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A Longitudinal Study on Hearing Loss in South Korean Air Force Pilots: Evidence from Electronic Medical Records

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ABSTRACT

Hearing loss is known to be one of the most common diseases that can occur among Air Force pilots. Since treatment for hearing loss varies greatly depending on the cause, an accurate diagnosis of the cause is important. However, few studies have comprehensively analysed the causes of hearing loss in Air Force pilots. Therefore, the purpose of this study is to contribute to the prevention of hearing loss by identifying the vulnerability of hearing loss in Air Force pilots in the long term through the analysis of Electronic Medical Records (EMRs). This study analysed the EMRs of Air Force pilots from 2012 to 2023 in South Korea. The EMRs included pilot demographic information as well as the results for each indicator of the general check, blood test, urine test, and Pure Ton Audiometry (PTA) test. Results of data analysis show that pilots who were older, had propeller aircraft types, and had a total flight time of 2,001 to 3,000 hours had a high rate of hearing loss. In addition, pilots with hearing loss were found to have both systolic and diastolic blood pressures outside the normal range. In particular, diastolic blood pressure and glucose levels showed a significant positive correlation with both left and right hearing test results in the high frequency range. In terms of PTA tests, pilots with hearing loss mainly exceeded the criteria in the left ear and high frequency range, and the C5-dip and asymmetry phenomenon were partially identified. The results of this study show the possibility of predicting hearing loss disease for Air Force pilots or suggesting medical treatment guidelines through the analysis of EMRs.

Keywords: Hearing loss, Air force pilot, Electronic medical records

INTRODUCTION

Hearing loss, a symptom of difficulty hearing sounds, is one of the most prevalent disorders that can affect Air Force pilots. People with hearing loss might perceive sounds as weak, distant, or less clear. It is essential for Air Force pilots to have sufficient hearing ability to recognize and understand common conversations and warning sounds in order to effectively complete perform flight missions. However, Air Force pilots are susceptible to hearing loss due to the nature of their work environment. Thus, preventive strategies

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and early detection of hearing loss in Air Force pilots are crucial since it is difficult to recover from impaired hearing ability (Muhr et al., 2019).

Since hearing loss can be caused by many different factors and treatment varies depending on the cause, an accurate diagnosis is critical. There are three types of hearing loss: conductive, sensorineural, and mixed hearing loss (Zahnert, 2011). Conductive hearing loss occurs in the outer or middle ear where sound waves cannot carry all the way through to the inner ear. It can be a result of earwax, ruptured eardrum, fluid, tumors, infection or a bone abnormality. Sensorineural hearing loss, the most common type of hearing loss, occurs when the inner ear or the hearing nerve itself is injured. It can be caused by aging, noise exposure, certain drugs, injury, disease or an inherited condition. Mixed hearing loss occurs in a combination of conductive and sensorineural hearing loss.

Although identifying the causes of hearing loss is important, existing studies were insufficient in terms of systematically and multifacetedly analysing the causes of hearing loss in Air Force pilots. More specifically, most previous studies focused on evaluating Pure Tone Audiometry (PTA) data to determine the cause of hearing loss in pilots. PTA is a test that measures hearing threshold by electrically generating pure tones using audiometer and adjusting the sound intensity for each frequency band (Corry et al., 2017). The hearing thresholds at each frequency band are measured by having the test subject wear a headset in a soundproof room and respond to auditory stimuli presented to the left and right ears. However, it can be difficult to determine the precise cause of hearing loss solely using PTA results, necessitating the concurrent collection and analysis of multiple types of data. Recent studies, on the other hand, are attempting to predict the cause of specific diseases using Electronic Medical Records (EMRs), which are unstructured and structured data sets of patient health information. Therefore, using EMRs can be helpful to gain a deeper understanding of the causes of hearing loss among Air Force pilots.

The goal of this study is to prevent hearing loss in Air Force pilots by analyzing EMRs to identify long-term vulnerability. The investigation includes a thorough analysis of PTA data, pilot demographics, and physical examination results in EMRs. This study can contribute to establishing fundamental data for hearing management of Air Force pilots by evaluating risk factors for hearing loss based on EMRs.

