Risk Factors for Hearing Decrement Among U.S. Air Force Aviation-Related Personnel

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INTRODUCTION: The purpose of this study was to analyze historical hearing sensitivity data to determine factors associated with an occupationally significant change in hearing sensitivity in U.S. Air Force aviation-related personnel.

METHODS: This study was a longitudinal, retrospective cohort analysis of audiogram records for Air Force aviation-related personnel on active duty during calendar year 2013 without a diagnosis of non-noise-related hearing loss. The outcomes of interest were raw change in hearing sensitivity from initial baseline to 2013 audiogram and initial occurrence of a significant threshold shift (STS) and non-H1 audiogram profile. Potential predictor variables included age and elapsed time in cohort for each audiogram, gender, and Air Force Specialty Code. Random forest analyses conducted on a learning sample were used to identify relevant predictor variables. Mixed effects models were fitted to a separate validation sample to make statistical inferences.

RESULTS: The final dataset included 167,253 nonbaseline audiograms on 10,567 participants. Only the interaction between time since baseline audiogram and age was significantly associated with raw change in hearing sensitivity by STS metric. None of the potential predictors were associated with the likelihood for an STS. Time since baseline audiogram, age, and their interaction were significantly associated with the likelihood for a non-HI hearing profile.

DISCUSSION: In this study population, age and elapsed time since baseline audiogram were modestly associated with decreased hearing sensitivity and increased likelihood for a non-H1 hearing profile. Aircraft type, as determined from Air Force Specialty Code, was not associated with changes in hearing sensitivity by STS metric.

KEYWORDS: audiogram, cohort analysis, hearing thresholds, hearing profile, standard threshold shift, significant threshold shift, aviators, hearing conservation, occupational health.

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Hearing sensitivity in U.S. Air Force (USAF) personnel performing aviation-related duties is assessed on an annual basis using air conduction pure tone audiometry for two reasons. First, hearing sensitivity is measured as part of a medical surveillance exam to screen for evidence of hearing loss occurring in association with exposures to environments in which potentially hazardous noise is present. Second, hearing sensitivity is measured as part of a fitness for duty exam to determine that minimum occupational standards are met. The annual periodicity of hearing sensitivity assessments accomplished within the context of a medical surveillance program is prescribed by law and associated policy (i.e., Department of Defense Instruction 6055.12 and Air Force Instruction 48-127). The periodicity of hearing sensitivity assessments accomplished for fitness for duty exams defaulted to an annual basis, primarily because the medical surveillance and fitness for duty exams are concurrently accomplished.

Given technological trends (e.g., proliferation of remotely piloted aircraft, etc.), however, a growing portion of USAF personnel performing aviation-related duties no longer works in an environment where occupationally generated hazardous noise exposures exist. Additionally, during a typical career, many personnel performing aviation-related duties have assignments

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where they are not exposed to occupationally generated hazardous noise. In these cases, personnel only require a fitness for duty exam, in which case we need to answer the question of the necessary frequency of the hearing sensitivity assessment. Presently, there are no longitudinal analyses of hearing sensitivity data to guide evidence-based decision making on the periodicity of the hearing sensitivity assessment within the annual fitness for duty exam. Furthermore, as the age of precision medicine dawns, the question should be asked whether there are identifiable factors that allow tailoring of population-level guidance for the individual service member. The purpose of this study is to perform a longitudinal analysis of available historical hearing sensitivity data to determine factors associated with an occupationally significant change in hearing sensitivity by a specific metric sensitive to changes in hearing from hazardous noise exposure.

METHODS

Subjects

This study was conducted under a human-use protocol approved by the 711th Human Performance Wing Institutional Review Board. A waiver of informed consent of participants was granted due to the impracticality of obtaining written consent from each subject in the study population. This study was a longitudinal, retrospective cohort analysis of USAF aviation-related personnel on active duty during calendar year 2013. Archival data were extracted from the following four databases: Air Force Personnel Center, Complete Ambulatory Patient Encounter Record,[4] Defense Occupational and Environmental Health Readiness System-Hearing Conservation Data Repository (DOEHRS-HC DR),[16] and the Aviation Resource Management System. Social Security numbers were used to match participant data across the four datasets and were then removed from the study dataset to ensure de-identification.

