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Hearing Deficit in a Birth Cohort of U.S. Male Commuter Air Carrier and Air Taxi Pilots

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Abstract

Purpose—Long-term exposure to multiple risk factors in aviation may place pilots at excess risk of developing hearing deficits. We examined the incidence and risk factors for hearing deficit in a birth cohort of male commuter and air taxi pilots.

Methods—The subjects ($N = 3019$), who were 45–54 yr of age and held Class I medical certificates in 1987, were followed up from 1987 to 1997 through the medical certification system of the Federal Aviation Administration (FAA). In this study, hearing deficit refers to the FAA pathology code 220 (defective hearing, deafness, not elsewhere classified). Poisson regression modeling based on generalized estimation equations was used to assess the associations between pilot characteristics and the risk of developing hearing deficit.

Results—The 10-yr follow-up accumulated a total of 20,671 person-years and 574 incident cases of hearing deficit, yielding an incidence rate of 27.8 per 1000 person-years. Compared with age 45–49 yr, the risk of developing hearing deficit at age 50–54 yr, 55–59 yr, and 60–64 yr increased by 12% [adjusted relative risk (RR) 1.12, 95% confidence interval (CI) 0.98–1.30], 34% (RR 1.34, 95% CI 1.13–1.59), and 79% (RR 1.79, 95% CI 1.20–2.67), respectively.

Conclusions—Hearing deficit is prevalent among commuter air carrier and air taxi pilots and the risk of hearing deficit increases progressively with pilot age. Effective programs for preventing excess hearing loss in the pilot population are warranted.

Keywords

aging; hearing deficit; noise safety

Noise-induced hearing loss is among the 10 leading work-related diseases and injuries in the United States (19). Each year, compensation related to occupational hearing loss costs society

over \$200 million (20). The National Institute of Occupational Safety and Health (NIOSH) has identified work-related hearing loss as a priority area for research and prevention (20).

Hearing loss is one of the most important physiological sensory deficits affecting pilots' safety performance (1). In order to maintain medical certificates, pilots are required to meet explicitly stated criteria for hearing functions (Federal Aviation Regulation Title 14 of the Code of Federal Regulation [CFR] Part 67) (9). As an occupational group, pilots are known to be at heightened risk of work-related hearing deficits (13,14,22). Multiple factors may have adverse effects on hearing function of pilots. Among them, noise in the work environment plays a critical role (20,22). According to the Occupational Safety and Health Administration (OSHA) (21), a time-weighted average of 8 h or longer exposure to noise above 85 decibels (dBA) per day is classified as an action level to start the hearing conservation program, a monitoring system to promote hearing protection.

Although aviation industries are not categorized by OSHA for such a monitoring system regardless of the magnitude of work-related noise, the noise level during aviation operations may exceed the hazardous threshold. Depending on the type of the aircraft, the phase of flight, the environment inside the cabin, and the outside weather condition, the magnitude of aircraft noise ranges from 80 dBA to 140 dBA in both civilian flights and military operations (5,13,14). Studies indicate that general aviation pilots, especially those age 60 yr and older, are at higher risk of impaired hearing function as compared to nonpilots in the same age group (3). Long-term continuous exposure to multiple sources of noise in aviation may place pilots at excess risk of hearing deficit (1,3,5).

In addition to noise from occupational exposure, hearing deficit is known to be associated with advancing age (7,18). The prevalence of hearing problems in the general population age 60 and older is estimated to surpass 40% (8,18). Hearing deficits are a problem of increasing importance as the aging of the U.S. population accelerates in the coming 20 yr (7,16).

Although the prevalence and risk factors of hearing deficit have been examined in military and airline pilots (5,13,14,22), epidemiological data on hearing impairment for commuter air carrier and air taxi pilots are lacking. Commuter air carrier and air taxi pilots fly smaller aircraft for shorter distances and at lower altitudes than airline pilots. As a result, these pilots are exposed to a higher level of noise than their counterparts flying major airlines (5). In this study, we examined the incidence rate and risk factors of hearing deficit in a birth cohort of male U.S. commuter air carrier and air taxi pilots.

