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PROTECTIVE EFFECT OF HELMET GENTEX HGO-56/P ON HEARING LOSS AMONG MILITARY HELICOPTER PILOTS

UDK 623.445.2:623.746.17]:613.644
RECEIVED: 2021-03-12
ACCEPTED: 2021-10-12

SUMMARY: Aviation noise represents an important hazard for hearing loss among military pilots as they are continuously exposed to excessive noise during flight operations. Modern military aircraft, due to their maneuverability and tactical capabilities, require increasing engine power, while noise protection is limited only to the personal protective equipment which protects to a limited extent. Previous generations of helicopter pilots in the Croatian Air Force (CAF) used GSSH-A-18 headphones, whereas Gentex HGU-56/P helmets have been in use in CAF since 2004, primarily as mechanical protection for the head and secondarily to protect hearing. A study on hearing threshold measurements was performed on multi-purpose transport helicopter pilots who used headphones and helmets, respectively. The population of pilots who used GSSH-A-18 headphones had significantly higher hearing loss at higher frequencies, in the left ear, and in the speech area compared to the group using Gentex HGU-56/P helmets. The results of this study confirm the benefit of using of the Gentex HGU-56/P helmet to preserve the pilots' hearing.

Key words: *military helicopter pilots, noise in aviation, noise induced hearing loss (NIHL), hearing protection, Gentex HGU-56/P helmet*

INTRODUCTION

Military pilots are exposed to numerous harmful hazards during flight operations, and noise represents the most significant one. Long-term exposure to excessive noise can cause noise induced hearing loss (NIHL) which, if prolonged, may result in deafness.

The degree of NIHL mostly depends on noise intensity and cumulative time of exposure. It can be noticed as a decrease in hearing threshold on audiometry measured at different frequencies. There are acute and chronic forms of NIHL. The acute form is characterized by reversible hearing loss at frequencies over 6 kHz, and is usually restored after cessation of exposure to excessive noise. Repeated acoustic trauma over time results in chronic NIHL when permanent hearing loss is present. The chronic type of NIHL is characterized by a notch on an audiogram, usually placed at 4 kHz. If exposure to excessive noise is prolonged and repeated the notch becomes deeper and wider, affecting lower and higher frequencies (Figure 1- thin line). When the notch affects the narrow speech area (500 Hz – 2 kHz), it interferes with listening, speech comprehension and, finally, disturbs normal conversation *(Kuronen, 2004)*.

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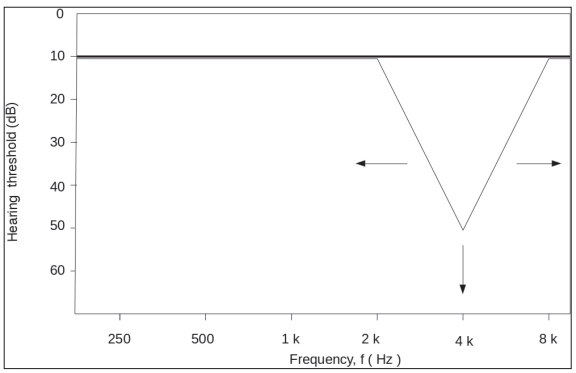

Figure 1. Audiometry finding of normal hearing threshold among military pilots at the beginning of career (thick line) and chronic NIHL (thin line) with the notch at 4 kHz

Slika 1. Audiometrijski nalaz normalnog praga sluha među vojnim pilotima na početku karijere (debela linija) i kronični NIHL (tanka linija) sa usjekom na 4 kHz

Flight characteristic improvement is the main focus of military aircraft development. Lighter aircraft with more engine power have better maneuver capabilities, as well as weapon, equipment and fuel carrying capacities, resulting in better combat readiness. Former generations of aircraft were developed focusing on aerodynamics and load capability, but current priorities are to minimize radar and thermal reflection, which require more powerful engines with same or better performance. Noise in helicopters is generated by engines, transmission and rotors. Factors that modify noise levels are resonant surfaces of aircraft, speed, flight mode, altitude, used materials, etc. *(Bucak, 2007, Živković, 1999, Stojanović, 2016)*.

The hearing threshold of military pilots at the beginning of their careers is seen as a straight line on audiometry, which represents perfect hearing (Figure 1- thick line). Over time, approximately after 15 years of flight service, the hearing threshold decreases on average by 20 dB. Initial hearing loss, however, can be noticed after 6 years of flight service as a 10% reduction at 6 kHz. NIHL is 2 to 3 times less common in pilots who use adequate hearing protection in comparison to those who do not use any. NIHL is more common among military pilots compared to the general population *(Kuronen, 2004, Rajguru, 2013, Nair et al. 2009., Smith et al., 2017)*.