This study was open to USAF aviation-related personnel on active duty during calendar year 2013 as identified from Air Force Personnel Center data. Participants were included in the study if they were in the following Air Force Specialty Code (AFSC) defined career fields as aviators or aircrew:

- Officer: 11A airlift pilot; 11B bomber pilot; 11E experimental test pilot; 11F fighter pilot; 11G generalist pilot; 11H helicopter pilot; 11K trainer pilot; 11M mobility pilot; 11R reconnaissance/surveillance/electronic warfare pilot; 11S special operations pilot; 11T tanker pilot; 11U remotely operated aircraft pilot; 12A airlift navigator; 12B bomber combat systems operator; 12E experimental test combat systems officer; 12F fighter combat systems officer; 12G generalist combat systems officer; 12K trainer combat systems officer; 12M mobility combat systems officer; 12R reconnaissance/surveillance/electronic warfare combat systems officer; 12S special operations combat systems officer; 12U remotely operated aircraft pilot; 13A astronaut; 13B air battle manager; 13D control and recovery; 13L air liaison officer; 13M airfield operation; 13S space and missile; 15W weather; 18A attack remotely piloted aircraft pilot; 43A aerospace and operational physiologist; 46F flight nurse; 48A aerospace medicine specialist; 48G general medical officer flight surgeon; 48R residency trained flight surgeon; and 48V pilot-physician.
- Enlisted: 1A0 in-flight refueling; 1A1 flight engineer; 1A2 aircraft loadmaster; 1A3 airborne mission system; 1A4 airborne operations; 1A6 flight attendant; 1A7 aerial gunner; 1A8 airborne cryptologic linguist; 1C1 air traffic control; 1C2 combat control; 1C4 tactical air control party; 1C5 command and control battle management operations; 1C6 space systems operations; 1T0 survival, evasion, resistance and escape; 1T2 pararescue; 1U0 career RPA sensor operator; 1W0 weather; and 4M0 aerospace and operational physiology.

Participants were excluded from the study if they: 1) had a diagnosis of hearing loss due to causes other than noise exposure as determined from Complete Ambulatory Patient Encounter Record data; or 2) lacked an initial baseline audiogram for each ear in DOEHRS-HC DR. The following International Classification of Diseases, Ninth Revision, codes were used as exclusion criteria in an effort to eliminate participants with non-noise-related hearing loss: 385 (other disorders of middle ear and mastoid), 386 (vertiginous syndromes and other disorders of the vestibular system), 387 (otosclerosis), 388.00 (degenerative and vascular disorders, unspecified), 388.02 (transient ischemic deafness), 388.5 (disorders of the acoustic nerve), 389.0 (conductive hearing loss), 389.7 (deaf nonspeaking, not elsewhere classifiable), 389.8 (other specified forms of hearing loss), or 389.9 (unspecified hearing loss). Participants entered the study cohort based on the date of the first baseline audiogram as recorded in DOEHRS-HC DR.

Procedure

Participant audiogram records were obtained from DOEHRS-HC DR; all available audiogram records were included provided an initial baseline audiogram was available for comparison. Each audiogram record contained the assessment date and the participant's detection thresholds in each ear in decibels hearing level (dB HL) for pure tone signals at 500, 1000, 2000, 3000, 4000, and 6000 Hz measured using a modified Hughson-Westlake procedure with an automated microprocessor audiometer. The outcomes of interest were the first occurrence of an audiogram exhibiting a significant threshold shift (STS) or a non-H1 hearing profile.

