



Does diving deteriorate hearing functions?

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ABSTRACT

Canarslan-Demir K, Ozgok-Kangal K, Kilic S, Genc H. Does diving deteriorate hearing functions? Undersea Hyperb Med. 2023 Third Quarter; 50(3):313-318.

Studies evaluating the hearing function of professional divers have yielded mixed results. In this study, we aimed to observe the effect of diving on hearing function by comparing the audiometry of experienced divers with a non-diver control group. Secondly, we aimed to compare the hearing function among divers according to the diving years and the number of dives in terms of diving exposure.

Experienced divers who applied to the University of Health Sciences Gülhane Training and Research Hospital Underwater and Hyperbaric Medicine Department between 2017-2021 for periodic fitness to dive examinations were included in our study. The control group was randomly selected from the non-diver population with similar ages and gender. The audiometry of the control group and the study group was compared.

While the control group was found to be better only at 8,000 Hz in the left ear ($p = 0.03$), there was no difference between the study group and the control group in other frequencies and pure-tone averages.

In conclusion, we did not find any evidence regarding the worsening effect of diving on the hearing functions of experienced divers. With the increased awareness of occupational safety in recent years, modern technologies, protective measures, and more conservative diving profiles may have minimized the possible adverse effects of diving on hearing function. Longitudinal studies on hearing functions in the same occupational diver groups should be conducted while observing the effect of different diving profiles and noise exposures.

Keywords: audiometry, diving; hearing; scuba

INTRODUCTION

Hearing loss is a common health problem affecting more than 1.23 billion people worldwide [1]. The World Health Organization (WHO) has reported that one-third of people over 65 have permanent hearing loss. The proportion of older adults with hearing loss is increasing daily. Noise-induced hearing loss is the second most common cause after presbycusis [2].

Diving may give rise to some adverse effects on hearing function [3]. Middle or inner-ear barotraumas (acute or recurrent) resulting from pressure changes can temporarily or permanently deteriorate hearing function [4,5]. Especially saturation divers may complain of otitis externa caused by *Pseudomonas aeruginosa* [6]. Divers are also subject to inner ear decompression sickness, caused by nitrogen bubbles blocking the blood vessels that circulate the inner ear and can lead to hearing loss [7-9].

Likewise, noise-induced hearing loss due to motor noise was also reported among scuba divers in the literature [10-12]. Exposure to loud noises from air-flow or communication systems inside the diving helmet, explosions, or during the use of waterjets, hydraulic wrenches, or hammers can also contribute to hearing loss [13,14]. The exposure varies among divers according to diving tasks. Divers might quit diving or resume diving due to these ear disorders. In Turkey, a medical examination of hearing function is required for professional divers every two years according to the Professional Diver Regulation and required for instructor divers of the Turkish Underwater Sports Federation (TUSF) every five years according to Instructor Divers Regulation.

The studies evaluating the hearing function of professional divers revealed mixed results [12-15], while no hearing loss was reported in recreational divers [16,17]. In this study, we aimed to observe the effect of diving on hearing function by comparing the audiometry of experienced divers with a non-diver control group representing a population of similar age groups. We also aimed to compare the hearing function among divers according to the diving years and the number of dives in terms of diving exposure.

MATERIALS AND METHODS

The protocol of this study was approved by the University of Health Sciences (UHS) Gülhane Training and Research Hospital Non-Interventional Research Ethics Committee at the meeting held on 21.04.2022 with the project/decision number 2022/127.

Experienced divers who applied to the UHS-Gülhane Training and Research Hospital Underwater Medicine and Hyperbaric Medicine Department between 1 January 2017 through 1 November 2021 for periodic fitness to dive examinations were included in our study. Candidate divers, divers with pathology in the otoscopic examination, conductive hearing loss and missing audiometry were excluded from the study.

The information of the divers included in the study was obtained retrospectively from their medical records. The diver's age, body mass index (BMI), smoking history, diving experience (diving year, number of dives), type of diving certificate, audiometry data,

and ear-related diving accident (barotrauma, inner ear decompression disease), otoscopic findings were recorded.

The control group was randomly selected from a non-diver population older than 18 who were admitted to the HSU Gülhane Training and Research Hospital Ear Nose and Throat Department for any reason other than hearing loss and upper respiratory tract infection. Patients with congenital hearing loss, conductive hearing loss, diagnosed eustachian dysfunction, middle or external ear problem, history of any ear surgeries, chronic otologic problems, history of ototoxic drug intake, any congenital anomalies of the auricle or external auditory meatus, history of temporal bone trauma or head injury, chronic neurological disease, noise trauma and pathological otoscopic findings noted on their medical records were excluded from the control group. These individuals did not work in an environment where they had been exposed to noise or pressure changes and were similar to the diver group in terms of age and gender.

