Journal of Otology 13 (2018) 75–79

Contents lists available at ScienceDirect

Journal of Otology

journal homepage: www.journals.elsevier.com/journal-of-otology/

Auditory characteristics of noise-exposed memberscrossing age-related groups☆

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ARTICLE INFO

Article history:
Received 28 April 2018
Received in revised form
17 May 2018
Accepted 17 May 2018

Keywords:
Noise
Hearing loss
Age-related hearing loss
Noise-induced hearing loss
Tinnitus

ABSTRACT

Objective: To report audiological characteristics in a group of noise-exposed crew members on board ships.
Methods and materials: Clinical and audiological measurements including pure-tone thresholds, acoustic immittance results and tinnitus questionnaires were collected from both the ship crew members (study subjects) and their land based colleagues (controls).
Results: 1) Noise exposed crew members showed not only high frequency, but also low frequency hearing loss; 2) Hearing impairment increased with age, with 65.5% of crew members younger than 50 years showing normal hearing while only 14.9% of those older than 50 years had normal hearing; 3) hearing loss gradually increased with the extension of on board career time; and 4) Most study subjects reported high pitch tinnitus, significantly more than the control group although not significantly different among different age groups.
Conclusion: Noise induced hearing impairment from working on board ships shows specific frequency and age characteristics. Understanding these characteristics is important for advancing relevant studies and for effective prevention of noise-induced hearing loss in ship crew members.

1. Introduction

Noise induced hearing loss (NIHL) is a common type of acquired hearing loss. About 15% of people from age 20–69 years are affected by high-frequency NIHL (Sha and Schacht, 2017). High-frequency hearing impairment is a typical audiological feature of NIHL, characterized by a sharp dip between 3 and 6 kHz (speech frequencies, especially 4 kHz). In extreme exposure situations, NIHL may cause auditory damage involving the whole audible frequencies. Long time exposure to noise on board a ship may induce permanent hearing loss and tinnitus (Yankaskas, 2013; Axelsson and Hamernik, 1987). Besides NIHL, aging process is another etiology of acquired hearing loss. Age-related hearing loss (ARHL) is also characterized mainly by high-frequency hearing impairment.

In this study, we performed audiology testing and tinnitus measurement on a group of crew members who were exposed to noise on board ships (more than 200 days in one year) to decipher specific clinical and auditory characteristics of ship noise related NIHL, as well as its potential correlation with the aging factor.

2. Methods and materials

2.1. Ethic statement

Written consents were obtained from all participants recruited in this study. The study was approved by the Ethics Committee of Chinese PLA General Hospital.

2.2. Inclusion and exclusion criteria

A total of 103 screw members exposed to ship noise were

☆ This project was supported by the National Basic Research Program of China (973 Program) (2014CB943002), the National Natural Science Foundation of China (81470700) and Noise Grant (BWS14J045).
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Peer review under responsibility of PLA General Hospital Department of Otolaryngology Head and Neck Surgery.

https://doi.org/10.1016/j.joto.2018.05.003

recruited as the study subjects in this study, after excluding abnormal external ear or tympanic membranes and ototoxicity history. Another 34 of the study subjects' land based colleagues who worked in an essentially noise free environment served as controls. Exclusion criteria included: ear diseases, history of exposure to ototoxic drugs, family history of deafness, or working career on board a ship of less than four years.

2.3. Clinical and auditory evaluation

Study subjects were interviewed by a team of experienced otolaryngologists to identify medical evidence of hearing loss, tinnitus, vestibular symptoms, use of aminoglycosides, and other clinical abnormalities. Audiometric evaluation included pure tone audiometry using an Madsen Xeta audiometer (0.125 to 8 k Hz, maximum output: 120 dB HL) in a standard sound-proof chamber with a background noise level of less than 30 dB A. The pure tone air- and bone-conduction testing protocols followed the national standard GB/T 16403–1996 of China. Average thresholds at different frequencies were calculated among the subjects. The averaged threshold from 4 to 8 kHz was used to represent high frequency hearing, and that from 0.25 to 0.5 kHz for low-frequency hearing. Hearing loss was categorized as mild if PTA was 26–40 dB HL, moderate if 41–60 dB HL, severe if 61–80 dB HL and profound if > 80 dB HL, in accordance to hearing impairment grading by the World Health Organization.

In acoustic immittance measurement, tympanum pressure (−200 to +200 dPa) and acoustic compliance value were determined (Madsen OTOflex), as well as ipsilateral and contralateral acoustic reflexes.