A number of studies have been carried out analyzing NIHL among military pilots, considering different types of aircraft and aiming at better hearing protection for aviators. Reduction of noise levels in aircraft is impossible without having a negative impact on aircraft performance. Therefore, research is focused on adequate hearing protection. Studies that included military pilots worldwide showed that military pilots, flying personnel, flight engineers and ground technicians are at a higher risk of developing NIHL. The noise levels in aircraft cockpits can reach up to 132 dB, whereas in helicopters they can reach up to 108 dB *(Živković et al., 1999, Stojanović, 2016, Gonzales-Gonzales, 2018)*.

Noise attenuation by helmets varies from 10 to 21 dB in real condition, while only in laboratory conditions the protective impact can be up to 30 dB. Active hearing protection devices can reduce noise exposure by additional 4 to 8 dB in lower frequencies *(Kuronen, 2004)*.

Studies published on NIHL among military pilots showed various results. A study among US military pilots showed that NIHL is two times more common among helicopter pilots in comparison to airplane pilots *(Raynal et al., 2006)*. On the contrary, one longitudinal USA study that observed military pilots over a period of 14 years concluded that hearing impairment is two times more common in fixed wing pilots compared to helicopter pilots *(Orsello et al., 2013)*. Similar research performed among Israeli military pilots did not show any differences regarding the type of aircraft; in fact, the most significant risk factors to develop NIHL were pilots' age and total flight time *(Gordon et al., 2016)*. Further on, a study among Saudi military pilots pointed out the high incidence of hearing impairment in helicopter and fixed wing pilots, highlighting that the most important risk factor for NIHL is a total flight time of more than 2000 hours *(Al-Omari et al., 2018)*. Hearing threshold studies conducted among military pilots in the US and India emphasized that the left ear is predominantly affected, as well as that supersonic aircraft pilots and helicopter pilots were at most risk for developing NIHL, while transport aircraft pilots have the least hearing impairment of all *(Nair et al., 2009, Raynal et al., 2006)*.

A study carried out among Croatian Air Force (CAF) pilots concluded that the greatest hearing impairment was present among helicopter pilots compared to pilots of subsonic aircraft, firefighting aircraft and supersonic aircraft *(Barčan et al., 2019)*. The Gentex HGO-56/P helmet has been in service in CAF since 2004. It was primarily introduced for mechanical protection of the pilot's head, while hearing protection is an additional benefit. Better hearing preservation was noticed among pilots who use Gentex HGO-56/P helmets compared to pilots who used GSSH-A-18 headphones. Among pilots who used GSSH-A-18 headphones, the initial damage was often observed at 2 kHz, within a narrow speech range. On the other hand, such hearing damage is rare in personnel using Gentex HGO-56/P helmets. The variability of audiometric findings of hearing thresholds in populations of military pilots who use different hearing protection underlines a requisite for this research.

MATERIALS AND METHODS

The research included 32 military pilots operating Mi-171 Sh, Mi-17 and Mi-8 transport helicopters. Those helicopters are very similar in construction. There are differences in engine power, design of cabin space and access to the helicopter. They are structurally powered by two turboprop engines with maximum power of 1500 kW (Mi-8) and 1650 kW (Mi-17 and Mi-171 Sh) per engine. The population is divided in two groups, each comprised of 16 pilots. The first group used the Gentex HGO-56/P helmet during flight operations. The measurements were carried out at annual medical examinations in the Institute of Aviation Medicine in the course of 2019 and 2020. The second group consists of pilots who used GSSH-A-18 headphones. For the purpose of the study, the audiological findings were taken from the archives. Measurements were performed in the period from the year 2001 to 2004. It is a repeated transversal (cross-sectional) draft where data was collected at two time points from different samples of the same population. The pilots were selected by a deliberate sampling method based on the type of aircraft flown with respect to age and total flight time. Another factor in the process of selection was flying service, with a minimum of 15 years.

The results were obtained by measuring the hearing threshold by tone audiometry on an Interacoustic AC40 device on both ears, at the frequencies of 250 Hz, 500 Hz, 1 kHz, 2 kHz, 3 kHz, 4 kHz and 8 kHz. Data were statistically processed in order to check the significance of the association between the groups of pilots, left and right ear, total flight hours and age. Only pilots with an active flying status were included in the research. The age of examinees in this study ranges from 40 to 52, total flight time from 650 to 7000 hours. There are age differences between the two groups of pilots, thus the group of pilots who used headphones is on average 4 years older, and they have 60% longer total flight time. This is statistically significant.

