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# Audiometric profile of civilian pilots according to noise exposure

## Perfil audiométrico segundo exposição de pilotos civis ao ruído

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### ABSTRACT

**OBJECTIVE:** To evaluate the audiometric profile of civilian pilots according to the noise exposure level.

**METHODS:** This observational cross-sectional study evaluated 3,130 male civilian pilots aged between 17 and 59 years. These pilots were subjected to audiometric examinations for obtaining or revalidating the functional capacity certificate in 2011. The degree of hearing loss was classified as normal, suspected noise-induced hearing loss, and no suspected hearing loss with other associated complications. Pure-tone air-conduction audiometry was performed using supra-aural headphones and acoustic stimulus of the pure-tone type, containing tone thresholds of frequencies between 250 Hz and 6,000 Hz. The independent variables were professional categories, length of service, hours of flight, and right or left ear. The dependent variable was pilots with suspected noise-induced hearing loss. The noise exposure level was considered low/medium or high, and the latter involved periods > 5,000 flight hours and > 10 years of flight service.

**RESULTS:** A total of 29.3% pilots had suspected noise-induced hearing loss, which was bilateral in 12.8% and predominant in the left ear (23.7%). The number of pilots with suspected hearing loss increased as the noise exposure level increased.

**CONCLUSIONS:** Hearing loss in civilian pilots may be associated with noise exposure during the period of service and hours of flight.

**DESCRIPTORS:** Aviation, Manpower, Hearing Loss, Noise-Induced, epidemiology, Noise, Transportation, adverse effects, Noise, Occupational, Occupational Health.

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## RESUMO

**OBJETIVO:** Analisar o perfil audiométrico de pilotos civis segundo grau de exposição ao ruído.

**MÉTODOS:** Trata-se de um estudo observacional, transversal, com 3.130 pilotos civis do sexo masculino de 17 a 59 anos submetidos a exames audiométricos iniciais ou de revalidação de Certificado de Capacidade Física em 2011. Os sujeitos foram categorizados segundo perda auditiva como: normais, sugestivos de perda auditiva induzida por ruído, e outros fatores associados e não sugestivos. A audiometria tonal liminar utilizada foi por via aérea, com a utilização de fones supra-aurais, por meio do estímulo acústico do tipo tom puro, contendo os limiares tonais das frequências de 250 a 6.000 Hz. As variáveis independentes foram as categorias dos pilotos, tempo de serviço, horas de voo e orelha direita ou esquerda. A variável dependente corresponde aos casos sugestivos de perda auditiva induzida por ruído. O grau de exposição foi considerado baixo/médio ou alto, sendo este último com horas de voo maiores que 5.000 e tempo de serviço maior que 10 anos.

**RESULTADOS:** Foram observados 29,3% casos sugestivos de perda auditiva induzida por ruído, 12,8% bilaterais com predomínio do lado esquerdo (23,7%). Com o aumento do grau de exposição ao ruído, o número de casos sugestivos de perda auditiva também aumentou.

**CONCLUSÕES:** A perda auditiva nos pilotos civis pode estar associada à exposição ao ruído ao longo do tempo de serviço e das horas de voo.

**DESCRITORES:** Aviação, recursos humanos. Perda Auditiva Provocada por Ruído, epidemiologia. Ruído dos Transportes, efeitos adversos. Ruído Ocupacional. Saúde do Trabalhador.

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## INTRODUCTION

Hearing is one of the main modalities through which humans interact with society and plays a key role in the acquisition and development of speech and language, learning, and social-emotional progress. It is a complex and crucial component of human communication. Hearing loss alters the ability of individuals to express themselves orally and may impair their relationship with other people and the environment, thereby limiting their contact with the environment.<sup>1</sup> Hearing integrity is critical to the performance of many professional activities, and it becomes even more important for aviation activities because perception errors can cause aviation accidents.<sup>3</sup>

The United Nations Conference on Environment and Development (ECO 92) held in Rio de Janeiro in 1992 established the Agenda 21 program on global actions

aimed to promote sustainable development. Noise was considered the third leading cause of environmental pollution, preceded by water and air pollution, and can be considered the health risk that affects the largest number of workers.<sup>a</sup>