2.4. Statistical analysis

Statistical analyses were performed using the Prism 6.0 statistical analysis (GraphPad) software. Chi-squared test (with or without continuity correction) and Fisher's exact test were used for comparisons of rates and proportions, and Student t-test for comparing hearing thresholds between study and control subjects.

3. Results

3.1. General information

A total of 103 study subjects (206 ears) were recruited, with no female subjects, aging from 24 to 63 years (median = 54 years). The 34 control subjects included 14 females and 20 males, aging from 27 to 59 years (median = 52 years).

3.2. Auditory characteristics in ship crew members

3.2.1. Prevalence of hearing impairment

Among the 103 study subjects (206 ears), 143 ears (69.4%) showed various degrees of hearing impairment, which was mild in 112 ears (54.4%), moderate in 30 ears (14.6%) and severe in 4 ears (1.95%).

3.2.2. Auditory thresholds across frequencies and age

The average threshold was 34.5, 32.9, 28.8, 24.5, 37.3 and 34.1 dB HL for 0.25, 0.5, 1, 2, 4 and 8 kHz, respectively (Table 1), with the average threshold at 4 kHz being the worst, showing typical audiogram manifestation in NIHL. When compared to the control group, thresholds at 0.25, 0.5, 1 and 4 kHz were significantly worse (Fig. 1, Table 1).

Frequency specific thresholds also showed differences across different age groups (Fig. 2). While no significant difference was observed among age groups for thresholds at 2 and 8 kHz, thresholds at 0.25, 0.5 and 1 kHz were worse in ship noise exposed subjects than in controls among subjects over 50 years of age, but showed no statistical difference between the two groups for those younger than 50 years. When averaged across high frequencies, speech frequencies or all tested frequencies, thresholds showed differences between ship noise exposed subjects and controls only in those older than 55 years, while average threshold across low frequencies was different between the two groups also among those 50–55 years of age.

3.2.3. Hearing impairment in different age groups (Table 2)

Hearing loss severity was different across age groups (Corrected $\chi^2 = 54.632$, $P = 0.000$). While hearing loss severity was not significantly different between subjects 50–55 years of age and those older than 55 years (Corrected $\chi^2 = 0.610$, $P = 0.894$), with mild hearing impairment seen in 65.6% (59/90) and 60.3% (35/58) of the subjects, respectively; it was different when compared to those younger than 50 years (Corrected $\chi^2 = 47.803$, $P = 0.000$; Corrected $\chi^2 = 33.936$, $P = 0.000$), with normal hearing accounting for 65.5% (38/58) in the latter group, compared to 13.3% (12/90) in the 50–55 years group and 17.2% (10/58) in those older than 55 years.

3.2.4. Acoustic immittance measurement

Tympanogram patterns among the 103 ship noise-exposed crew members were types A, As and Ad, with no significant abnormality acoustic reflexes.

3.2.5. Career time and hearing loss

The relationship between hearing loss and working career time on board ships can be seen in Table 3 (the following table). As career time increased, hearing loss also gradually increased ($P = 0.000 < 0.01$) (See Fig. 3).

3.3. Coexisting tinnitus among different age groups (Table 2)

The total tinnitus prevalence among the noise exposed crew members was 54.4% (112/206). Tinnitus was reported to be low pitched in 16 ears (7.8%) and high pitched in 96 ears (46.6%). Tinnitus usually affected both ears, with or without hearing impairment on audiogram. Audiogram patterns were not significantly different among ship noise exposed subjects with low or high pitched tinnitus (Fig. 4). In the 34 control subjects without

Table 1
Comparison of hearing threshold at different-frequencies between ship noise-exposed crew members and controls.

Frequency (kHz)	P value	Mean1[a]	Mean2[a]	Difference	SE of difference	t ratio	df
0.25	1.071056e-010	34.5146	24.2647	10.2499	1.52559	6.71861	272.0
0.5	2.908769e-009	32.9126	24.5588	8.3538	1.36051	6.14022	272.0
1	4.966956e-006	28.8107	22.7206	6.09009	1.30702	4.65951	272.0
2	0.374878	24.5388	23.0147	1.52413	1.71475	0.888833	272.0
4	4.110005e-006	37.3058	25.9559	11.3499	2.41412	4.70148	272.0
8	0.0888202	34.1019	29.4118	4.69018	2.74638	1.70777	272.0

[a] Mean1 = average threshold from noise-exposed crew members. Mean2 = average threshold from controls.