MATERIALS AND METHODS

This study analysed the EMRs of Air Force pilots who underwent regular physical examinations at the Republic of Korea Air Force Aerospace Medical Centre from 2012 to 2023. At first, hearing loss-related factors were selected from EMRs in order to conduct a study on pilot hearing loss. More specifically, the indicators were determined by performing a relevance assessment (literature reviews related to hearing loss, interviews with medical professionals) and data quality evaluation (check for data type, redundancy, and error rate). The final selected indicators included three pilot demographics (age, aircraft type, and total flight time), 20 physical examination results (measured values through general check, blood test, and urine test), and 12 PTA outcomes (hearing thresholds for left and right ear at 500, 1,000, 2,000, 3,000, 4,000, and 6,000 Hz frequencies).

Next, pre-processing on the EMRs was performed to improve the efficiency of data analysis. The data cleansing process was carried out by removing incorrect data and integrating redundant data among EMRs. As a result of pre-processing, the total quantity of data was reduced from 48,931 to 16,990 before and after pre-processing. In addition, the pre-processed data corresponded to a total of 5,097 pilots (the number of data: 16,990), of which 5,041 pilots (the number of data: 16,753) were normal and 56 pilots (the number of data: 237) were diagnosed with hearing loss.

Lastly, the statistical analysis was performed on pilot demographic indicators using the Chi-square goodness of fit test at a significance level of 0.05 for each group. In this case, the theoretical distribution assumed that the frequencies for each group were the identical. For physical examination indicators, descriptive statistics (mean, standard deviation) were calculated for each indicator of both pilots without and with hearing loss. Besides, Pearson correlation analysis was performed at a significance level of 0.05 in order to confirm the association between physical examination and PTA indicators. For PTA indicators, descriptive statistics (mean, standard deviation) were calculated for the hearing thresholds on left and right ear for each frequency for both pilots without and with hearing loss. Additionally, the Chi-square test of homogeneity was performed at a significance level of 0.05 to determine whether there were differences in the frequency band, pattern, and symmetry features of the PTA indicators of the pilots with hearing loss between the left and right ears. This study was performed with prior approval from the Institutional Review Board (IRB) of the Republic of Korea Air Force Aerospace Medical Centre (approval number: ASMC-23-IRB-08).

RESULTS

Pilot Demographic Indicators

There was a statistically significant difference in the frequency of each group of pilots with hearing loss in terms of age, aircraft type, and total flight time (age: $\chi^2 = 60.429$, $df = 3$, $p < 0.001$; types of aircraft: $\chi^2 = 28.857$, $df = 3$, $p < 0.001$; total flight time: $\chi^2 = 21.321$, $df = 4$, $p < 0.001$). In terms of age, the rate of hearing loss tended to increase progressively with age (see Table 1). In terms of aircraft type, the rate of hearing loss in the propeller aircraft type was found to be relatively high, despite the fact that the total number of Republic of Korea Air Force pilots in the propeller aircraft groups (cargo/transport, helicopter, and prop trainer) is much lower than that of the pilots in the fixed-wing aircraft (fighter/attack) group (see Table 2). In particular, the helicopter pilots showed the highest rate of hearing loss among the propeller aircraft groups. In terms of total flight time, the group with a total flight time of 2,001 to 3,000 hours had the highest rate of hearing loss (see Table 3).

Physical Examination Indicators

While the mean values of all physical examination indicators for normal pilots were within a normal range, the mean systolic and diastolic blood pressures for pilots with hearing loss were found to be abnormal (see Table 4). On the other hand, the results of Pearson correlation analysis showed that the correlation between all physical examination and PTA indicators was statistically significant with a low correlation coefficient of $r = \pm 0.1$ or below. For the hearing thresholds on left and right ear in the high frequency band (4,000 Hz, 6,000 Hz), however, diastolic blood pressure ($r = 0.137$ to 0.146) and glucose ($r = 0.141$ to 0.155) showed a relatively high positive correlation compared to other indicators (see Table 5).

Table 1. Frequency table for the Chi-square goodness of fit test of age.