Even considering the possibility of underreporting, statistics from the Ministry of Social Security in 2010 show that, among the 15,593 cases of occupational diseases, 1,367 (8.8%) involved hearing-related complications.<sup>b</sup>

The Social Security system reported 578 cases of work accidents related to inner ear disorders (CID-10 – H83) in 2011, including 32 that were not registered in the work accident category. Between January and December 2012, 2,013 benefits were

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<sup>a</sup> Ministério da Saúde, Secretaria de Atenção à Saúde, Departamento de Ações Programáticas Estratégicas. Perda auditiva induzida por ruído (Pair). Brasília (DF); 2006. (Série A. Normas e Manuais Técnicos. Saúde do Trabalhador, 5. Protocolos de Complexidade Diferenciada).

<sup>b</sup> Ministério da Previdência Social. Acompanhamento mensal dos benefícios auxílios-doença previdenciários concedidos segundo os códigos da CID-10: janeiro a dezembro de 2012. Brasília (DF); 2013 [cited 2013 Feb 7]. Available from: [http://www.inss.gov.br/arquivos/office/1\\_130207-104653-108.pdf](http://www.inss.gov.br/arquivos/office/1_130207-104653-108.pdf)

granted to pension holders experiencing noise-induced hearing loss (NIHL).<sup>c</sup>

According to Gerk Filho,<sup>5</sup> aviation medical services for airline crew members can and should be understood as a branch of occupational medicine. The aviation environment is hostile because of the limited time available to adapt to this challenging occupational environment during each flight. Therefore, aviation medicine should take a preventive approach and be understood as a public health service for aviation professionals.

The noise hazards to aviation professionals are predominantly associated with NIHL. The control of NIHL is essential because, in addition to all known physiological consequences, it can directly lead to decreased flight safety, maintenance failures, and even aircraft accidents.<sup>12</sup>

This study aimed to evaluate the audiometric profile of civilian pilots according to their noise exposure levels.

## METHODS

This cross-sectional study evaluated 3,130 male civilian pilots aged between 17 and 59 years who underwent audiometric examinations for obtaining or revalidating the functional capacity certificate (FCC) at the Aerospace Medical Center (AMC) of the Brazilian Air Force in Rio de Janeiro in 2011. The data analyzed were obtained from the AMC database, comprising interview records and audiometry data of pilots. The audiometric tests were performed by one of the authors of this study.

The Brazilian Aeronautical Certification Regulation (BACR) from 1999 establishes general rules for the performance of health examination and related procedures for obtaining or revalidating FCC. BACR establishes different categories for civilian pilots: airline pilot (AP), commercial pilot (CP), and private pilot (PP).

Civilian pilots<sup>d</sup> generally go through the following stages: PPs (pilots who fly their own aircrafts/helicopters or those of someone who has entitled or rented it to them. PPs are not eligible to work in commercial or remunerated aviation), CPs (pilots who cannot fly commercial airline aircrafts), and APs (pilots who fly airlift jets, transcontinental aircrafts, and others). To become a PP, you need<sup>d</sup> 1) to be in good health and own an FCC; 2) get approved in theoretical tests

in five disciplines, conducted by the National Civil Aviation Agency (NCAA); 3) have practical aviation experience measured in flight hours; and 4) obtain approval in all three previous requirements, including the tests that are applied by increasingly demanding examiners to the extent that testing is dependent on the pilot stage (PP, CP, and AP) because piloting errors in these stages involve a progressive increase in the risk of lives.

According to Santos<sup>e</sup> (2012), CP and PP courses last four months. The former requires a 150h flight time and the latter requires a 35h flight time. FCC can be obtained during the course. Those interested in these courses must be at least 17 years old and will receive a license that enables them to obtain the license to fly solo when they become 18 years old.

The workload, vacations, and flight and rest periods, among others, are similar between the CP and AP categories, considering that both are regulated by Law 7,183/84.<sup>f</sup> However, the work schedule for PP is less controlled; therefore, their working hours and noise exposure are different from those of the other categories.