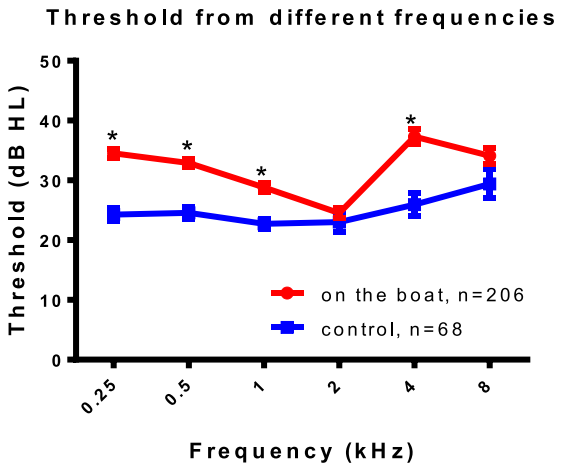

Fig. 1. Average thresholds across frequencies in ship noise exposed crew members (red, N = 206 ears), and their land based colleagues (controls, blue) with no noise exposure history. *: $p < 0.005$.

exposure to ship noises, tinnitus was reported in only 6 ears (8.8%), as compared to 54.4% in ship noise-exposed subjects ($\chi^2 = 35.315$, $P = 0.000$).

Neither tinnitus prevalence nor its reported pitch showed significant difference across age groups among ship noise exposed subjects ($p = 0.079$). However, among the control subjects, tinnitus prevalence did show significant differences when compared among different age groups ($\chi^2 = 31.924$, $P = 0.000$; $\chi^2 = 26.227$, $P = 0.000$; $\chi^2 = 12.584$, $P = 0.000$, respectively).

4. Discussion

Noise is the most common etiology of acquired hearing loss, although other factors for acquired hearing loss such as age and ototoxicity may overlap and thereby confound the investigation in the NIHL population (Kurien et al., 1989; Gates et al., 1993). Aging was therefore considered in this study. Relevant factors other than noise exposure may be involved in the mechanism for hearing impairment in different age groups. For example, older people may have been exposed to noise for a longer time than their younger shipmates.

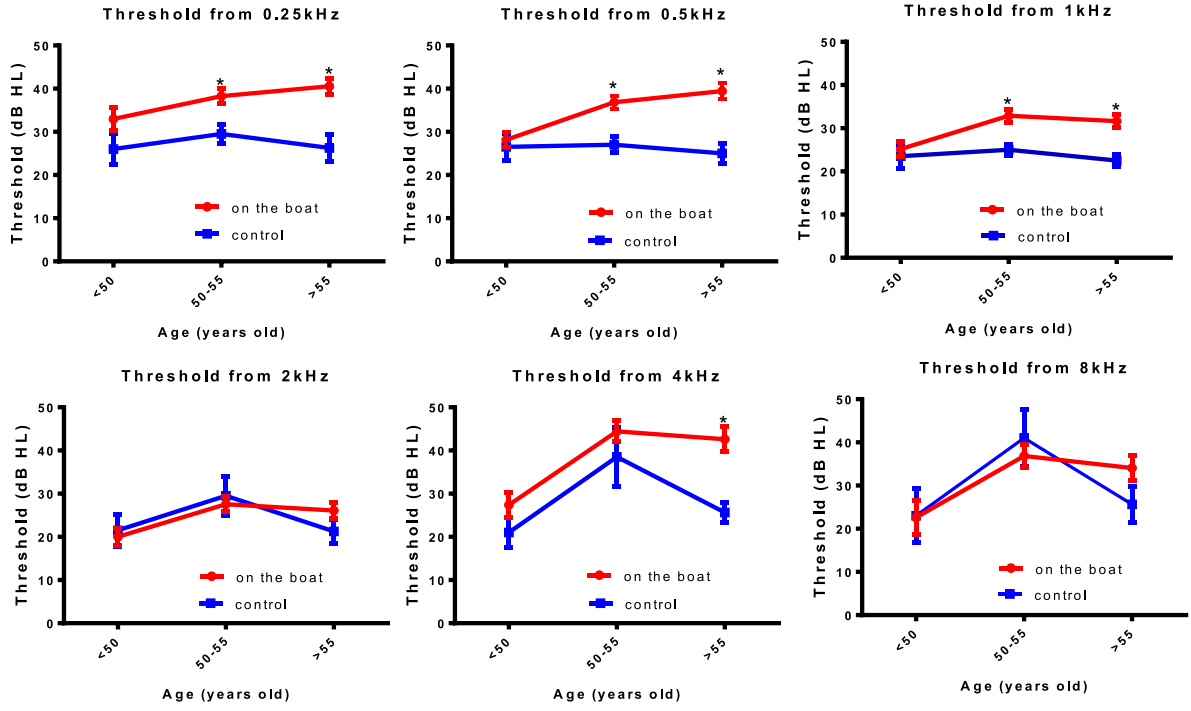

Fig. 2. Threshold comparison at different frequencies and for different age groups. n = 58, 90 and 58 for ages <50, 50–55 and > 55 years, respectively, for ship crew members; and n = 12, 12 and 10, respectively, for the controls. *: $p < 0.005$.

