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Original Article

Use of Otoacoustic Emissions (OAE) to detect sub-clinical inner ear damage in divers of the Indian Navy

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ABSTRACT

Background: Professional Divers are at a high risk of Sensorineural Hearing Impairment. Divers may sustain sub-clinical hearing loss that is not identified on pure tone audiometry (PTA). Otoacoustic Emissions (OAE) reflect the functional status of the Outer Hair Cells. OAE testing constitutes the only non-invasive means of objective cochlear investigation and may be a more sensitive measure than PTA in identifying sub-clinical hearing loss.

Methods: This cross-sectional study was performed to determine utility of Otoacoustic Emissions testing in detecting sub-clinical Inner Ear damage in divers of Indian Navy. Transient Evoked Otoacoustic Emissions (TEOAE) levels were measured in 50 audiotologically asymptomatic ship divers of Indian Navy and compared with control group comprising of 50 normal hearing individuals.

Results: No statistically significant differences were observed between the study and control group. Also no correlation was observed between diving years and TEOAE levels. There was no correlation greater than -0.49 between diving years and TEOAE SNR.

Conclusions: We concluded that TEOAE levels are not a sensitive tool in identifying ships divers without any history of noise exposure at risk for developing hearing loss.

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Introduction

Divers in the Navy undergo regular Medical Examination including Pure Tone Audiometry to assess their fitness to dive. They also may seek medical attention due to acute injuries and occasionally due to concerns about long-term health effects of diving. Ear injury is the most common medical problem in diving. Many studies have reported that

diving places the Inner Ear at risk and leads to hearing loss.^{1–4} Divers are susceptible to Inner Ear damage due to various factors inherent in their profession including Inner & Middle Ear Barotrauma, Inner Ear Decompression Sickness, Accidental Carbon-Monoxide Poisoning, Nitrogen Narcosis and Noise.

Hearing loss on Pure Tone Audiometry (PTA) becomes apparent only after significant Outer Hair Cell (OHC) damage

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occurs. PTA is insensitive to such early and subtle cochlear changes and cannot serve as a method for early detection of sub-clinical cochlear damage.

As a part of any hearing conservation program, it is imperative to detect the hearing loss at the earliest and commence appropriate measures and therapy to reverse/limit the damage.

Evoked Otoacoustic Emissions being an objective measure of Inner Ear and Outer Hair Cell function, offer a means of evaluating their function directly, before damage to the Inner Ear manifests as clinical hearing loss. In this context, Otoacoustic Emissions (OAE) being the only non-invasive means of objective cochlear investigation might provide indispensable information.

This study aimed to study the utility of Otoacoustic Emissions in detecting sub-clinical Inner Ear damage in divers of the Indian Navy by screening audiotologically asymptomatic divers of the Indian Navy using Otoacoustic Emissions to detect evidence of Inner Ear damage.

Material and methods

This study was conducted for early detection of sub-clinical Inner Ear damage from April 2011 to April 2013.

Ship Divers (Officers & Sailors) reporting to the ENT department for audiometry as a part of Annual Diving Medical Examination were recruited in the study. Age matched non-divers with normal hearing thresholds on Pure Tone Audiometry served as controls.

Pure tone audiometry to assess hearing thresholds was done using Grason-Stadler Inc GSI 68 audiometer in a standard sound treated audiometry room. Air conduction hearing thresholds were measured at 0.5, 1, 2, 3, 4, 6 and 8 KHz. Thresholds were considered normal when threshold at each frequency was <25 dBHL.

A standard questionnaire was used for all the subjects for data collection before inclusion in the study. This included an otologic history, documentation of the length of service as divers and diver profile. Ear examination was performed by the authors using a pneumatic otoscope. 226 Hz probe tone Tympanometry was used to ensure absence of external or middle ear pathology or current middle ear barotrauma from recent diving.

The following inclusion and exclusion criteria were used for this study.

Inclusion criteria

1. Males
2. Age range: 21–45 years
3. Normal hearing sensitivity in both ears on pure tone audiometry
4. Diving years: minimum 1 year

Exclusion criteria

1. Hearing loss in one or both ears on pure tone audiometry
2. H/o middle ear disorder
3. H/o prolonged exposure to occupational noise
4. H/o ototoxicity
5. H/o serious medical illness like diabetes mellitus, cardiovascular diseases and hypercholesterolemia
6. H/o head injury

After a brief overview of the study objectives and procedures, the study subjects signed an informed consent.