An STS is defined by the Occupational Safety and Health Administration as a change in hearing, relative to the baseline, averaging ≥10 dB HL within the range of 2000–4000 Hz in at least one ear. In this study, a raw change score (RCS) was calculated for each participant p in ear e for an audiogram accomplished at visit v relative to the initial baseline audiogram (defined as the first initial baseline on record) ($v = 0$):

$$RCS_{p,e,v} = \frac{1}{3}\sum_{f} Threshold_{p,e,v} - \frac{1}{3}\sum_{f} Threshold_{p,e,0},$$

where $f = \{2000\text{ Hz}, 3000\text{ Hz}, 4000\text{ Hz}\}$ is the set of pure tone frequencies used in the Occupational Safety and Health Administration definition for STS. The first audiogram with an RCS $\geq$10 dB HL was considered an STS. A binary indicator variable, $STS_{p,e,v}$, was used to indicate whether or not participant *p* had an STS for ear *e* during visit *v*.

Per USAF physical standards, an H1 hearing profile is considered occupationally acceptable. A hearing profile is not H1 if the listener's detection threshold is $>$25 dB HL at 500, 1000, or 2000 Hz; $>$35 dB HL at 3000 Hz; or $>$45 dB HL at 4000 or 6000 Hz. A binary indicator variable, $H1_{p,e,v}$, was used to indicate whether or not participant *p* had an H1 profile for ear *e* during visit *v*.

Explanatory variables in this study included age, elapsed time in cohort for each audiogram, gender, and AFSC. Age at each audiogram was calculated based on participant age recorded in the Aviation Resource Management System. Elapsed time in cohort for each participant was calculated as the number of years since the initial baseline audiogram. Both gender and AFSC were available for each audiogram archived in DOEHRS-HC DR.

Statistical Analysis

All analyses were accomplished using R version 3.3.0.[11] A power analysis was performed to determine an approximate sample size necessary to detect a small to medium effects size ($R^2 \approx 5\%$) with 80% power using a significance level of 0.01 and eight predictors.[2] A significance level of 0.01 was chosen because of the large dataset available and to increase the sample size of the validation set (discussed later), thereby making the regression models with random effects more stable. The eight predictors were age, time since baseline audiogram, gender, and the five most influential AFSCs. The study investigators decided to include only the top five AFSCs based on initial data exploration and application of the Pareto principle to the random forest variable importance results (i.e., these predictors accounted for roughly 80% of the relative influence for each response).

The results of the power analysis indicated that at least 1500 observations were required. Based on the resulting sample size requirement, the study dataset was randomly partitioned into two samples: a learning sample for exploratory analysis (165,708 observations on 10,469 participants) and a validation sample for model building and statistical inference (1545 observations on 100 participants). Nonparametric methods were used for the exploratory analysis and parametric methods were used for model building and statistical inference given the greater ease of interpretation of the latter (e.g., standard errors, *P*-values, etc.). Separating variable selection and model building ensured that the reported standard errors, and hence the corresponding 99% confidence intervals and *P*-values, were valid. Additionally, the use of a smaller dataset for model building controlled for the effect of sample size on *P*-values.

Random forests,[1] a machine learning algorithm, were used for exploratory analysis on the learning sample. The random forest variable importance capability was used to select the most influential predictors to include in the parametric analysis based on the method described by Hastie and colleagues.[6] Larger variable importance scores suggest greater importance in terms of predicting the response. Excluding ear (which was treated as a random effect), the eight most important predictors were selected for inclusion in the parametric analyses. Parametric, mixed-effects models[8] were then used to model the validation samples: a linear mixed-effects model (LMM) was used to model RCS and generalized linear mixed-effects models (GLMM) were used to model the probability of an STS and a non-H1 hearing profile. Participant and ear (left vs. right) were used as random classification factors because they are associated with repeated measures on the individual experimental units. Partial dependence plots[6] were used to interpret the marginal effect of the statistically significant terms in the mixed-effects models.

RESULTS

After removing 1417 participants based on exclusion criteria, the final dataset included 167,253 nonbaseline audiograms on 10,569 participants for an average of about 16 observations per participant. **Table I** describes selected characteristics of the study cohort.