The influence of diving exposure on hearing function was also analyzed in terms of diving experience in years and the total number of dives separately. For statistical comparison, the divers were divided into groups as those with 15 years or less of diving experience, those with more than 15 years of diving, and those with 3,000 or more dives and those with fewer than 3,000 dives according to the total number of dives.

Statistical analyses

Statistical analyses were performed using SPSS Package Program version 21. Data are expressed as n (%), mean \pm standard deviation, and median (minimum-maximum). The Kolmogorov-Smirnov and Shapiro-Wilk tests performed normal distribution analyses of continuous variables. The categorical variables were compared with chi-square test. Audiometry results of the control and study groups were compared separately for each frequency and pure-tone average (PTA). For comparison, Student's t-test was used in a normal distribution, and the Mann-Whitney U test was used in the absence of normal distribution. A p-value of < 0.05 was considered statistically significant.

RESULTS

Our study included 70 participants (56%) in the control group and 55 (44%) in the diver group. Descriptive information of divers is presented in Table 1. While the mean age of the control group was 40 ± 13.3 years, the mean age of divers was 44.4 ± 10 years. The male/female ratio was 56 (80%) /14 (20%) women in the control group and 49 (89.1%) / six (10.9%) in the diver group. There was no statistically significant difference between the control group and the diver group in terms of age and gender (respectively p = 0.17, p = 0.06). The pure-tone thresholds of the diver and the control group are compared in Table 2. When the hearing function of divers compared according to diving experience, divers experienced more than 15 years had significant deterioration only at 6,000 Hz in the right ear (p= 0.03). No significant difference was found at oth-

	N(%)	Mean ± SD	Median (min-max)
age		44.4±10	40 (22-66)
male / female	49 (89.1) / 6 (10.9)		
body mass index		25.9 ± 2.9	25.5 (20.3-33.7)
smoke history			
smokers	16 (29.1)		
non-smokers	39 (70.9)		
Smoking year			10 (1-40)
diving certificate			
professional	12 (21.8)		
scuba diving instruction	43 (78.2)		
diving year		17.6 ± 7.1	18 (5-41)
number of dives			2000 (300-15000)
max depth(metre)			150 (38-150)
mixed gas dive	30 (73.2)		
diving accident related to otolaryngology	5 (12.2)		
diving experience (year)			
≤ 15	17 (41.5)		
>15	24 (58.5)		

(SD: standard deviation)

Table 1. Descriptive Characteristics of Divers

er frequencies and PTA (Figures 1 and 2). When the divers were classified according to the total number of dives, the auditory function was statistically significantly better only at 6000 Hz in the right ear in divers who had 3000 and above a total number of dives (p = 0.02). No significant difference was found at other frequencies and PTA (Figures 3 and 4).

DISCUSSION

The importance of occupational health is remarkably growing worldwide. In this respect, diving as an occupation requires the rigorous attention of physicians in order to take appropriate preventions in working sites and optimize health standards. The auditory function of a diver may worsen temporarily or permanently due to rapid pressure changes, acute injuries, and noise exposure during diving tasks [10]. This study aimed to observe the effect of diving on the hearing function of experienced divers. In our

audiometry	diver group	control group	p value
frequency (Hz)	hearing thresholds (dB)	hearing thresholds (dB)	
right			
250	10 (5-30)	10 (0-30)	0.61
500	10 (5-100)	10 (0-25)	0.26
1000	10 (5-25)	10 (0-25)	1.00
2000	10 (0-25)	10 (0-25)	0.91
4000	10 (0-90)	10 (0-25)	0.15
6000	15 (5-95)	15 (5-55)	0.21
8000	17.5 (5-70)	15 (0-50)	0.52
PTA (air)	8.3 (3-40)	11 (2-34)	0.65
left			
250	10 (5-60)	12.5 (0-35)	0.89
500	10 (5-50)	10 (0-25)	0.68
1000	10 (5-40)	10 (0-25)	0.50
2000	10 (0-50)	10 (0-30)	0.49
4000	15 (5-100)	10 (0-60)	0.15
6000	20 (0-95)	15 (0-65)	0.60
8000	27.5 (5-85)	15 (5-60)	0.03*
PTA (air)	8.3 (3-37)	10 (3-31)	0.41

(PTA: pure tone average)

Table 2. Comparison of Audiometry of Diver and Control Group (Hearing thresholds are expressed as Median (minimum-maximum))