Examination

The testing included PTA and TEOAE. Subjects who fulfilled the above mentioned criteria were included in the study and subjected to TEOAE measurement. A total of 50 divers were recruited into the study. They were compared with a control group of age matched 50 non-divers.

Madsen Capella instrument was used to measure TEOAE in a relatively quiet room. TEOAE were recorded and analyzed using clicks of 40 μ s presented at the rate of 50/s in fast screen mode. The stimulus level was 80 dB SPL. The response was windowed from 3.00 ms to 12.50 ms and stored in two buffers after completion of 2000 sweeps. The stop criteria used for analysis was an average of 2000 sweeps. The responses were recorded and analyzed at 1, 1.5, 2, 3 and 4 KHz.

Data analysis

TEOAE Signal to Noise Ratio (SNR) was compared between study group and control group by Student's t-test (independent samples, two-tailed) (Table 1).

Pearson linear correlations between diving years and average TEOAE SNR values at 3 and 4 KHz were calculated (Table 2).

Statistical analysis was performed using appropriate statistical tools.

Table 1 – TEOAE SNR values for right and left ear (mean and standard deviations).

Frequency in KHz	TEOAE SNR values in right ear				TEOAE SNR values in left ear			
	Study group		Control group		Study group		Control group	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	9.7	3.92	9.99	3.69	9.3	2.96	9.5	3.35
1.5	12.21	5.57	12.53	5.17	12.14	4.56	12.94	5.24
2	11.71	3.73	11.83	3.99	11.45	5.93	11.95	3.67
3	14.44	6.57	14.78	5.99	12.15	5.75	11.65	6.45
4	9.91	6.35	10.5	4.72	9.11	3.97	9.12	4.75

Table 2 – Pearson linear correlation coefficients between TEOAE SNR and diving years.

Ear	Correlation between diving years and TEOAE SNR at 3 KHz	Correlation between diving years and TEOAE SNR at 4 KHz
Right	–0.49	–0.29
Left	–0.37	–0.27

Results

The aim of our study was to study the utility of Otoacoustic Emissions in detecting sub-clinical Inner Ear damage in divers of the Indian Navy. A total of 50 divers in the age range of 21–45 years (mean = 26 years) met our criteria and were included in the study (Fig. 1).

TEOAE SNR was compared at 1, 1.5, 2, 3 and 4 KHz between study and control group using student's t-test. No statistically significant difference was observed between the study and control group.

Pearson's linear correlation was used to measure relationship between diving years and TEOAE SNR values at 3 and 4 KHz in both ears. We found negative correlations between the two variables. There was no correlation greater than –0.49 between diving years and TEOAE SNR (Figs. 2 and 3).

Discussion

Previous cross-sectional studies and longitudinal studies have shown presence of Sensorineural Hearing Loss in divers on pure tone audiometry.^{4–7} These studies point towards the need for investigating the presence of sub-clinical hearing loss before it has a permanent effect on the hearing of divers. In the present study, a group consisting of Ship Divers with normal hearing was compared with a control group using TEOAE. No significant difference in TEOAE SNR was observed.

Only two previously published studies used OAEs to evaluate sub-clinical hearing loss in divers. Duplessis C (2009) evaluated eight US Navy-trained male divers who participated in a repetitive diving protocol encompassing up to a maximum of 10 weeks of diving.⁸ OAE testing and audiometry

Fig. 1 – Age range of study and control group in years. **Fig. 2 – TEOAE SNR values of right ears study and control group.**

was conducted on both ears prior to and immediately after each dive. They found an average group wideband transient-evoked OAE shift of –1.24 dB. Only 25 significant threshold shifts were identified in over 1000 comparisons via audiometry. Thus they concluded that OAE testing identified significant Transient Emission Shift (TES) and suggested that surveillance may identify those at risk for subsequent Inner Ear Barotrauma (IEBT) and hearing loss.