The random forest for modeling RCS obtained a cross-validated R^2 of 16.8%; that is, the included predictors explained roughly 16.8% of the variance in RCS while participants were in the cohort. The random forests for modeling the probability of an STS and non-H1 profile obtained cross-validated prediction errors of 19.92% and 20.69%, respectively; the models correctly predicted STS 80.08% of the time and hearing profile type (H1 vs. non-H1) 79.31% of the time. The variable importance scores for the top eight predictors in each model are displayed in **Fig. 1**. The plots indicated that time since baseline audiogram and age were the most important predictors for RCS, probability of a STS, and probability of a non-H1 hearing profile, followed thereafter by gender and AFSC.

The LMM for RCS included time since baseline audiogram, age, gender, and the top five AFSCs discovered by the random forest [i.e., 1A1 (flight engineer), 11A (airlift pilot), 11B (bomber pilot), 11F (fighter pilot), and 11M (mobility pilot)], as well as an interaction term for time since baseline audiogram and age. Participant and ear, nested within participant, were included as random classification factors and only contributed to the estimated within subject correlation structure. The intercept was allowed to vary between participants, leading to a compound symmetry correlation structure. **Table II** displays the estimated regression coefficients, including approximate standard errors and *P*-values. Only the interaction between time since baseline audiogram and age was significantly associated with RCS at the 0.01 level.

The GLMM for probability of STS included time since baseline audiogram, age, gender, and five of the AFSCs discovered by the random forest [i.e., 1A2 (aircraft loadmaster), 1A3 (airborne mission system), 11A (airlift pilot), 1A0 (in-flight refueling), and 11F (fighter pilot)]. As with the LMM for RCS, participant and ear, nested within participant, were included as

Table I. Study Cohort Characteristics.

		STS*		NON-H1 HEARING PROFILE	
VARIABLE	**COHORT TOTAL**	**YES**	**NO**	**YES**	**NO**
N (%)	10,547 (100)	2215 (21.00)	8332 (79.00)	1109 (10.51)	9438 (89.49)
Male, no. (%)	9589 (90.92)	2111 (22.01)	7478 (77.99)	1066 (11.12)	8523 (88.88)
Age, yr, mean (SD)†	24.51 (4.24)	25.43 (4.51)	24.26 (4.13)	25.62 (5.11)	24.37 (4.10)
Age, yr, median (IQR)†	24 (4)	25 (4)	24 (5)	25 (6)	24 (4)
Time in cohort, yr, median (IQR)	8.06 (8.60)	5.98 (7.10)	–	3.38 (7.68)	–
AFSC, no. (%)					
11X	3270 (31.00)	962 (29.42)	2308 (70.58)	416 (12.72)	2854 (87.28)
12X	893 (8.47)	243 (27.21)	650 (72.79)	105 (11.76)	788 (88.24)
13X	1084 (10.28)	234 (21.59)	850 (78.41)	126 (11.62)	958 (88.38)
15X	11 (0.10)	3 (27.27)	8 (72.73)	1 (9.09)	10 (90.91)
18X	2 (0.02)	0 (0)	2 (100)	0 (0)	2 (100)
1AX	4475 (42.43)	609 (13.61)	3866 (86.39)	353 (7.89)	4122 (92.11)
1BX	1 (0.01)	0 (0)	1 (100)	0 (0)	1 (100)
1CX	93 (0.08)	15 (16.13)	78 (83.87)	11 (11.83)	82 (88.17)
1TX	250 (2.37)	56 (22.40)	194 (77.60)	31 (12.40)	219 (87.60)
1UX	84 (0.80)	9 (10.71)	75 (89.29)	5 (5.95)	79 (94.05)
1WX	4 (0.04)	2 (50.00)	2 (50.00)	0 (0)	4 (100)
43X	5 (0.05)	1 (20.00)	4 (80.00)	1 (20.00)	4 (80.00)
46X	115 (1.09)	20 (17.39)	95 (82.61)	13 (11.30)	102 (88.70)
48X	239 (2.27)	57 (23.85)	182 (76.15)	46 (19.25)	193 (80.75)
4MX	21 (0.20)	4 (19.05)	17 (80.95)	1 (4.76)	20 (95.24)
RCS, mean (SD)					
Left ear	1.06 (5.67)	5.86 (7.29)	-0.22 (4.33)	4.61 (9.75)	0.64 (4.80)
Right ear	1.03 (5.34)	5.44 (6.71)	-0.15 (4.19)	4.15 (8.80)	0.66 (4.63)

* As calculated from initial baseline audiogram.