METHODS

Population and Study Sample

According to the Aeronautic and Space Medical Standards and Certification prescribed by the U.S. Federal Regulation for the purposes of airmen certification procedure (23), medical certificates issued to U.S. civilian pilots are categorized into three classes based on the strictness of the medical standard (Title 14 of the Code of Federal Regulation [CFR] Part 67). The medical standard applied to Class I medical certificates is the strictest. In order to have the license renewed, pilots holding Class I medical certificates are required by the Federal Aviation Regulation to have periodic medical examinations every six months. The medical standard for Class II medical certificate holders is less strict. Such pilot license renewal is mandated to take place every 12 mo. The least strict standard is Class III, which should be renewed every 24 mo. Only pilots with Class I or Class II medical certificates are allowed to fly commuter air carriers and unscheduled air taxis (i.e., Part 135), while major airlines (Part 121) are mandated to be operated by pilots with valid Class I medical certificates. Prior to January 2008, pilots were not allowed to fly major airlines after their 60th birthday (Title 14 CFR 121.383(c)) in

the United States (the mandatory retirement age has been extended to 65 ears since January 2008).

In order to investigate age-related safety performance among commuter air carrier and air taxi pilots, all pilots flying Part 135 operations were retrospectively selected from the 1987 records of the Federal Aviation Administration (FAA)'s Airman Information System (6) if they met the following inclusion criteria: being 45–54 yr of age; holding a Class I medical certificate; being employed by a commuter air carrier or air taxi company; flying for business or both business and pleasure; listing pilot or commercial pilot as the occupation; and having at least 20 h of flight time in the last 6 mo and 500 h prior to the first medical examination in 1987. A total of 3306 pilots met the inclusion criteria and were eligible for this study. Excluded from the analysis were 244 male pilots who did not have available follow-up data during the subsequent years and 43 female pilots because the small sample precluded any meaningful statistical analysis. Therefore, the study sample included 3019 male U.S. commuter air carrier and air taxi pilots.

Follow-up and Data Collection

The retrospective follow-up of the birth cohort started in 1987 and ended in 1997. During the 10 yr of longitudinal observation through multiple surveillance systems maintained by the FAA and National Transportation Safety Board (NTSB), age, sex, bodyweight, height, and pathology codes for each pilot were recorded every 6 mo based on the information documented in the medical certification process. Using date of birth and social security number of each pilot, we searched the National Death Index for the vital status. A detailed description of the study design and data collection can be found elsewhere (15).

The FAA records each pathological condition using a pathology prefix (the first digit) and a pathology code (the next three digits) in the periodic medical examination. If the pathology prefix (code 1–9) was “C” or “3,” the individual was recognized as a new case for its pathologic status. Codes 200–239 provide detailed diagnoses of ear pathology. Up to eight pathologic conditions were recorded for each pilot during each physical examination. In this study, hearing deficit refers to the pathology code 220, defined as “defective hearing, deafness, not elsewhere classified (NEC) (Use with Waiver issuance or Denial only).”

The follow-up accumulated a total of 20,671 person-years. In addition to the hearing deficit recorded in 1987 (baseline), explanatory variables included in this study are total flight time at baseline and pilot age. During the 10-yr follow-up, the total number of incident hearing deficits in each year was updated periodically. During the study period, if a pilot stopped renewing the medical certificate because of retirement, death, or any other reason; or if the medical certificate was downgraded to Class II or Class III, he was censored from follow-up. In this study, the total flight time at baseline (in hours) was used as a surrogate indicating the accumulated occupational exposure to aviation noise.

Data Analysis

The incidence rate of hearing deficit was calculated as the total number of hearing deficits divided by the corresponding follow-up time in 1000 person-years. Prior to the parametric analysis with statistical models, the relative risk and 95% confidence intervals were compared in pilots with different demographic and occupational characteristics to explore the risk factors related to hearing deficit. The contingency table and stratification analysis were used to investigate whether the associations between the risk of hearing deficit and a particular disease predictor varies across the exposure to another risk factor.

According to the statistical characteristics, it was assumed that the count of incident hearing deficit cases approximates a standard Poisson distribution and the within-individual correlation among the repeated measurement follows an exponential structure. Poisson regression analysis with generalized estimation equations (GEE) (12) was applied for the statistical modeling analysis to estimate the risk of hearing deficits relative to the total flight time and time-dependent pilot age. A marginal model providing the population average disease-predictor relationship was preferred for statistical inference. Pearson residual analysis was applied for model checking.

