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# Otological Complaints in Free Divers

## *Serbest Dalışlarda Otolojik Yakınmalar*

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**ABSTRACT**

**Objective:** This study aimed to assess daily otological symptoms of participants during a 10-day course of free diving, thereby determining their ear equalization rates and revealing differences on course days; moreover, the importance of Valsalva maneuver is evaluated.

**Materials and methods:** Daily examination data were collected from divers with normal physical examination and respiratory function tests during a 10-day diving course. During the study, a 3 m dive was performed on the first day; a 5 m dive on the second day; a 7 m dive on the third day; an 8 m dive on the fifth day; and 10 m dives on the 6th, 7th and 8th days. Each of the 29 participants who received the diving course were interrogated for their ability to make pressure equalization in both ears, eye pain, tooth ache, and palpitations. It was also assessed whether subjects having ear pressure equalization problems could solve their problem, and the ways by which the participants could solve their problems. A p value of $<0.05$ was considered to be statistically significant.

**Results:** A comparison between the first day and the second, third, fifth, sixth, and eighth days with respect to comfort in diving revealed significant differences ($p<0.05$). No significant differences were found in otological symptoms with regard to smoking in any of the seven different diving days ($p>0.05$).

**Conclusions:** The training of freedivers with repetitive dives can provide effective learning of the Valsalva maneuver and thus reduce autological symptoms.

**Keywords:** Free diving, eustachian tube, barotrauma, ear diseases

**ÖZ**

**Amaç:** Bu çalışmada 10 günlük serbest dalış sırasında katılımcıların günlük otolojik semptomlarının değerlendirilerek, kulak eşitleme oranlarının, kurs günlerindeki farklılıklarının ortaya konulması, ayrıca Valsalva manevrasının öneminin değerlendirilmesi amaçlandı.

**Gereç ve Yöntemler:** Fizik muayenesi ve solunum fonksiyon testleri normal sınırlarda olan serbest dalıcılarda 10 günlük dalış eğitimi sırasında günlük muayene verileri toplandı. Çalışma sırasında 1. gün 3 m, 2. gün 5 m, 3. gün 7 m, 5. gün 8 m, 6., 7. ve 8. günlerde ise 10 m dalış gerçekleştirildi. On günlük bir süre boyunca dalış eğitimi verilen 29 katılımcının her bir dalış gününde her iki kulakta basınç eşitlemesi

yapıp yapamadıkları, göz ağrıları, diş ağrıları ve çarpıntı hislerinin olup olmadığı sorgulandı. Kulakta basınç eşitleme problemi yaşayanların bu sorunları çözüp çözemedikleri, kulakta basınç eşitleme sorunu çözebilenlerin çözüm yolları değerlendirildi. Gruplar arasındaki verilerin karşılaştırması ki-kare ve T-testleri kullanılarak yapıldı. P<0.05 değerleri istatistiksel olarak anlamlı kabul edildi.

**Bulgular:** Dalış yapılan ilk gün ile 2., 3., 5., 6. ve 8. günler arasında dalışlardaki rahatlık açısından incelendiğinde istatistiksel olarak anlamlı farklılıklar izlendi (p<0.05). Dalış yapılan yedi farklı günde de sigara kullanımı ile otolojik yakınmalardaki sıklık açısından istatistiksel olarak anlamlı sonuçlar bulunmadı (p>0.05).

**Sonuç:** Sonuç olarak, serbest dalış sporcularının eğitimlerinin tekrarlayan dalışlarla yapılması Valsalva manevrasının etkin öğrenilmesini ve böylece otolojik semptomların azalmasını sağlayabilmektedir.

**Anahtar Sözcükler:** Serbest dalış, östaki tüpü, barotravma, kulak hastalıkları

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## INTRODUCTION

Water sports are progressing rapidly nowadays. Among them, the diving branch has been attracting a great deal of attention, and the number of persons willing to get diving courses has been rapidly expanding in recent years. The effects of diving on human physiology, pathological conditions associated with the branch, and diving safety during diving courses have been studied (1). The most common disorder among divers is middle ear barotrauma, reported to occur between 30 to 46% in studies (2,3). It usually emerges during descent, when the eustachian tube does not allow air entry into the middle ear to equalize the pressure gradient with the middle ear (4,5). This generally occurs when appropriate equalization techniques are not used or when upper respiratory infections are present, allergic rhinitis and/or anatomic deformities or variations prevail (6,7). Studies have reported that an additional 23 mmHg pressure per 30 cm diving is born by the tympanic membrane. Thanks to some maneuvers used during diving, excess pressure and the added pressure burden can be reduced. When pressure equalization begins in the first few meters of diving, a more comfortable diving experience can be achieved (8,9).

Most divers are instructed to perform the Valsalva maneuver to equalize middle ear pressure during descent (10). When such equalization cannot be done due to any reason, a pressure gradient of approximately 90 mmHg starts to build up after the first few meters. This pressure gradient leads to eustachian tube collapse, which in turn renders pressure equalization impossible despite performing available maneuvers (6). As the pressure gradient increases and when the diving depth reaches an average of 1.5 m, the risk of tympanic membrane perforation significantly increases (11).