† Age at time of baseline audiogram.

IQR = interquartile range; SD = standard deviation.

random classification factors, allowing the intercept to vary appropriately between participants. A model convergence issue occurred when fitting the GLMM due to quasi-complete separation. This phenomenon happens when the binary outcome variable separates some combination of the explanatory variables to a certain degree. Employing a Bayesian solution by adding weak priors to the fixed-effect parameters was tried to mitigate this issue. It resolved the abnormally large standard errors, but did not result in model convergence. Given the small relative influence of AFSC on the response variable (see Fig. 1), the AFSC predictor variables with abnormally large standard errors were removed one by one until the model converged and reasonable standard errors were obtained. Removal of the 11F (fighter pilot) AFSC resolved the model convergence issue. **Table III** displays the resulting estimated regression coefficients, including approximate standard errors and *P*-values. No variables were significantly associated with likelihood for a STS at the 0.01 level.

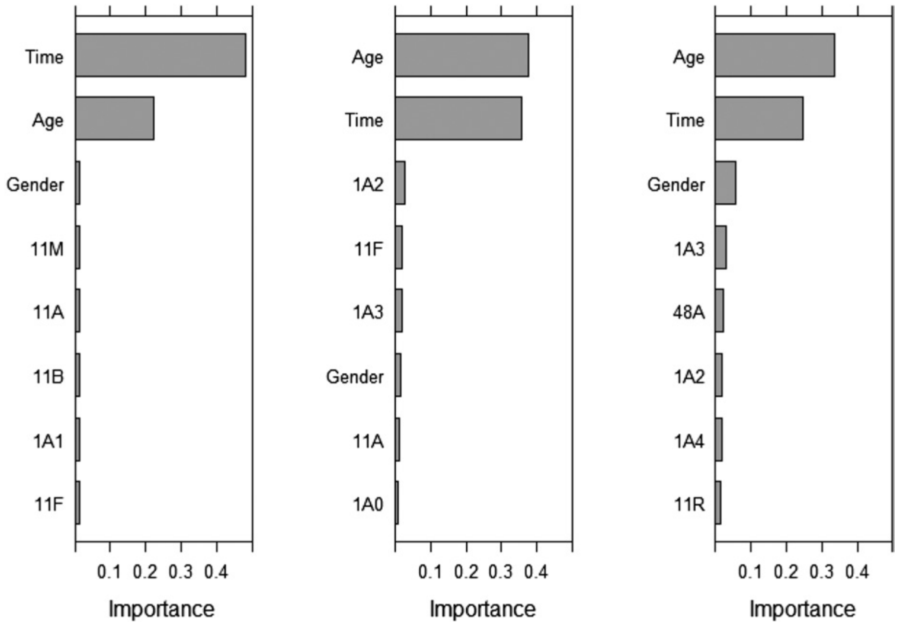

Fig. 1. Random forest variable importance scores for the following outcomes: raw change score (left plot), probability of a significant threshold shift (middle plot), and probability of a non-H1 profile (right plot). Larger variable importance scores suggest greater importance in terms of predicting the response. Plots were limited to eight predictors: age, time since baseline audiogram, gender, and the five most influential Air Force Specialty Codes.

The GLMM for probability of non-H1 hearing profile included time since baseline audiogram, age, gender, and five of the AFSCs discovered by the random forest [i.e., 1A2 (aircraft loadmaster), 1A3 (airborne mission system), 1A4 (airborne operations), 11R (reconnaissance/surveillance/electronic warfare pilot), and 48A (aerospace medicine specialist)]. Again, participant and ear, nested

Table II. Fixed Effects Estimates for the LMM for RCS Fit to the Validation Sample.