Given the intrinsic biology of disease development after exposure, the incident hearing pathology was linked to the exposure measured in the previous year. Therefore, newly developed hearing deficits recorded in 1987 and risk predictors reported in 1997 were not included in the analysis because of unavailable exposure in the former and untraceable outcome information for the latter. During the analytical process, the age of pilot was considered as a time-dependent exposure while the total flight time at baseline was independent of time.

RESULTS

When entering the study in 1987, the 3019 pilots had an average age of 48 yr (SD = 2.8 yr). The mean total flight time at baseline was 9857 h (SD = 5770 h). During the last 6 mo prior to the first medical examination of 1987, the self-reported flight time ranged from 20 to 850 h (mean = 287 h, SD = 144 h). Approximately 2% of the pilots ($N = 61$) had pre-existing pathology of hearing deficits according to the periodical medical examination of the FAA (Table I).

The 10-yr follow-up accumulated a total of 20,671 person-years and 574 incident cases of hearing deficit, yielding an incidence rate of 27.8 per 1000 person-years. The incidence rates of hearing deficit per 1000 person-years were 9.0, 19.4, 35.6, and 48.1, respectively, for pilots with baseline total flight hours of less than 5000, 5000–9999, 10,000–14,999, and 15,000 or more. The rate of hearing deficit was significantly higher in older pilots and pilots with more total flight time (Table I). Further analysis revealed that the risk of hearing deficit increased progressively as the pilots aged (Table I). Total flight time, which was positively correlated with age, showed substantially increased risk of hearing deficit in the univariate model (Table II). The effect of total flight time on hearing deficit became statistically nonsignificant after adjusting for pilot age and baseline history of hearing pathology (Table II). Age remained significant in the multivariate model, with the relative risk of hearing deficit increasing progressively as pilots grew older (Table II).

DISCUSSION

Commuter air carriers and air taxis are an important part of commercial aviation in the United States. According to the NTSB, there are approximately 60,000 commuter air carrier and air taxi pilots performing a total of 5 million flights each year. These pilots work in an especially challenging environment and are known to be at a much greater risk of crashes than major airline pilots (2).

Our study suggests that older age is associated with increased risks of hearing deficit in commuter air carrier and air taxi pilots. The observed age effect on hearing deficit may, to a large extent, reflect the role of presbycusis in hearing functions during the process of aging. During the process of aging, hearing function may be affected by a variety of factors (23). Some systemic diseases such as diabetes and hypertension may induce hearing disorders (17, 24,25). Age-related degenerative changes may affect hearing function through impaired auditory neuron and damaged stria vascularis (5,11). The biological development of disease-

related and age-related hearing deficits in the pilot population appears to be similar to the general population (17,24,25).

On the other hand, the hazardous work environment could be a major risk factor for hearing impairment. Hearing functions can be impaired by long-term exposure to excessive levels of noise (13,14). Depending on the magnitude and duration of exposure, noise may lead to a shift of the hearing threshold either temporarily or permanently. Noise-related damage to the hair cells of the organ of Corti marks the initiation of the pathophysiology regarding hearing loss induced by noise exposure (4,10). In addition to noise, hearing function could be impaired due to the change of pressure while the aircraft is operated at different altitudes (13).

This study also indicates that the risk of hearing deficit increases with total flight time. Although the effect of total flight time on hearing deficit became statistically nonsignificant after adjustment for age, the “dose-response” pattern remained (13,14,22).

Since the data available for this study were collected through the FAA’s periodic medical examination for pilot license renewal, which is not specifically designed for audiology research, information regarding audiometric measurement, detailed classification of hearing deficits, and clinical features were not documented in the available database. Therefore, a well-designed observational study concentrated on the relationship between aviation noise and noise-induced hearing loss could not be conducted using the archived information. However, results from this study provided documentary incidence rates of hearing deficit in the defined occupational group during the process of aging. They may be helpful in generating hypotheses for future research on hearing problems among pilots.

Although hearing pathology is not necessarily equivalent to a clinical diagnosis of hearing impairment or permanent hearing loss, the FAA uses the pathology codes to determine whether the same grade of pilot license should be granted without safety concerns. With the mandated periodic medical examination, the FAA pilot regulation systems are able to detect early signs of hearing deficits before clinical signs and symptoms bring the pilot in for more serious health care. Thus, results of this study present very important information relevant to the early stages of hearing dysfunction development.