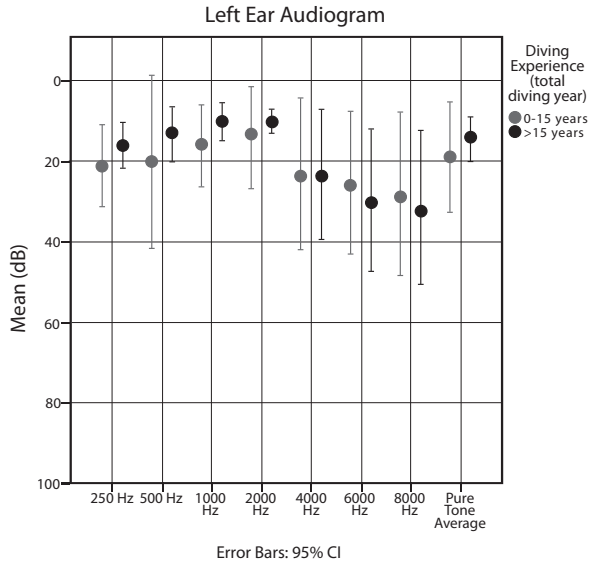


Figure 1. Left ear audiogram-diving experience (total diving year)

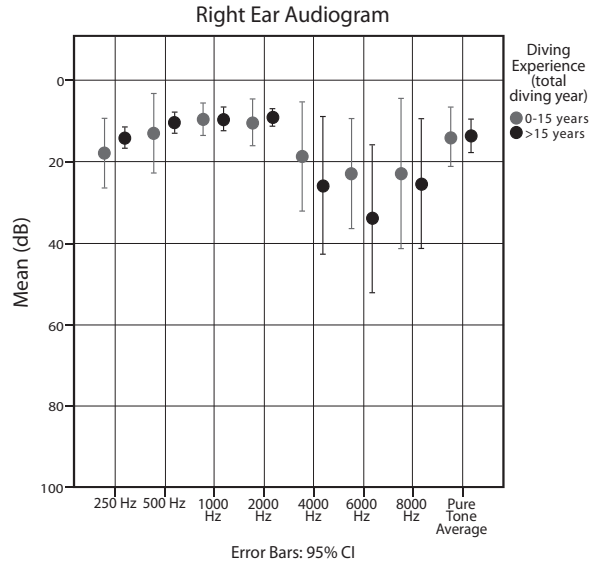


Figure 2. Right ear audiogram-diving experience (total diving year)

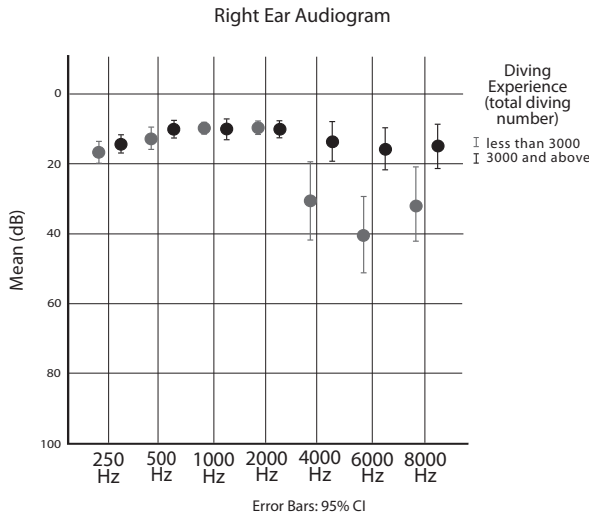


Figure 3. Right ear audiogram-diving experience (total diving year)

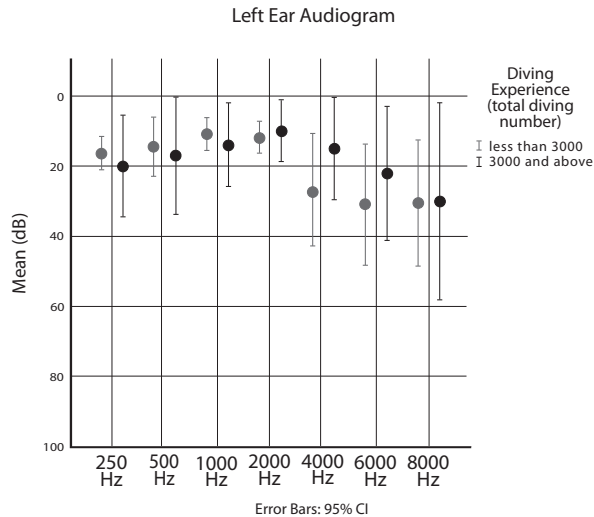


Figure 4. Left ear audiogram-diving experience (total diving year)

study, the hearing function of divers was similar to a non-diver control group. While the control group was found to be better only at 8000 Hz in the left ear, there was no difference between the study group and the control group in other frequencies and PTAs.