Table 2
Hearing and tinnitus in ship noise exposed crew members across age groups (N = 206 ears), n (%).

	<50 years (n = 58)	50–55 years (n = 90)	>55 years (n = 58)	Test value[a]	P
Hearing (Loss) [b]					
Normal	38 (65.5)	12 (13.3)	10 (17.2)	54.632	0.000
Mild	18 (31.0)	59 (65.6)	35 (60.3)		
Moderate	1 (1.7)	17 (18.9)	12 (20.7)		
Severe	1 (1.7)	2 (2.2)	1 (1.7)		
Profound	0 (0.0)	0 (0.0)	0 (0.0)		
Tinnitus	26 (44.8)	48 (53.3)	38 (65.5)	5.073	0.079

[a] Chi-squared test (Continuity Correction) for hearing comparison and Fisher's exact test for tinnitus comparison.
[b] Categorized based on average pure-tone thresholds at 0.5, 1, 2 and 4 kHz; mild hearing loss: 26–40 dB HL, moderate hearing loss: 41–60 dB HL, severe hearing loss: 61–80 dB HL, profound hearing loss: >80 dB HL.

Table 3
Prevalence of hearing loss and career time.

Career time (years)	Total ears (Number)	Ears with hearing loss (Number)	Ears without hearing loss (Number)	Hearing loss (%)
0–10	60	29	31	48.3%
11–20	24	18	6	75.0%
21–30	34	27	7	79.4%
>30	88	85	3	96.6%

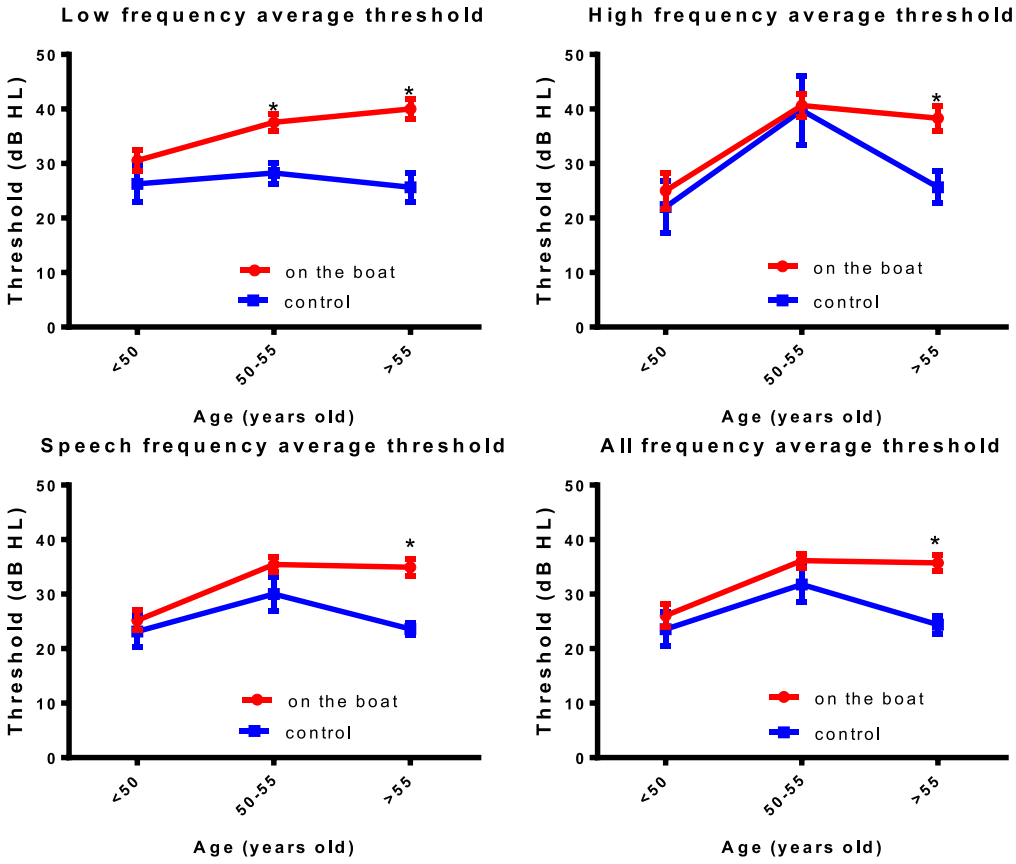

Fig. 3. Threshold comparison for different frequency categories and different age groups. n = 58, 90 and 58 for ages <50, 50–55 and > 55 years, respectively, for ship crew members; and n = 12, 12 and 10, respectively, for the controls. *: $p < 0.005$.