Age (Yrs)	Observed Frequencies (%)
≤ 30	1.8
$31 \sim 40$	7.1
$41 \sim 50$	23.2
≥ 51	67.9

Table 2. Frequency table for the Chi-square goodness of fit test of aircraft types.

Aircraft types	Observed Frequencies (%)
Fighter/Attack	55.4
Cargo/Transport	16.1
Helicopter	19.6
Trainer (prop)	8.9

Table 3. Frequency table for the Chi-square goodness of fit test of total flight time.

Total flight time (hrs)	Observed Frequencies (%)
$\leq$ 1,000	12.5
1,001 $\sim$ 2,000	16.1
2,001 $\sim$ 3,000	42.9
3,001 $\sim$ 4,000	21.4
$\geq$ 4,000	7.1

Table 4. Descriptive statistics (mean and standard deviation) for physical examination and pure tone audiometry indicators.

Indicators	Hearing Loss ($M\pm SD$)	Normal ($M\pm SD$)	Lower Bound	Upper Bound
BMI	24.89±2.15	25.08±31.44	-	-
Blood pressure(systolic)	126.73±9.82	122.47±10.42	89 mmHg	119 mmHg
Blood pressure(diastolic)	81.07±6.99	77.17±8.25	49 mmHg	79 mmHg
BUN	14.32±3.88	14.28±3.45	7 mg/dL	24 mg/dL

(Continued)

Table 4. Continued

Indicators	Hearing Loss ($M \pm SD$)	Normal ($M \pm SD$)	Lower Bound	Upper Bound
Creatine	0.99±0.15	0.99±0.14	0.4 mg/dL	1.3 mg/dL
Total Bilirubin	0.99±0.29	0.97±0.40	0.2 mg/dL	1.2 mg/dL
SGOT(AST)	27.63±7.81	26.24±13.43	5 IU/L	50 IU/L
SGOT(ALT)	29.14±14.64	28.36±21.04	5 IU/L	50 IU/L
Alkaline Phosphatase	162.78±85.77	164.89±79.54	115 IU/L	359 IU/L
Gamma-GT(GGT)	43.23±41.46	35.02±34.25	0 IU/L	50 IU/L
Glucose	97.24±10.22	95.76±9.64	60 mg/dL	110 mg/dL
Total Cholesterol	203.86±37.03	197.55±33.70	130 mg/dL	250 mg/dL
Triglyceride	135.80±65.87	113.83±88.34	34 mg/dL	143 mg/dL
WBC	6.06±1.35	5.81±1.36	4 k/μL	10 k/μL
RBC	4.92±0.38	5.03±0.34	4.2 m/μL	5.8 m/μL
Hb	15.46±0.93	15.47±1.00	12 g/dL	18 g/dL
Hct	45.07±2.75	45.06±2.69	39%	52%
PLT	241.92±40.85	239.73±45.52	150 k/μL	400 k/μL
S. G	1.01±0.01	1.02±0.01	1.003	1.03
PH	6.16±0.91	6.16±0.87	5	8.5
Left ear-500 Hz	14.15±12.12	6.31±4.62	0	35
Left ear-1,000 Hz	20.30±17.76	6.97±5.16	0	35
Left ear-2,000 Hz	25.95±18.15	6.41±6.30	0	35
Left ear-3,000 Hz	42.24±21.86	7.19±7.95	0	45
Left ear-4,000 Hz	48.77±22.23	9.25±10.68	0	45
Left ear-6,000 Hz	51.61±23.71	14.94±12.51	0	45
Right ear-500 Hz	12.54±13.06	6.41±4.80	0	35
Right ear-1,000 Hz	18.24±18.17	6.64±5.03	0	35
Right ear-2,000 Hz	20.80±19.74	6.07±5.82	0	35
Right ear-3,000 Hz	34.57±24.80	6.25±7.08	0	45
Right ear-4,000 Hz	40.18±25.07	8.09±9.65	0	45
Right ear-6,000 Hz	41.93±24.71	14.05±11.83	0	45

Table 5. Results of correlation analysis between physical examination and pure tone audiometry indicators in high frequency band (4,000 Hz and 6,000 Hz).