Earlier studies reported the negative influence of diving on hearing functions. In one study, 30 professional divers were followed for 12 years, and a significant decrease was found in auditory function at 250, 500, 2,000, 3,000, and 6,000 Hz for the right ear and 3,000, 4,000, and 6,000 Hz for the left ear [10]. In another long-term follow-up audiometry data of divers, a statistically significant decrease in hearing function was detected at 4,000 to 8,000 Hz

[18,19]. However, recent studies concluded that diving does not worsen hearing function. Sames et al. analyzed the change in audiological records of 227 professional divers between 10 and 25 years. This study demonstrated no significant effect of diving on hearing functions in long-term follow-ups [20]. In a longitudinal study conducted by Winglear et al. on 35 divers, it was found that the hearing thresholds of divers increased over time. Still, this deterioration was less than expected due to age [21]. Similarly, in our study, diving did not adversely affect the hearing functions of experienced divers compared to a non-diver control group.

On the other hand, researchers have discussed the effect of noise and the cumulative effect of diving in terms of the diving year, diving frequency, and diving depth on the hearing function of divers. In a study with a group of U.S. Navy divers, the diving year did not significantly affect hearing [22]. In a longitudinal study of 67 professional divers followed for six years, there was a significant threshold shift in hearing functions at 4 kHz (mean 2.6 dB, 95% confidence interval 0.9 to 4.3 dB). The authors suggested that this deterioration was associated with occupational noise exposure but not diving frequency [10]. In a study comparing the hearing function of 151 divers and 120 offshore workers, divers were more likely to have a pattern of severe noise-induced hearing loss (OR 4.61, 95% CI 1.39-15.39, $p < 0.05$). The authors concluded that noise is the cause of hearing loss in divers [6].

In our study, we classified divers according to their diving experience (diving years and the number of dives) to analyze the effect of diving exposure on hearing function. Hearing deteriorated significantly only at 6,000 Hz in the right ear of divers experienced more than 15 years. We did not find any significant influence of diving year on hearing function. When the divers were grouped according to the number of dives, the auditory function was statistically significantly better in those who made 3000 and above dives at 6000 Hz only in the right ear ($p = 0.02$). No significant difference was found at other frequencies and PTA. However, our study population mainly consisted of instructor divers (78,2%). As the instructor divers perform more conservative and safe dives for training purposes, the diving exposure of instructor divers may significantly vary from other subgroups of professional divers in terms of diving depth, diving frequency, and diving injuries.

Although noise is still the most common cause of hearing loss in developed countries, noise-reduction technology may successfully reduce its adverse effects [23,24]. With the increased awareness of safe diving among divers in recent years, modern technologies and protective measures to prevent hearing loss may have minimized the possible adverse effects of diving on hearing function. This may contribute to the protection of the hearing function of

experienced divers. In our study, 78.2% of the divers were diving instructors. Diving instructors are trained and careful about diving health and safety as they accompany novice divers. Also, they might have been exposed to relatively less noise than other subgroups of professional divers.

On the other hand, the routine periodic examination and medical fitness requirement for experienced divers in Turkey ensure that they should take extra care of their health. It is noteworthy that the selected healthy group continues to dive in each medical examination. Those with deteriorated hearing function cannot continue diving or might quit diving voluntarily. These may also be defined as the "healthy worker effect"

Limitations

Due to the retrospective nature of our study, we could not observe the actual dives. The data about the diving experience were gathered from divers who might not remember correctly. In addition, we could not record the noise exposure level and the audiograms of divers at the beginning of their diving careers. Finally, professional divers were relatively less than instructor divers, which might lead to a non-homogenized diving profile for our study profile regarding diving depth and noise exposure.

CONCLUSION

In conclusion, we did not find any evidence regarding the worsening effect of diving on hearing functions in experienced divers. In addition, diving experience (dive years, total number of dives) did not cause any deterioration in the hearing functions of divers. Our results are similar to recent studies conducted on experienced divers. With the increased awareness of occupational safety in recent years, modern technologies, protective measures, and more conservative diving profiles may have minimized the possible adverse effects of diving on hearing function. Longitudinal studies on hearing functions in the same occupational diver groups should be conducted while observing the effect of different diving profiles and noise exposures.



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