In Brazil, 54 doctors and nine clinics are accredited to assist this category, in addition to 19 special health committees, which include AMC. Accredited doctors can only conduct health examinations on private pilots and flight attendants, whereas accredited clinics and special health committees can also conduct health examinations on commercial and airline pilots.<sup>g</sup>

The following data on the study subjects were collected: gender, age, length of service, function, professional category, flight hours, and examination date. These data were collected through interviews and occupational audiometry tests (pure-tone air-conduction audiometry using supra-aural headphones and a pure-tone acoustic stimulus).

Tone thresholds of frequencies between 250 and 6,000 Hz were evaluated, assuming normal tone thresholds of  $\leq 25$  dB HL (standard ANSI-69). The frequency of 8,000 Hz was also used at AMC but was only registered in the participant's record and not included in the database because there was no specific field for inputting this data. Therefore, the analysis was performed at a frequency of  $\leq 6,000$  Hz.

<sup>c</sup> Ministério da Previdência Social. Anuário estatístico de acidentes de trabalho 2012. Brasília (DF); 2013. Quantidade de acidentes do trabalho, por situação de registro e motivos, segundo os 200 códigos da Classificação Internacional de Doenças – CID-10 mais incidentes, no Brasil – 2012; Seção I, Subseção C, capítulo 57, 57.3. [cited 2013 Feb 9]. Available from: [http://www.previdencia.gov.br/arquivos/office/1\\_130108-164029-787](http://www.previdencia.gov.br/arquivos/office/1_130108-164029-787)

<sup>d</sup> Marinho R. Para ser piloto: como tirar "brevê". [cited 2014 Sept 12]. Available from: <http://paraserpiloto.wordpress.com/como-tirar-breve/>

<sup>e</sup> Santos MP. Piloto de avião. [cited 2012 Sept 29]. Available from: <http://madaipinto.wordpress.com/>

<sup>f</sup> Brasil. Lei nº 7.183, de 5 de abril de 1984. Regula o exercício da profissão de aeronauta e dá outras providências. *Diário Oficial União*. 6 abr 1984; Seção 1. [cited 2014 Jul 12].

<sup>g</sup> Agência Nacional de Aviação Civil. Informações sobre exame de saúde. [cited 2013 Feb 3]. Available from: <http://www2.anac.gov.br/habilitacao/inspecaoSaude.asp>

The equipment used to perform pure-tone audiometry was a Medical Beta audiometer model Beta 6,000 and an Amplaid audiometer model A321. The calibration and maintenance of both devices and audiometric booths were within the expiration date and followed Ordinance 19, issued on 4/9/1998, and Resolutions 364 and 365 of 3/30/2009 from the Federal Council of Speech Therapy.<sup>h,i,j</sup>

Group 1 comprised pilots with normal hearing, whereas groups 2, 3, and 4 comprised those with hearing disorders. Group 2 comprised pilots with suspected NIHL, i.e., a loss of  $\leq 40$  dB in at least one of the frequencies of 500, 1,000, or 2,000 Hz and  $\leq 75$  dB in at least one of the frequencies of 3, 4, or 6 kHz. Group 3 comprised those with other associated complications, including pilots with acoustic trauma and with hearing losses in frequencies different from those evaluated in the previous pilots. Group 4 comprised pilots without suspected NIHL.

The criteria adopted for the definition of noise exposure levels were the flight hours and length of service of pilots. Pilots with  $> 5,000$  flight hours and  $> 10$  years of service time were considered as having high exposure. Those with  $< 150$  flight hours and  $< 1$  year of service were considered as having low exposure. The cases distinct from the above were classified as having moderate exposure.

Individuals aged  $\geq 60$  years were excluded from the study to avoid confusion with presbycusis. Women were excluded because of the small sample size. In addition, their inclusion in aviation is recent and therefore not of interest to the present study because the evaluation and description of audiometric profiles were conducted on the basis of service length and flight hours.

The SPSS Statistics software version 18 was used to evaluate the significance of the prevalence of pilots with suspected NIHL. A Chi-squared test with a significance level of 0.05 was performed.

This project was approved by the Research Ethics Committee of the *Instituto de Estudos em Saúde Coletiva* of the *Universidade Federal do Rio de Janeiro* (Opinion 180,008/2012).