Indicators	4,000 Hz-L	6,000 Hz-L	4,000 Hz-R	6,000 Hz-R
BMI	0.009	0.006	0.011	0.005
Blood pressure(systolic)	0.076***	0.058***	0.082***	0.058***
Blood pressure(diastolic)	0.146***	0.145***	0.140***	0.137***
BUN	0.068***	0.063***	0.070***	0.069***
Creatine	0.048***	0.048***	0.050***	0.056***
Total Bilirubin	0.022**	0.033***	0.016*	0.020*
SGOT(AST)	0.034***	0.031***	0.028***	0.035***
SGOT(ALT)	0.037***	0.024**	0.037***	0.039***
Alkaline Phosphatase	-0.033***	-0.021**	-0.029***	-0.018*
Gamma-GT(GGT)	0.094***	0.083***	0.089***	0.083***
Glucose	0.143***	0.142***	0.141***	0.155***
Total Cholesterol	0.081***	0.089***	0.072***	0.074***

(Continued)

Table 5. Continued

Indicators	4,000 Hz-L	6,000 Hz-L	4,000 Hz-R	6,000 Hz-R
Triglyceride	0.086***	0.081***	0.089***	0.098***
WBC	0.006	0.001	0.035***	0.028***
RBC	-0.064***	-0.072***	-0.072***	-0.075***
Hb	-0.001	-0.011	-0.012	-0.012
Hct	0.005	-0.007	-0.009	-0.012
PLT	-0.032***	-0.050***	-0.038***	-0.054***
S. G	-0.061***	-0.063***	-0.060***	-0.059***
PH	0.017*	0.019*	0.009	0.021**

Note. L: Left, R: Right. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Pure Tone Audiometry (PTA) Indicators

While the mean values of all PTA indicators for normal pilots were within a normal range, the mean hearing thresholds on the left ear for 3,000, 4,000, and 6,000 Hz frequencies were determined to be abnormal (see Table 4). On the other hand, the results of the homogeneity test showed that there was no statistically significant difference in the distribution of the left and right ears for the pilots with hearing loss in terms of the frequency band, pattern, and symmetry features of the PTA indicators (frequency band: $\chi^2 = 1.254$, $df = 1$, $p = 0.263$; pattern: $\chi^2 = 1.666$, $df = 1$, $p = 0.197$; symmetry: $\chi^2 = 0.812$, $df = 1$, $p = 0.368$). In terms of frequency band, the frequency of occurrence in which the mean hearing thresholds at high frequency band were higher than those at low frequency band was more prevalent in both ears (see Table 6). In this case, the high frequency band refers to 4,000 Hz and 6,000 Hz, whereas the low frequency band refers to the remaining 500 Hz to 3,000 Hz. In terms of pattern, the frequency of occurrence for the notch and descending pattern were evenly distributed in both ears (see Table 7). In this case, the notch pattern refers to a pattern in which the hearing threshold value drops at 4,000 Hz and then ascends from 4,000 Hz to 6,000 Hz, whereas the descending pattern refers to a pattern in which the hearing threshold value descends from 4,000 Hz to 6,000 Hz. In terms of symmetry, the frequency of occurrence for the symmetrical and asymmetrical cases were evenly distributed in both ears (see Table 8). In this case, asymmetry refers to a case where the difference is more than 25 dB in two or more consecutive frequency bands when comparing both ear sides, whereas the symmetry refers to the opposite. Furthermore, left asymmetry indicates that the hearing threshold of the left ear is higher than that of the right ear in an asymmetric case, whereas the right asymmetry indicates the opposite.

Table 6. Contingency table for the Chi-square test of homogeneity of frequency band.

Frequency band	Observed Frequencies in Left Ear (%)	Observed Frequencies in Right Ear (%)
Low $\geq$ high frequency	10.1	13.9
Low < high frequency	89.9	86.1

Table 7. Contingency table for the Chi-square test of homogeneity of pattern.

Pattern	Observed Frequencies in Left Ear (%)	Observed Frequencies in Right Ear (%)
Notch	51.1	57.3
Descending	48.9	42.7

Table 8. Contingency table for the Chi-square test of homogeneity of symmetry.