It is worth noting that total flight time at baseline is a crude measurement of exposure. It does not provide any information about off-job exposure to noise or the sources of noise during work time. In order to assess the association between noise exposure and hearing function, a better indicator is needed to measure the chronic noise exposure in pilots. Moreover, the FAA’s pathology code for hearing deficit does not differentiate cause-specific hearing problems, nor does it distinguish permanent hearing loss from transient hearing impairment. Future research should improve the measurement of both exposures and outcomes.

It has been found in the general population that hearing function may be impaired during the aging process and by exposure to noise. Our study indicates that hearing deficit is prevalent in commuter air carrier and air taxi pilots and that the risk of hearing deficit increases with advancing age. Effective programs for preventing hearing loss in this special occupational group are needed.

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References

1. Antuñaño, MJ.; Spanyers, JP. Oklahoma City, OK: Federal Aviation Administration, Civil Aerospace Medical Institute; Hearing and noise in aviation. Retrieved March 20, 2008 from the World Wide Web of Federal Aviation Administration:http://www.faa.gov/pilots/safety/pilotsafetybrochures/media/hearing_brochure.pdf
Publication Number:AM-400-98/3
2. Baker, SP.; O'Neill, B.; Ginsburg, MJ.; Li, G. The injury fact book. 2. New York: Oxford University Press; 1992.
3. Beringer, DB.; Harris, HC, Jr. A comparison of baseline hearing thresholds between pilots and non-pilots and the effects of engine noise. Washington, DC: FAA Office of Aviation Medicine; 2005. Report number DOT/FAA/AM-05/12
4. Borg E, Engstrom B. Damage to sensory hairs of inner hair cells after exposure to noise in rabbits without outer hair cells. *Hear Res* 1983;11:1-6. [PubMed: 6885646]
5. Büyükcakir C. Hearing loss in Turkish aviators. *Mil Med* 2005;170:572-6. [PubMed: 16130635]
6. Civil Aeromedical Institute. 1987 aeromedical certification statistical handbook. Washington, DC: Federal Aviation Administration; 1988.
7. Cruickshanks KJ, Wiley TL, Tweed TS, Klein BE, Klein R, Chappell R, et al. The 5-year incidence and progression of hearing loss: the epidemiology of hearing loss study. *Arch Otolaryngol Head Neck Surg* 2003;129:1041-6. [PubMed: 14568784]
8. Davis A. Population study of the ability to benefit from amplification and the provision of a hearing aid in 55-74-year-old first-time hearing aid users. *Int J Audiol* 2003;42(Suppl 2):2S39-52. [PubMed: 12918628]
9. Electronic Code of Federal Regulation (e-CFR,) United States Government Printing Office. Title 14: Aeronautics and Space; Part 67 —Medical Standards and Certification. Retrieved June 30, 2008 from the World Wide Web of National Archives and Records Administration:
<http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr;sid=a583618a877a1f452f9538134a7d3de3;rgn=div5;view=text;node=14>
10. Engstrom B, Borg E. Lesions to cochlear inner hair cells induced by noise. *Arch Otorhinolaryngol* 1981;230:279-84. [PubMed: 7023442]
11. Ferrite S, Santana V. Joint effects of smoking, noise exposure and age on hearing loss. *Occup Med* 2005;55:48-53.
12. Heagerty, P.; Liang, KY.; Zeger, SL.; Diggle, PJ. Analysis of longitudinal data. 2. New York: Oxford University Press; 2002.
13. Kuronen P, Sorri MJ, Paakkonen R, Muhli A. Temporary threshold shift in military pilots measured using conventional and extended high-frequency audiometry after one flight. *Int J Audiol* 2003;42:29-33. [PubMed: 12564513]
14. Kuronen P, Toppila E, Starck J, Paakkonen R, Sorri MJ. Modelling the risk of noise-induced hearing loss among military pilots. *Int J Audiol* 2004;43:79-84. [PubMed: 15035560]
15. Li G, Baker SP, Grabowski JG, Qiang Y, McCarthy ML, Rebok GW. Age, flight experience, and risk of crash involvement in a cohort of professional pilots. *Am J Epidemiol* 2003;157:874-80. [PubMed: 12746239]
16. Liu XZ, Yan D. Ageing and hearing loss. *J Pathol* 2007;211:188-97. [PubMed: 17200945]
17. Ma F, Gomez-Marin O, Lee DJ, Balkany T. Diabetes and hearing impairment in Mexican American adults: a population-based study. *J Laryngol Otol* 1998;112:835-9. [PubMed: 9876372]
18. Moscicki EK, Elkins EF, Baum HM, McNamara PM. Hearing loss in the elderly: an epidemiologic study of the Framingham Heart Study Cohort. *Ear Hear* 1985;6:184-90. [PubMed: 4043571]
19. National Institute for Occupational Safety and Health (NIOSH.). United States Department of Health and Human Services. Hearing Loss Research Program Review. Retrieved March 20, 2008 from the World Wide Web of Centers for Disease Control and Prevention:
http://www.cdc.gov/niosh/nas/hlr/wihlp_overview.html
20. National Institute for Occupational Safety and Health (NIOSH). United States Department of Health and Human Services. Work Related Hearing Loss. Retrieved March 20, 2008 from the World Wide Web of Centers for Disease Control and Prevention: <http://www.cdc.gov/niosh/01-103.html>