VARIABLE	$\hat{\beta}$	SE ($\hat{\beta}$)	*P*-VALUE	LOWER 99%	UPPER 99%
(Intercept)	−1.582	1.966	0.423	−6.646	3.482
Time	−0.181	0.134	0.178	−0.527	0.165
Age	0.005	0.067	0.935	−0.167	0.178
Time × Age	0.010	0.003	0.001	0.003	0.018
Gender (Male)	1.172	1.168	0.318	−1.837	4.181
AFSC:					
11A	−0.341	0.849	0.688	−2.529	1.846
11B	−0.195	0.907	0.830	−2.532	2.143
11F	−0.054	0.527	0.918	−1.412	1.303
11M	−0.494	0.888	0.578	−2.783	1.794
1A1	1.242	0.988	0.209	−1.303	3.787

within participant, were included as random classification factors, allowing the intercept to vary appropriately between participants. As with the prior GLMM, model convergence issues occurred and were addressed in the same manner; removing the AFSC predictor variables for 1A3 (airborne mission system), 11R (reconnaissance/surveillance/electronic warfare pilot), and 48A (aerospace medicine specialist) allowed the model to converge with reasonable standard errors. **Table IV** displays the resulting estimated regression coefficients, including approximate standard errors and *P*-values. Time since baseline audiogram, age, and their interaction were significantly associated with likelihood for a change in hearing profile at the 0.01 level.

Based on the nonparametric analyses, time since initial baseline audiogram and age were both positively associated with RCS and likelihood for an STS and a non-H1 hearing profile. The random forest-based marginal effect of time since baseline audiogram and age on RCS is graphically shown in the left side of **Fig. 2**. The contour lines (solid black curves) correspond to predicted RCS in integer values from 0–7. Similarly, the marginal effects of time since baseline audiogram and age on the probability of a STS and non-H1 hearing profile are graphically shown in the middle and right sides of Fig. 2, respectively. The contour lines correspond to predicted probabilities of 0.3, 0.4, 0.5, 0.6, and 0.7.

DISCUSSION

For the population of USAF aviation-related personnel included in this study, the observed change in hearing threshold was small during the first 20 yr of an individual's career and before age 50. Age and elapsed time since initial baseline audiogram were both positively associated with increased hearing thresholds and likelihood for a non-H1 hearing profile. However, age and elapsed time since baseline audiogram were not significantly linearly associated with likelihood for an STS at the 0.01 level. Aircraft type, as determined from AFSC, was not associated with any of the hearing-related outcomes of interest, which is noteworthy since some aviation-related occupations are not associated with workplace hazardous noise and so differences based on aircraft type were expected. Additionally, as assessed in the random forests, less than one-quarter of the variability in hearing sensitivity was explained by the factors assessed in this study, suggesting the majority of the change in hearing sensitivity is caused by other factors not assessed in this study or by the method the STS metric was defined by in this study.

The observed associations between both hearing threshold changes and probability for a non-H1 hearing profile with age and elapsed time since initial baseline audiogram, as well as the absence of associations with AFSC, give rise to several explanatory hypotheses. First, the observed changes over time could simply reflect presbyacusis[17] and general, nonoccupational noise exposures.[10] Second, AFSC was an inadequate surrogate[7] for occupational noise exposure, which can vary based on a confluence of factors, including aircraft type, crew position, mission profile, etc. This hypothesis would explain the observed variability across the outcome measures in terms of the five most influential AFSCs identified based on the random forest models. Third, unmeasured, non-aviation-related noise was the primary driver for the observed changes.[14] None of these hypotheses can be resolved until total (i.e., occupational and nonoccupational) noise exposures are adequately characterized and measured and correlated with changes in hearing sensitivity. Additionally, the absence of any observed associations with the outcome of probability of a STS raises the hypothesis that individual differences in susceptibility to noise-induced hearing loss (i.e., intrinsic factors) may play a significant role.[3,15] Taken in aggregate, while it is suspected that including flight hours (i.e., duration of exposure) would marginally improve model performance, more research is required before it will be possible to take a precision medicine based approach and individually tailor audiometric testing for airmen.