## RESULTS

The mean age of the civilian pilots was 34.4 years (DP = 10.8) and the median age was 32 years; 42.9% were PPs, 29.5% were APs, and 27.6% were CPs (Table 1). Approximately 87.3% PPs and 82.7% CPs

were aged  $< 40$  years and 35.6% APs were aged 40-49 years; 95.0% PPs were at the beginning of their career and had  $< 1$  year of service, whereas 42.3% CPs had 1-5 years of service and 76.1% APs had  $\geq 11$  years of service. Flight hours were compatible with the categories evaluated and increased according to the category level (PP, CP, and AP).

The maximum intensity of hearing loss was 115 dB at 4 kHz and 100 dB at 6 kHz in the left ear (LE) and 100 dB at 3 kHz in the right ear (RE). The frequencies and the proportion of pilots with associated hearing loss were as follows (in LE and RE, respectively): 4 kHz, 20.6% and 17.1%; 6 kHz, 16.9% and 14.7%; and 3 kHz, 10.5% and 8.6% (Table 2).

Most pilots (62.2%) had normal audiometric test results in both ears (Table 3); 28.3% had hearing loss with suspected NIHL in at least one ear, 1.0% had suspected NIHL and other associated complications, and 8.5% did not have suspected NIHL. When the ears were assessed separately, 23.7% and 20.1% pilots had suspected NIHL in LE and RE, respectively. Hearing loss suggestive of NIHL with other associated complications represented 0.9% and 0.5% cases in RE and LE, respectively; 12.8% pilots had suspected NIHL with or without other associated complications that involved both ears.

The higher was the noise exposure, the higher was the number of pilots with suspected NIHL in all categories and age groups analyzed. This was particularly evident in the CP and AP categories in the age group of  $\geq 40$  years ( $p = 0.003$ ) (Table 4).

## DISCUSSION

Noise exposure over time may be responsible for the occurrence of peripheral hearing loss in the aviation industry. The results are consistent with those reported in previous studies.<sup>2,4,6,7,9,10,11</sup>

In addition, 29.3% pilots had suspected NIHL, which is a significant number, as corroborated by Harger & Barbosa-Branco<sup>7</sup> (2004), Silva et al<sup>11</sup> (2004), Gerostergiou et al<sup>6</sup> (2008), and Foltz et al<sup>4</sup> (2010). In contrast, Lindgren et al<sup>8</sup> (2009) found no indication that the cabin crew of a Swedish commercial airline company had increased rates of hearing loss compared with a population of the same country not exposed to noise, despite the relative exposure to high noise levels. Gerostergiou et al<sup>6</sup> (2008) conducted a study involving 15 pilots of the Larissa Aeroclub in

<sup>h</sup> Conselho Federal de Fonoaudiologia. Resolução nº 364, de 30 de março de 2009. Dispõe sobre o nível de pressão sonora das cabinas/salas de testes audiológicos, e dá outras providências. *Diário Oficial Uniao*. 7 abr 2009; Seção 1 [cited 2012 Jun 7].

<sup>i</sup> Conselho Federal de Fonoaudiologia. Resolução nº 365, de 30 de março de 2009. Dispõe sobre a calibração de audiômetros e dá outras providências. *Diário Oficial Uniao*. 7 abr 2009. Seção 1. [cited 2009 Apr 7].

<sup>j</sup> Ministério do Trabalho, Secretaria de Segurança e Saúde no Trabalho. Portaria nº 19, de 9 de abril de 1998. Estabelece diretrizes e parâmetros mínimos para a avaliação e o acompanhamento da audição dos trabalhadores, expostos a níveis de pressão sonora elevados e o texto técnico apresentado pelo Grupo de Trabalho Tripartite constituído através da Portaria SSST/MTb nº 5, de 25 de fevereiro de 1997. *Diário Oficial Uniao*. 22 abr. 1998; Seção 1, p.64-66.

**Table 1.** Pilot profile according to age, length of service, and hours of flight. Aerospace Medical Center, Rio de Janeiro, Southeastern Brazil, 2011.