21. Occupational Safety and Health Administration (OSHA). Occupational Injury and Illness Recording and Reporting Requirements—Final Rule. Fed Regist 2002;44037–48. [PubMed: 12120663]
22. Raynal M, Kossowski M, Job A. Hearing in military pilots: one-time audiometry in pilots of fighters, transports, and helicopters. Aviat Space Environ Med 2006;77:57–61. [PubMed: 16422455]
23. Rosenhall U. The influence of ageing on noise-induced hearing loss. Noise Health 2003;5:47–53. [PubMed: 14558892]
24. Talbott E, Helmkamp J, Matthews K, Kuller L, Cottington E, Redmond G. Occupational noise exposure, noise-induced hearing loss, and the epidemiology of high blood pressure. Am J Epidemiol 1985;121:501–14. [PubMed: 3874543]
25. Tay HL, Ray N, Ohri R, Frootko NJ. Diabetes mellitus and hearing loss. Clin Otolaryngol Allied Sci 1995;20:130–4. [PubMed: 7634518]

TABLE 1
BASELINE CHARACTERISTICS AND INCIDENCE RATES OF HEARING DEFICIT IN A COHORT OF U.S. MALE COMMUTER AIR CARRIER AND AIR TAXI PILOTS, 1987–1997.

Characteristic	Total Number of Pilots (N = 3019)	Total Person-Years	Number of Pilots with Hearing Deficits	Rate/1000 Person-Years	P-value
Age (yr)					
45–49	2097	15,086	365	24.19	< 0.0001
50–54	922	5585	209	37.42	
Total Flight Time (h)					
<5000	625	4102	37	9.02	< 0.0001
5000–9999	898	6072	118	19.43	
10,000–14,999	986	6883	245	35.60	
≥ 15,000	510	3614	174	48.14	
History of Hearing Deficit					
No	2958	20,233	160	7.91	< 0.0001
Yes	61	438	414	945.96	

TABLE II
 CRUDE AND ADJUSTED RELATIVE RISKS (RR) AND 95% CONFIDENCE
 INTERVALS (CI) OF HEARING DEFICIT* IN A COHORT OF U.S. MALE
 COMMUTER AIR CARRIER AND AIR TAXI PILOTS, 1987–1997.

Characteristics	Crude		Adjusted	
	$\hat{R}R$	95% CI	$\hat{R}R$	95% CI
Age (yr)				
45–49	1.00		1.00	
50–54	1.14	0.95, 1.37	1.12	0.98, 1.30
55–59	1.39	1.11, 1.75	1.34	1.13, 1.59
60–64	1.74	1.18, 2.57	1.79	1.20, 2.67
Total Flight Time at Baseline (h)				
< 5000	1.00		1.00	
5000–9999	1.66	0.67, 4.08	1.32	0.71, 2.47
10,000–14,999	2.77	1.18, 6.51	1.37	0.76, 2.47
≥ 15,000	4.27	1.79, 10.17	1.55	0.83, 2.90
History of Hearing Deficit				
No	1.00		1.00	
Yes	116.61	80.39, 169.14	99.28	66.30, 148.66

* Estimated from Poisson regression analysis using generalized estimating equations.