RESULTS

There is no significant difference between examined groups in hearing at lower frequencies (500 Hz, 1 kHz and 2 kHz), while at higher frequencies differences are significant. In the group of pilots who use Gentex HGO-56/P helmets, a decrease in the hearing threshold is observed, insignificant at lower frequencies, while significant at frequencies above 4 kHz. The decrease in the auditory thresholds shows similar distribution in both ears, but the left ear is more strongly affected.

Results presented in figures 2 and 3 show the average hearing thresholds in decibels at a determined frequency, for the two groups, right and left ear respectively. The data were statistically processed descriptively, as well as by using the Mann-Whitney U test.

The statistical results are presented in Table 1. The obtained data for the left ear show statistically significant differences at 3 kHz, 4 kHz and 8 kHz. Results for the right ear, however, show significant differences at 4 kHz and 8 kHz. Results indicate a significant difference in the hearing threshold, supporting the protective effect of the Gentex HGO-56/P helmet at higher frequencies compared to the GSSH-A-18 headphones. Further on, there is a significant difference in hearing loss between the left and right ear at 3 kHz, with notable left ear involvement.

There is also a significant difference in age and total flight time. Pilots in the group using GSSH-A-18 headphones were slightly more than 4 years older and also had a higher total flight time.

Table 1. Results of descriptive statistic and analysis relate to age, total flight time, hearing thresholds among military pilots depending applied hearing protection

Tablica 1. Rezultati deskriptivne statistike i analiza povezana sa dobi, ukupnim vremenom leta, pragovima sluha među vojnim pilotima ovisno o primijenjenoj zaštiti sluha

Group	Type	N	Mean	SD	Minimum	Maximum	p
Age	Gentex GSSH	16	43,38 48,06	3,58 3,19	40 42	52 52	**0,001**
Total flight time	Gentex GSSH	16	1650 2841,25	774,17 1390,45	650 1200	3600 7000	**0,002**
L 250 Hz	Gentex GSSH	16	10,63 11,88	1,71 3,59	10 10	15 20	0,318
L 500 Hz	Gentex GSSH	16	11,25 12,5	2,24 4,8	10 10	15 20	0,53
L 1 kHz	Gentex GSSH	16	10 11,88	0 3,59	10 10	10 20	0,056
L 2 kHz	Gentex GSSH	16	10,94 15,31	2,72 9,57	10 10	20 40	0,159
L 3 kHz	Gentex GSSH	16	13,75 25	6,45 12,65	10 10	30 50	**0,003**
L 4 kHz	Gentex GSSH	16	21,25 35	11,9 14,72	10 10	40 75	**0,009**
L 8 kHz	Gentex GSSH	16	26,56 37,19	19,38 19,49	10 10	80 90	**0,026**
R 250 Hz	Gentex GSSH	16	12,19 11,88	3,64 4,43	10 10	20 25	0,519
R 500 Hz	Gentex GSSH	16	12,19 14,6	4,07 8,98	10 10	20 45	0,703
R 1 kHz	Gentex GSSH	16	11,88 13,44	2,5 7,69	10 10	15 40	0,928
R 2 kHz	Gentex GSSH	16	11,56 19,38	3,52 13,52	10 10	20 50	0,073
R 3 kHz	Gentex GSSH	16	18,13 25	9,46 12,65	10 10	45 50	0,104
R 4 kHz	Gentex GSSH	16	22,5 39,38	13,9 17,02	10 20	55 70	**0,003**
R 8 kHz	Gentex GSSH	16	29,6 45,56	22,3 21,81	10 20	75 90	**0,017**

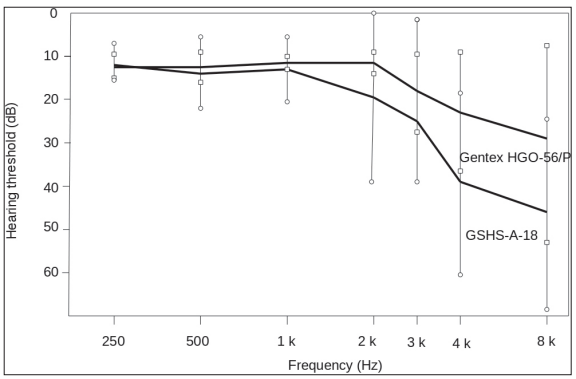

Figure 2. Hearing thresholds in the right ear among military helicopter pilots depending on the applied hearing protection