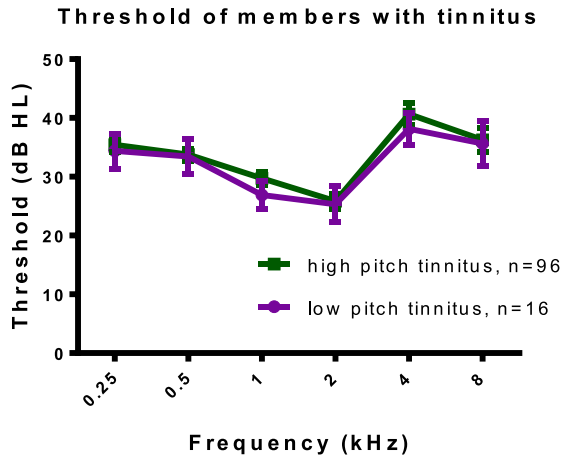

Fig. 4. Average thresholds for ship crew members with high pitch (green, 96 ears) or low pitch (purple, 16 ears) tinnitus.

4.1. Frequency features of noise induced hearing loss in crew members on board ships

Unlike previous studies, our results show that noise exposure on board a ship can affect both high and low frequency hearing. To date, there have been few reports on low frequency NIHL. From Figs. 1 and 2, it can be seen that significant differences in threshold are detected at low frequencies (0.25, 0.5 and 1 kHz) among subjects between 50 and 55 years of age, but not at other frequencies, until age was great than 55 years. We hypothesize that age plays a crucial role in the development of NIHL. Noise may only affect low frequencies at a younger age, and progressively affects higher frequencies as exposure time increases. While this low frequency impairment may also potentially be attributed to noise spectrum distribution on the ship, there has been no evidence proving this mechanism. Further work is obviously needed on this aspect.

4.2. Severity of noise induced hearing impairment in crew members on board ships (Table 2)

For crew members younger than 50 years in this study, 65.5%

showed normal hearing, while only 14.9% of those older than 50 years (both 50–55 years and >55 years) had normal hearing. Considering the age factor, it is probably the best for crew members to stop working on a ship after 50 years of age.

4.3. Comorbid tinnitus

In this study, tinnitus prevalence was significantly higher in ship noise-exposed subjects than in the control group, but showed no difference across age groups. Tinnitus is often accompanied by hearing loss. Once having occurred, it is likely to be permanent. Many tinnitus patients suffer from persistent and high pitch tinnitus with negative emotional experiences, including anxiety, depression, insomnia and attention deficits (Langguth et al., 2007; Alster et al., 1993; Hallam et al., 2004). Although many diseases are known to lead to auditory dysfunction and tinnitus, noise exposure is one of the key causes (Halford and Anderson, 1991; Adoga et al., 2015; Bartels et al., 2008). Occurrence of tinnitus may also be closely related to age and psychological factors. Early diagnosis and treatment of tinnitus are important in order to reduce its impact on ship crew members.

4.4. Management of NIHL

Intervention in NIHL in animal models has been promising (Ohlemiller, 2006), although there has lacked definite positive management in the human NIHL population. While difficult to treat, hearing loss can be probably avoided through protection against noise exposure. From this study, it is clear that hearing impairment is common among crew members working on board ships. It is therefore necessary to provide protection strategies for these individuals appropriate for their auditory features and age.

4.5. Limitations

Pure-tone audiogram is not a complete representation of the audiological outcomes of NIHL, which can include other auditory impairments, such as hidden hearing loss. Additional audiological measurement tools are needed to identify other changes to provide precise assessment of NIHL.

In conclusion, NIHL in ship crew members has specific frequency characteristics and age distributions, which can provide clinical and audiological basis for further studies and prevention of noise induced hearing impairment in this population.

Conflicts of interest

The authors have declared that no competing interests exist.

Acknowledgements

This project was supported by the National Basic Research Program of China (973 Program) (2014CB943002), the National Natural Science Foundation of China (81470700) and Noise Grant (BWS14J045). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.joto.2018.05.003.

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