Consistent with the above conclusions, the published literature on noise-induced hearing loss among military aviation-related personnel is varied. Ribak and colleagues[13] conducted a retrospective cohort analysis of Israeli Air Force pilots and navigators to evaluate the relationship

Table III. Fixed-Effects Estimates for the GLMM for Probability of an STS Fit to the Validation Sample.

VARIABLE	$\hat{\beta}$	SE ($\hat{\beta}$)	*P*-VALUE	LOWER 99%	UPPER 99%
(Intercept)	−4.978	2.567	0.053	−11.591	1.636
Time	0.053	0.113	0.635	−0.237	0.344
Age	−0.028	0.085	0.743	−0.246	0.191
Time × Age	0.004	0.002	0.034	−0.001	0.008
Gender (Male)	−0.138	1.362	0.920	−3.647	3.372
AFSC:					
1A2	−0.446	1.106	0.687	−3.295	2.403
11F	-	-	-	-	-
1A3	−0.840	1.370	0.540	−4.369	2.690
11A	−0.253	0.493	0.608	−1.523	1.017
1A0	−2.241	1.241	0.071	−5.438	0.957

Table IV. Fixed-Effects Estimates for the GLMM for Probability of a Non-H1 Hearing Profile Fit to the Validation Sample.

VARIABLE	$\hat{\beta}$	S.E. ($\hat{\beta}$)	*P*-VALUE	LOWER 99%	UPPER 99%
(Intercept)	−17.323	2.916	0.000	−24.834	−9.811
Time	0.637	0.234	0.007	0.034	1.240
Age	0.272	0.099	0.006	0.018	0.527
Time × Age	-0.017	0.006	0.003	−0.031	−0.002
Gender (Male)	-	-	-	-	-
AFSC:					
1A3	-	-	-	-	-
48A	-	-	-	-	-
1A2	2.096	1.235	0.090	−1.085	5.277
1A4	3.608	1.679	0.032	−0.716	7.932
11R	-	-	-	-	-

between age, flying time, and aircraft type as factors for hearing loss. They based their analysis on audiometric records of 777 aircrew members that comprised annual audiograms from recruitment to the time of the study. Using two different criteria for categorizing hearing loss, they determined the prevalence of hearing loss was 13.5% (USAF criteria) and 23% (acoustic trauma criteria), with most being mild damage (10.9% and 19.7%, respectively). Based on a multivariate analysis, it was shown that age was strongly associated with values of hearing threshold shift between first and last audiogram, while aircraft type and accumulated flying time exhibited only a weak association. They concluded that hearing loss was not significantly affected by aircraft type or duration of exposure, but rather resulted from the biological process of aging.

Fitzpatrick,[5] in response to the study by Ribak and colleagues,[13] conducted a retrospective cohort analysis of U.S. Army helicopter pilots in a single brigade to ascertain the relative contributions of age, flight hours, type of aircraft, and type of hearing protection to hearing loss. He based his analysis on the results of a medical records review of 178 pilots that included initial and most recent audiograms as well as questionnaire data. Using two different criteria for categorizing hearing loss, he determined the prevalence of hearing loss was 8.4% (U.S. Army criteria) and 29.7% (American Academy of Otolaryngology-Head and Neck Surgery criteria). Based on a multivariate analysis, it was shown that both age and flight hours were significantly associated with hearing loss, especially in the high frequency range; there was a minimal association between hearing loss and hearing protection and no association with aircraft type. He concluded that hearing loss in Army aviators was mainly a function of helicopter noise exposure, as measured by flying hours, and the effects of age were also a contributing factor.

