excluding age and years of employment, respectively, gave similar results.

The correlations (Spearman´s rho) between hearing loss and annoyance due to hearing loss was significant (<0.000, 2-tailed) with a correlation coefficient of 0.401. When comparing hearing loss and annoyance due to hearing loss between different occupations, supply personnel was used as a reference. No major differences were observed between different occupations, table 4 and 5. Moreover, blood pressure, years of employment and psychosocial work environment had no influence on hearing loss or annoyance due to hearing loss.

Table 4. Adjusted Odds Ratios (OR)* with 95% CI for relationships between at least 20 dB hearing loss, age, years of employment, different working occupations, and exposure to solvents.

Variable	OR (CI)
Age	6.9 (3.7 – 13.0) ***
Years of employment	0.6 ((0.4 – 1.2)
Exposure to solvents	0.9 (0.6 – 1.3)
Technicians	0.9 ((0.2 – 5.2)
Mechanics	1.1 (0.2 – 6.2)
Working in hangar with riveting hammer and sheet-metal	0.8 (0.01 – 6.9)
Aircraft electrician	0.98 (0.1 – 8.7)
Administration work in hangar	1.4 (0.2 -9.2)

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$

‡ When comparing hearing loss between occupations, supply workers were used as a reference value.

† More or equal than 20 dB hearing loss are dichotomized, defining = 1, and less = 0

Table 5. Adjusted Odds Ratios (OR)* with 95% CI for relationships between annoyance due to hearing loss, age, years of employment, different working occupations, exposure solvents, blood pressure and the two questions on psychosocial work conditions

Variable	OR (CI)
Age	1.6(0.92-2.86)
Years of employment	1.59(0.90-2.79)
Exposure to solvents	1.64(1.12-2.40)*
Technicians	2.92(0.42-20.6)
Mechanics	3.26(0.43-24.7)
Working in hangar with riveting hammer and sheet-metal	2.71(0.25-29.0)
Aircraft electrician	2.6(0.24-28.3)
Administration work in hangar	6.3(0.77-51.9)

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$

‡ When comparing hearing loss between occupations, supply workers were used as a reference value.

† Annoyance due to hearing loss are dichotomized, yes often or yes sometimes = 1, and no seldom or no never = 0

Discussion and conclusions

We found that younger aircraft technicians and mechanics in a Swedish commercial airline had a higher rate of hearing loss in the worse ear than the non-noise exposed reference population from the same country. However, at older age there was no difference in hearing ability. We also found that annoyance due to hearing loss was associated to exposure to solvents.

The hearing test was not compulsory, but the participation rate was relatively high (76%), thus we do not expect any major selection bias in this study. However, there were some differences in the methodology in audiometry between the present study and the reference population. The present study used a semi-automatic self-recording Békésy-audiometer whereas the reference population used the manual ascending method (pure-tone) to determine hearing threshold. In a pure-tone investigation obtained hearing thresholds are higher than in a Békésy investigation (Erlandsson et al., 1979). That may imply that the hearing loss among the young aircraft workers was even higher than recorded.

The audiometric tests were performed at random times during the work shift. As a temporary lowered hearing threshold may occur after noise exposure, measured hearing thresholds may be slightly higher than compared to if audiometry had been performed before work. However, there should be no difference in this respect between workers of different age group.

From around the age of 40, the maintenance personnel had a better hearing ability than the reference population. This might indicate a healthy worker effect. One could speculate that hearing ability is worsened with age, due to occupational exposure, and that around 40 those with the worse hearing ability tend to leave.

In other occupational settings, equivalent noise levels above 85 dB (A) during 8-hours and age have been shown to increase the risk for hearing loss (SEN 590111 1972) and the Swedish workers protection standard requires that exposure should not exceed this level (National Board of Occupational Safety and Health, 2005). Our noise measurements indicated that some occupations were exposed to equivalent A-weighted and maximal sound pressure level just above this limit value. However the mean exposure level was 81dB (A). Thus the higher hearing loss among the younger, especially the 35-40 years old, is not easily explained. During the last years, this airline company, like many other, have had to reduce the number of employees, and this have resulted in fewer persons in the youngest age groups. However, the study still included 68 workers younger than 40 years, thus this being a chance finding seems unlikely. Smoking habits and high blood pressure are risk factors for hearing loss, but we have no data on smoking habits in our material. High blood pressure is unlikely in the youngest age group and smoking frequency in the normal population in Sweden is low (16%, Swedish National Institute of Public Health). We speculate that peak exposures might be of importance. There was an age effect but time of employment had no effect on hearing loss (except when excluding age in the statistical model) and we found no relationship between hearing loss and occupation. Changing of work tasks between employees is common and noise exposure in hangar is similar between occupations. Moreover, nowadays the airline company performs education programs on noise risks and use of ear protection devices has become common outdoors at platform and during tasks with high noise level in hangar.

We found exposure to solvents was related to annoyance due to hearing loss. Both these factors were self reported and a reporting bias could be apprehended. However, we also found a significant correlation between annoyance to hearing loss and measured hearing loss, which supports this finding

In conclusion, some aircraft technicians and mechanics were exposed to equivalent noise levels just above the current Swedish occupational standard of 85 dB (A) despite frequent use of hearing protection devices and relatively short duration of high noise levels. Furthermore, younger employees had more hearing loss compared to a reference population not exposed to occupational noise.

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