Symmetry	Observed Frequencies in Left Ear (%)	Observed Frequencies in Right Ear (%)
Symmetrical	60.4	52.9
Asymmetrical	39.6	47.1

DISCUSSION

This study conducted a multifaceted analysis of EMRs, including pilot demographics, physical examination results, and PTA hearing thresholds in order to identify the main influencing factors for hearing loss in Air Force pilots. In terms of pilot demographic indicators, similar to the results of previous studies, it was found that pilots who were older, operated propeller aircrafts, and had a longer total flight time tended to have a higher rate of hearing loss. For example, existing studies have confirmed that the prevalence of hearing loss increases with age, impacting more than 40% of the population over 50 years of age and rising up to 71% of the population over 70 years of age (Slade et al., 2020). In Addition, previous studies reported that helicopter pilots had the highest rate of hearing loss among propeller aircraft groups (Raynal et al., 2006). This implies that helicopters are not equipped with engine cowlings like fixed-wing aircraft, making the pilots more vulnerable to noise exposure. On the other hand, several studies showed that there was a significant correlation between flight time and the rate of hearing loss (Fitzpatrick, 1988). This suggests that pilots are continually exposed to loud noise, such as aircraft engines, over a long period of time, and that the accumulated noise dose exceeds the allowable threshold of the ears.

In terms of physical examination indicators, it was confirmed that glucose and blood pressure may be associated with pilot hearing loss. According to recent researches, it is reported that there is a high correlation between hearing loss and hypertension, diabetes, and hyperlipidemia, which are related to glucose and blood pressure values. More specifically, previous studies have shown that hypertension can cause an increase in blood viscosity, which reduces capillary blood flow and, as a consequence, decreases the transfers of oxygen to the inner ear, resulting in hearing loss (Agarwal et al., 2013). On the other hand, recent studies have shown that diabetes and hyperlipidemia can promote oxidative stress-induced intrinsic apoptosis in hair cells by increasing the level of reactive oxygen species, resulting in hearing loss (Lee et al., 2020a; Lee et al., 2020b). Therefore, it would be essential to try an early hearing test to prevent hearing loss in pilots with hypertension, diabetes, and hyperlipidemia.

In terms of PTA indicators, through the investigation of the frequency band, pattern, and symmetry features, it was determined that noise can be considered one of the main influencing factors on hearing loss in pilots. People with noise-induced hearing loss generally have higher hearing levels in the low frequency range than in the high frequency range. Moreover, the PTA audiogram graph for noise-induced hearing loss may show the C5-dip phenomenon, which occurs when the hearing threshold abruptly drops at 4,000 Hz and forms a notch pattern (McBride & Williams, 2001). On the other hand, it is plausible to assume that noise exposure causes asymmetrical hearing loss when there is a long-term history of noise exposure, no specific medical record, and no signs of otologic disease. The current study has identified some of these features of noise-induced hearing loss, showing the necessity of wearing hearing protection for pilots in order to prevent noise-induced hearing loss.

CONCLUSION

The study investigated hearing loss in Air Force pilots by analysing EMRs. The findings indicate that multiple factors contribute to hearing loss in these pilots, including aging, flight environment (such as noise, aircraft type, and flight time), and lifestyle diseases (such as hypertension, diabetes, and hyperlipidemia). In order to prevent hearing loss in pilots, the study suggests the importance of implementing measures such as regular hearing tests, the use of hearing protection, and the regulation of lifestyle behaviors, including diet, exercise, smoking, and alcohol consumption. These measures aim to address various aspects of the pilots' health and well-being to mitigate the risk of hearing impairment. The study acknowledges that it is a preliminary investigation, demonstrating that EMRs can be used to identify influencing factors for hearing loss in Air Force pilots. It emphasizes the need for further research, suggesting that more extensive studies involving automatic data processing and analysis, as well as the integration of artificial intelligence technology, are necessary to obtain more significant and detailed findings. The potential future application of EMRs analysis is highlighted in predicting hearing loss for Air Force pilots and providing medical treatment guidelines. The study envisions that, with advancements in technology, EMRs analysis could play a crucial role in early detection, prediction, and intervention for hearing-related issues in military pilots.

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