Raynal and colleagues[12] conducted a cross-sectional analysis of French pilots to assess the prevalence of hearing loss and associated risk factors for abnormal hearing (defined as a hearing threshold ≥20 dB). They based their analysis on audiometric and questionnaire data gathered from a convenience sample of 521 pilots during their annual flying medical examination. Overall, abnormal hearing levels were found at higher frequencies with a marked notch on audiograms at 6 kHz, and left ears had significantly poorer performance compared with right ears. The prevalence of pilots who had abnormal hearing was 30.1%, with an age-stratified prevalence of 19% and 38% for 20- to 30-yr-olds and 30- to 40-yr-olds, respectively. Helicopter pilots had a significantly higher prevalence of abnormal hearing (55%) compared to fighter (36%) and transport (34%) pilots, while transport pilots had significantly more flight hours as compared to fighter and helicopter pilots. When the analysis was stratified by aircraft category, an age effect was observed only for fighter pilots.

Lastly, Orsello and colleagues[9] compared mean annual sensorineural hearing loss incidence rates among U.S. military aviators between 1997 and 2011 to determine if there was an effect of aircraft type (fixed vs. rotary wing) and service branch. They data mined a large medical epidemiological database that captured 467,064 person-years of observations. Based on multivariate analysis, it was shown that incidence rates were higher for Army and Air Force aviators relative to Navy and Marine Corps aviators. Incidence rates were also higher among fixed wing compared to rotatory wing aviators, and the difference increased with age.

This study adds to the existing literature by analyzing a comparatively large, longitudinal dataset comprising the population of USAF aviation-related personnel on active duty in

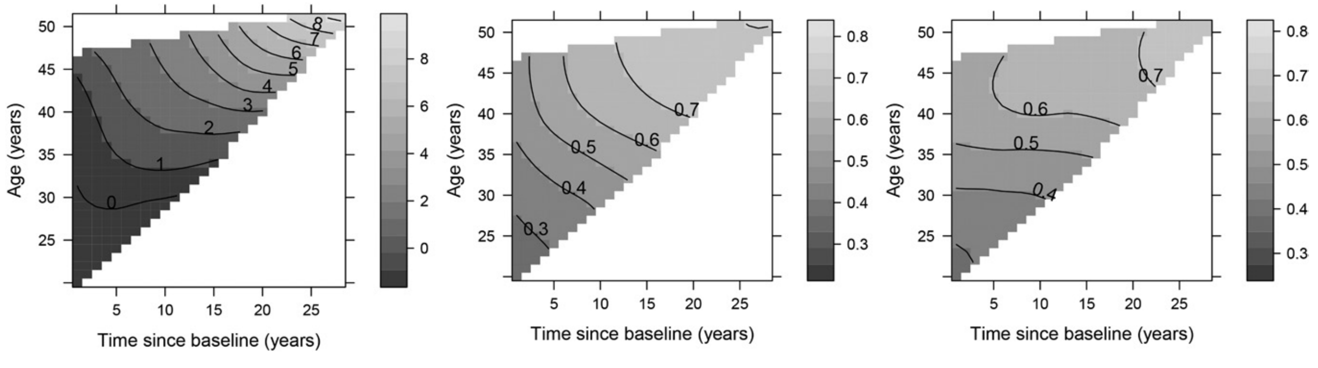

Fig. 2. Marginal effect plots of time since baseline audiogram and age on raw change score (left), probability of a STS (middle), and probability of a non-H1 hearing profile (right).

calendar year 2013 and employing more sophisticated analytic methods that allowed a relatively granular view of variables such as aircraft type as determined by AFSC. The results of this study, however, must be considered in the context of study limitations. This study used an observational design, so the authors cannot account for unmeasured confounding due to factors that may have been associated with changes in hearing thresholds.[7] For example, use of hearing protection and actual exposures to both occupational and nonoccupational noise may have influenced the results. While hearing protection device data are available in DOEHRS-HC DR, the data are believed to be of low reliability and only reflect reported use. Additionally, data on nonoccupational noise exposures are not routinely collected.

In conclusion, among the population of USAF aviation-related personnel on active duty in 2013, age and elapsed time since initial baseline audiogram were both positively associated with increased hearing thresholds and likelihood for a non-H1 hearing profile. Aircraft type as determined from AFSC was not associated with changes in hearing as measured by study metrics. A well-designed prospective cohort analysis is needed to determine actual noise exposure and its contribution to changes in hearing thresholds.

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