Variable	Private pilot		Commercial pilot		Airline pilot	
	n	%	n	%	n	%
	1,342	42.9	865	27.6	923	29.5
Age (years)						
< 40	1,172	87.3	715	82.7	292	31.6
40 to 49	118	8.8	106	12.3	329	35.6
> 50	52	3.9	44	5.1	302	32.7
Length of service (years)						
0	1,275	95.0	212	24.5	0	0.0
1 to 5	32	2.4	366	42.3	87	9.4
6 to 10	13	1.0	105	12.1	112	12.1
≥ 11	22	1.6	111	12.8	702	76.1
Hours of flight						
≥ 150	1,299	96.8	485	56.1	8	0.9
151 to 5,000	35	2.6	349	40.3	391	42.4
5,001 to 12,000	3	0.2	23	2.7	271	29.4
≥ 12,001	1	0.1	6	0.7	253	27.4

Greece and observed that 30.0% pilots experienced hearing impairments suggestive of NIHL. A retrospective, observational, and cross-sectional study evaluated 41 agricultural pilots<sup>4</sup> and reported a high prevalence of hearing loss, although > 50.0% pilots had normal hearing threshold levels with slot configuration. Agricultural pilots, even wearing personal protective equipment (PPE) (95.1% made use of PPE during flight), suffer hearing impairments caused by noise and lack better alternatives for the prevention of hearing loss.

A hearing loss prevalence of 48.0% was found in the studies by Harger & Barbosa-Branco<sup>7</sup> (2004), and more severe hearing loss was found at 6,000 Hz, which was the first frequency to be affected, particularly on LE. Among those presenting early NIHL (41.0%), 13.9% hearing losses were bilateral, 19.4% were on RE, and 66.7% were on LE.

Differences were found at the sound pressure level according to the type of aircraft used in the study by Raynal et al<sup>9</sup> (2006). They compared audiometric data of transport, fighter, and rotorcraft pilots and concluded that

the latter two activities were more harmful to hearing, with the largest number of abnormal test results in comparison with the transport pilots. Furthermore, they found a high slot configuration at 6 kHz and lower performance on LE, confirming findings of other studies.<sup>7,11</sup>

LE is reported to be more susceptible to noise injury; however, sufficient evidence for such a claim is not available. In the present study, 24.2% pilots had suspected NIHL on LE and 21.0% on RE, which is consistent with the results by Harger & Barbosa-Branco<sup>7</sup> (2004) and Raynal et al<sup>9</sup> (2006). The fact that some engines are located on the left side of aircrafts is a possible explanation. However, further studies are necessary to corroborate this hypothesis.

The frequencies with the highest percentage of hearing loss were as follows (on LE and RE, respectively): 4 kHz: 20.6% and 17.1%; 6 kHz: 16.9% and 14.7%; and 3 kHz: 10.5% and 8.6%. However, these results were different from those of Harger & Barbosa-Branco<sup>7</sup> (2004). According to these authors, NIHL starts at 4 kHz, whereas more recent studies indicate that NIHL begins at 6 kHz.

**Table 2.** Hearing thresholds on the left and right ears according to the frequencies tested. Aerospace Medical Center, Rio de Janeiro, Southeastern Brazil, 2011.

Frequency	Right ear						Left ear					
	Mean	Median	sd	Minimum	Maximum	% Loss	Mean	Median	sd	Minimum	Maximum	% Loss
250	21.2	20.0	3.7	20	85	5.1	21.3	20.0	3.8	20	85	6.1
500	20.8	20.0	3.5	20	90	3.2	20.8	20.0	3.3	20	90	3.3
1,000	20.7	20.0	3.4	20	85	2.0	20.6	20.0	3.5	20	95	2.1
2,000	21.0	20.0	4.3	20	90	4.0	21.0	20.0	4.3	20	95	4.0
3,000	21.9	20.0	6.5	20	100	8.6	22.2	20.0	6.6	20	85	10.5
4,000	24.0	20.0	9.6	20	95	17.1	24.6	20.0	9.5	20	115	20.6
6,000	23.5	20.0	9.4	20	95	14.7	23.8	20.0	9.0	20	100	16.9

**Table 3.** Audiometric profile of civilian pilots on the left and right ears. Center for Aerospace Medicine, Rio de Janeiro, Southeastern Brazil, 2011.