On the other hand Hausmann et al (2011) similar to our results found that OAE did not reveal significant differences between 81 sport divers with a mean of 300 dives to a control group of 81 non-divers.⁹ The differences in the studies may be attributed to the methodology used. Duplessis and Fothergill (2009) investigated transient emission shift after each dive whereas our study had not considered time duration between the test and last dive. The subjects in our study were officers and sailors of the Indian Navy reporting to the department for audiometry as a part of their annual medical examination.

Hausmann et al (2011) observed significant differences of the hearing thresholds at several frequencies between sport divers and non-divers in all age groups on PTA, although a Bonferroni correction for multiple testing was applied. Interestingly, the results were contradictory. Divers obtained better hearing results in air conduction, whereas non-divers showed better results in bone conduction.

Fig. 3 – TEOAE SNR values of left ears of study and control group.

A number of studies have compared the hearing threshold in professional divers using only Pure Tone Audiometry. In 1961 in a group of 62 Royal Navy divers and submarine escape training instructors, a high-frequency hearing loss was found in most of the divers.¹⁰ However, these divers had been exposed to gunfire and machinery noise during their naval careers and noise could not be excluded as the causative mechanism.

An important finding was a prevalence of 60% of hearing impairment in a group of abalone divers who had not been exposed to noise.¹¹ These individuals, however, had been subjected to a repeated compression-decompression stress by a mean history of 6 years of diving with an average diving depth of 15–20 m for 4 h on 100 days per year. The divers with recognizable hearing loss remembered having barotrauma in the past.

In another study by Molvaer OI et al (1985) 164 professional Norwegian divers were subdivided into different age groups and hearing thresholds were compared with a standard population from Norway.^{12,13} Young divers were found to have better hearing compared with the reference group, and with increasing age this difference decreased. The authors claimed that hearing deteriorates faster in professional divers with increasing age. These results were confirmed when 116 divers were reexamined 5 years later. Noise at work and barotrauma were thought to contribute to the rapid deterioration of hearing in the professional divers.¹

It is postulated that the human hearing range is reduced from 130 dB in air to 55–60 dB in water. The reduction causes the diver to be less resistant to noise underwater because acoustic energy underwater does not resolve as fast as in air.¹⁴ In addition, sawing, drilling, and grinding underwater may give rise to noise levels of 90–105 dB and noise from the air stream venting inside underwater helmets can reach average noise levels of 93–99.5 dB.^{15,16}

Most of the studies examined professional divers who had been exposed to gunfire or other noise at work->1,10,12</sup>. Noise was likely the main cause of the altered pure-tone thresholds.

This interpretation is supported by the fact that pure-tone thresholds of divers who had been exposed to noise underwater are similar to those obtained from control subjects who had been exposed to noise on land. In a cross-sectional study, auditory function was compared in 26 Norwegian construction divers and 26 workshop workers. Both groups had been exposed to noise, and divers had less hearing impairment at low frequencies (0.25 and 0.5 kHz).¹⁷

In a cross-sectional study by Klingmann C et al (2004) the data collected had the advantage that the subject group of divers and the control group of non-divers had similar noise exposure histories.¹⁸ None of the divers included in the subject group had a history of Inner Ear Barotrauma (IEBT), and this can be excluded as a possible cause of any deterioration of Inner Ear function detected. Pure-tone audiometric thresholds did not reveal significant differences between divers and controls in all groups. However, there were marked inter-individual differences in the hearing levels in each age group, so with increasing SDs, the power of statistical comparison was reduced. These authors did not find statistically reduced hearing levels in sport divers compared with a non-diving control group.

In our study we did not find any statistically significant difference in TEOAE level in divers with normal hearing when

compared to control group. This suggests that the divers in our study did not have any significant sub-clinical hearing loss in absence of clinical hearing loss on audiometry.

Our results of poor to moderate correlations only between diving years and TEOAE levels suggest that diving years does not have any significant influence on TEOAE levels.

The following conclusions can be drawn from the study:

1. TEOAE does not appear to be a sensitive tool to investigate sub-clinical hearing damage in ship divers with normal hearing without any significant history of noise exposure or Inner Ear barotrauma
2. No correlation was found in this study between diving years and TEOAE levels

It is therefore concluded that routine screening for hearing loss by Otoacoustic Emissions testing of asymptomatic divers with normal hearing on pure tone audiometry is not recommended.

Conflicts of interest

All authors have none to declare.

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