Slika 2. Pragovi sluha u desnom uhu među pilotima vojnih helikoptera ovisno o primijenjenoj zaštiti sluha

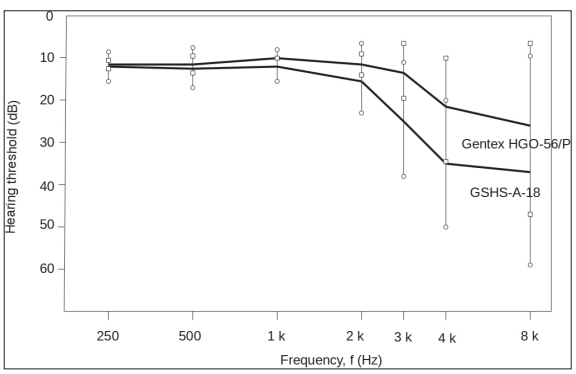

Figure 3. Hearing thresholds in the left ear among military helicopter pilots depending on the applied hearing protection

Slika 3. Pragovi sluha u lijevom uhu među pilotima vojnih helikoptera ovisno o primijenjenoj zaštiti sluha

DISCUSSION

The results of this study correlate with previously published research. Significant hearing loss in the left ear affecting the speech area at 3 kHz interferes with normal communication. This is consistent with published studies *(Nair et al., 2009, Gonzales-Gonzales, 2018)*. Hearing loss in the left ear at 3 kHz that involves the speech area is present among pilots with GSSH-A-18 headphones. It represents the most detrimental factor of hearing impairment because such a condition threatens hearing loss. If significant hearing loss affecting speech area is noticed, it is necessary to cease further exposure to the noise in order to protect hearing and prevent hearing loss.

In helicopters, along with the noise, there are pronounced vibrations emanating from the engines and the transmission, as well as from the two rotors that are perpendicular to each other. The maximum noise level in the cabin of the Mi-8 helicopter is up to 108 dB in the cockpit, especially at low frequencies with additionally pronounced vibrations *(Živković et al., 1999, Stojanović, 2016, Maradin, 2016)*. The use of protective helmets, which in addition to mechanical protection also provide hearing protection, contribute to the reduction of hearing loss in population of military pilots. The results of this study show that helicopter pilots who used the Gentex HGU-56/P helmet experienced a lesser degree of hearing loss. Preservation of hearing within the speech range and at higher frequencies is significant with the use of Gentex HGU-56/P helmets. GSSH-A-18 headphones were in use until 2004, when helmets became mandatory in CAF. A further significant factor with adverse impact on hearing of pilots who used GSSH-A-18 headphones is age, as this group is on average 4 years older. Slightly older age is a difference that should not significantly affect the overall results of the study. Total flight time is a significant factor for NIHL in some studies. Most often, military pilots with a higher total flight time are also older. A study conducted among military pilots in Saudi Arabia showed significantly greater hearing loss in airplane pilots than among helicopter pilots, as well as among pilots with more than 2000 hours of total flight time. Other studies also found total flight time to be a significant risk factor. A study conducted among Israeli military pilots confirmed the association between age, total flight time and NIHL, while aircraft type was not associated with hearing loss *(Orsello et al., 2013, Al-Omari et al., 2018, Jaruchinda et al., 2005)*. A study conducted on a large number of US military pilots between 1997 and 2011 showed significantly greater hearing loss among airplane pilots compared to helicopter pilots. In the Croatian study on CAF pilots, the population most affected with NIHL are helicopter pilots *(Barčan et al., 2019)*.

CONCLUSION

The results of this study confirm the benefit of using the Gentex HGU-56/P helmet in hearing protection for pilots of multi-purpose helicopters in comparison to the protective effects of GSSH-A-18 headphones. The protective effect of the helmet on hearing is more pronounced at higher frequencies of 4 kHz and 8 kHz in both ears compared to headphones. A significant hearing loss at 3 kHz in the left ear among pilots using headphones represents a serious indicator of hearing impairment since it affects the speech area. Wearing protective helmets significantly reduces hearing impairment in the left ear and at 3 kHz, which is near to the speech area. Further on, appropriate use of the helmet in the population of helicopter pilots decreases cost for the particular air force, since helmet use protects pilots' hearing, prolongs their career and precludes the need to be removed from the working enviroment due to hering impairment.

There is room for improvement. Upgrading the helmet with an active hearing protection would raise hearing protection to an even higher level. Also, such upgrading helmets could be implemented in a various occupational settings with high noise exposure to improve mechanical and hearing protection of the workers.