Variable	Right ear		Left ear		At least one ear	
	n	%	n	%	n	%
Normal	2,306	73.7	2,199	70.3	1,946	62.2
Suspected NIHL	628	20.1	743	23.7	887	28.3
Suspected NIHL with other associated complications	28	0.9	15	0.5	31	1.0
Without suspected NIHL	168	5.4	173	5.5	266	8.5

Note: 400 pilots (12.8%) had NIHL in both ears.

NIHL: Noise-induced hearing loss

Satish & Kashyap<sup>10</sup> (2008) show that the involvement of the 6 kHz frequency was significantly greater in the Indian Air Force crew in comparison with that of other frequencies, particularly in subjects with evidence of NIHL. Furthermore, with technological advancements, the sound output generated by aircraft and heavy machinery has increased. Therefore, the audiometric finding of a slot configuration at a frequency of 6 kHz as a diagnostic measure of NIHL may be more suitable than the measure at 4 kHz. However, the results of the present study contradict this finding.

The study by Büyükcakir<sup>2</sup> (2005) with Turkish pilots showed that hearing loss is a result of noise exposure during flight, and that hearing loss increases as flight hours increase. Accordingly, the present study indicated that NIHL increased as the exposure to noise increased in all categories and age groups analyzed, particularly in the CP and AP categories in the age group  $\geq 40$  years.

Special attention should be given to this group during prevention and hearing conservation programs, in addition

to improvements in public policies on these issues, particularly with regard to prevention. Additional studies need to be conducted to elucidate potential associated factors that can aggravate the occurrence of NIHL in this group.

A limitation of this study is related to the frequency of 8,000 Hz, which, despite being evaluated in AMC, was registered in the participant's record but not included in the database because there was no specific field for its registration. Therefore, the analysis was performed using a frequency of  $\leq 6,000$  Hz.

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**Table 4.** Cases with suspected NIHL according to the noise exposure levels (hours of flight and length of service), adjusted to the professional category and age of civilian pilots. Aerospace Medical Center, Rio de Janeiro, Southeastern Brazil, 2011.

Variable	Suspected NIHL		Without suspected NIHL		Total		p Chi-square
	n	%	n	%	n	%	
CP and AP with $\leq 39$ years							0.219
Low exposure	41	18.5	181	81.5	222	100	
Medium exposure	151	20.8	575	79.2	726	100	
High exposure	17	28.8	42	71.2	59	100	
CP and AP with $\geq 40$ years							0.003
Low exposure	6	42.9	8	57.1	14	100	
Medium exposure	122	41.4	173	58.6	295	100	
High exposure	254	53.8	218	46.2	472	100	
PP with $\leq 39$ years <sup>a</sup>							0.779
Low exposure	228	20.2	903	79.8	1,131	100	
Medium exposure	9	22.0	32	78.0	41	100	
PP with $\geq 40$ years							0.550 <sup>b</sup>
Low exposure	65	51.6	61	48.4	128	100	
Medium exposure	23	54.8	19	45.2	42	100	
High exposure	2	100	0	0	2	100	

NIHL: Noise-induced hearing loss; PP: private pilot; AP: airline pilot; CP: commercial pilot

<sup>a</sup> No PP was found in the high-exposure category.

<sup>b</sup> p was calculated from the combination of medium-exposure and high-exposure conditions.

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Article based on the master's dissertation of Falcão TP, titled: "Perfil audiométrico de pilotos civis registrados no Centro de Medicina Aeroespacial (CEMAL) da Força Aérea Brasileira no ano de 2011", presented to the *Programa de Pós-graduação em Saúde Coletiva do Instituto de Estudos em Saúde Coletiva da Universidade Federal do Rio de Janeiro*, in 2013. These results were presented at the Clinical Session of the *Diretoria de Saúde da Aeronáutica* in the *Centro de Estudos* of the *Hospital Central da Aeronáutica (HCA)* in Rio de Janeiro, in 2014. The authors declare no conflict of interest.