LITERATURE

Al-Omari, A.S., Al-Khalaf, H.M., Hussien, N.F.M.: Association of flying time with hearing loss in military pilots, *Saudi J Med Med Sci*, 2018., 6, 155-9.

Barčan, T., Barčan, M.: Varijabilnost praga sluha kod vojnih pilota ovisno o tipu zrakoplova na kojima lete, *Medica Jadertina*, 49, 2019., 9.

Bucak, T.: On aircraft interior noise, *3rd congress of the alps adria acoustics association*, Graz 2007.

Debuš, M.: *Eksperimentalno određivanje karakteristika buke helikoptera Bell OH-58D Kiowa Warrior*, diplomski rad, Sveučilište u Zagrebu, Fakultet prometnih znanosti, Zagreb, 2019.

Gonzalez-Gonzalez, S.: Noise-Induced Hearing Loss and Tinnitus in Military Personnel, *M J E-Med*, 3, 2018., 1, 027.

Gordon, M.B., Joachims, Z., Cohen, H.B., Grossman, A., Derazne, E., Carmon, E., Zilberberg, M., Levy, Y.: Hearing loss in Israeli air force aviators: natural history and risk factors, *Military Medicine*, 2016., 7, 687-92.

Jaruchinda, P., Thongdeetae, T., Panichkul, S., Hanchumpol, P.: Prevalence and an analysis of noise--induced hearing loss in army helicopter pilots and aircraft mechanics, *J Med Assoc Thai*, 2005., 88, 232-9.

Kuronen, P.: Military aviation noise noise-induced hearing impairment and noise protection. *Doctor thesis*, 2004.

Maradin, M.: *Analiza i vrednovanje unutarnje buke helikoptera Mi-8*. Diplomski rad, Zagreb, 2016.

Nair, S., Kashyap, R.C.: Prevalence of noise induced hearing loss in Indian air force personnel, *MJAFI*, 2009., 65, 247-51.

Orsello, C.A., Moore, J.E., Reese, C.: Sensorineural hearing loss incidence among u.s. Military aviators between 1997 and 2011, *Aviat Space Environ Med*, 2013., 84, 975-9.

Rajguru, R.: Military aircrew and noise-induced hearing loss: prevention and management, *Aviat space environ med*, 2013., 84, 1268-76.

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.

Smith, E., Burrell, C.: *A study of risk factors and prevalence for noise-induced hearing loss in Canadian armed forces pilots*, 2017.

Stojanović, I.: Mjerenje buke i vibracija u kabini helikoptera Mi-8, *Vojnotehnički glasnik/Military technical courier*, 2016., 64, 176-94.

Živković, D., Hrnjak, M., Basarić, G.: Buka infrazvuk i ultrazvuk oko jednog tipa helikoptera, *Naučnotehnički pregled*, 1999., 4, 43-6.

ZAŠTITNI UTJECAJ KACIGE GENTEX HGO-56/P NA GUBITAK SLUHA MEĐU PILOTIMA VOJNIH HELIKOPTERA

SAŽETAK: Zrakoplovna buka predstavlja važnu opasnost za gubitak sluha među vojnim pilotima, jer su kontinuirano izloženi prekomjernoj buci tijekom letačkih operacija. Moderno vojno zrakoplovstvo zbog svojih manevarskih sposobnosti i taktičkih mogućnosti zahtjeva povećanje snage motora, dok je zaštita od buke ograničena na osobnu zaštitnu opremu koja štiti do određene granice. Prijašnje generacije pilota helikoptera u Hrvatskom ratnom zrakoplovstvu (HRZ) koristile su GSSH-A-18 slušalice, dok su Gentex HGU-56/P kacige u upotrebi u HRZ-u od 2004. godine; primarno kao mehanička zaštita za glavu te sekundarno kao zaštita sluha. Studija o mjerenju praga sluha provedena je kod pilota višenamjenskih transportnih helikoptera, koji su koristili slušalice, odnosno kacige. Populacija pilota koja je koristila GSSH-A-18 slušalice imala je znatno viši gubitak sluha na visokim frekvencijama u lijevom uhu i u govornom području, u usporedbi s grupom koja je koristila kacige Gentex HGU-56/P. Rezultati ovog istraživanja potvrđuju korist korištenja kacige Gentex HGU-56/P pri očuvanju sluha pilota.

Ključne riječi: *piloti vojnih helikoptera, buka u avijaciji, gubitak sluha izazvan bukom (NIHL), zaštita sluha, kaciga Gentex HGU-56/P*

Originalni znanstveni rad
Primljeno: 12.3.2021.
Prihvaćeno: 12.10.2021.