Tympanic membrane may be ruptured in most severe forms; this type of injury may cause severe vertigo; and, as a result of disorientation, may threaten life secondary to caloric stimulation exerted by cold water entering the middle ear (3). Barotrauma affecting middle ear may also cause tinnitus, vertigo, nausea, and hearing loss (3,12).

Herein, we aimed to investigate daily otological symptoms of the participants during a 10-day free diving course to reveal divers' ear equalization rates and the differences between the course days. It was also aimed to question smoking status to determine the effect of smoking on ear equalization rates. In addition, as the number of dives and the duration of dives increased, it is hypothesized that athletes learn the Valsalva maneuver more effectively, and that a positive effect results in terms of decreasing otologic complaints.

## MATERIALS AND METHODS

The study was approved by the clinical research local ethics committee (decree No:19). The work included patients with normal physical examination and respiratory function tests. Their daily

examination data were collected during a 10-day diving course in at a seawater temperature of approximately 19-20°C, in still water, and under arid weather conditions. Weather conditions allowed diving activity only on seven days of the 10-day course, and only data pertaining to those days were analyzed. The participants underwent a general systemic examination including a detailed otorhinolaryngological examination each day they dove. The divers who were diagnosed with a condition precluding diving or who stated that he or she could not tolerate diving were not allowed to dive. During the diving course, participants were told to perform Valsalva maneuver to equalize pressure in both ears at each 1-m depth. During the study the participants dove 3 m on the first day, 5 m on the second day and 7 m on the third day. As weather conditions were unfavorable, diving was cancelled on the fourth day. An 8 m dive was performed on the fifth day and a 10 m dive on the sixth, seventh and eighth days. Diving activities were withheld on the ninth and tenth days due to unfavorable weather conditions.

The study questioned whether the 29 participants who received the diving course for a 10-day period could perform pressure equalization in both ears on every diving day, and whether they had eye pain, toothache, or palpitations. It was also assessed if those who experienced problems with ear pressure equalization solved their problems; as well as how those who solved their problems did so. The participants were evaluated by an otorhinolaryngologist and a general systemic examination after each diving activity.

### Statistical analysis

Statistical analyses were performed using SPSS for Windows 18.0 (Chicago, IL) software package. Descriptive statistics included mean±standard deviation for normally distributed variables. Inter-group comparisons of the variables were performed using the chi-square and T-tests. A p value <0.05 was considered to be statistically significant.

## RESULTS

This study enrolled a total of 29 participants of whom 17 (58.6%) were males and 12 (41.4%) were females. The age range of the study population was 21.7±4.4 (min: 16- max: 34) years. The mean height was 174.5±7.9 (min: 163, max. 185) cm and the mean body weight was 70.2±12.6 (min: 52, max: 100) kg. The mean pulse rate measured immediately prior to diving on the first day of course was 74.6±9.6 (min: 60, max: 98) bpm, and the mean saturation was 97±2 (min: 88, max: 99) %. Three (10.3%) participants had engaged in water sports for about a year. two (6.8%) participants for about 1.5 years. one (3.4%) participant for about two years. and 23 (79.3%) participants for about four months. Questioning the participants about history of deep diving activity revealed that 18 (62.1%) participants had not engaged in deep diving, but 11 (37.9%) had engaged in such activity. When smoking rates of the participants were evaluated, it was determined that only one in 29 participants (3.4%) started smoking three years ago and used 1 pack of cigarettes per week.

On the first day of the course, the participants performed a mean of 7.8±2.6 (min: 4- max: 15) dives. The participants stated that a mean of 6.1±3.5 (min: 0, max: 15) dives were comfortable and free of ear pain, obstruction, or any other irritating symptom. It was noted that participants performed a given number of dives on the first day. On the second day all participants stated that they could perform diving, and none of them were found to have any condition that would cancel diving. On the second day of the course program the participants performed a mean of 8.8±3.8 (min: 5, max: 20) dives. The participants stated that a mean of 8.3±4.3 (min: 0, max: 20) dives were comfortable and free of ear pain, obstruction, or any other irritating symptom. On the third day of the course all participants also stated that they could perform diving, and none of them were found to have any condition that would cause cancellation of diving. Participants performed a mean of 8.7±2.9 (min: 6, max: 20) dives on the third day. They stated that a mean of 7.8±3.8 (min: 1, max:

20) dives were comfortable and free of ear pain, obstruction, or any other irritating symptom.

An otolaryngological examination on the fifth day of the course revealed thickening of tympanic membranes and otitis media with minimal acute effusion in five patients. A participant was found to have reduced breath sounds over the lower lung zones on auscultation. A chest X-ray showed pneumotic consolidation, for which treatment was begun and that participant's dives were cancelled. A participant that developed pneumonia and four participants that developed acute serous otitis media and who stated that they would not tolerate diving were excluded from the program. On the fifth day, the dives continued with 24 participants. A mean of 8.4±2.7 (min: 5, max: n15) dives were performed. The participants stated that a mean of 7.9±3.2 (min: 2, max: 15) dives were comfortable and free of ear pain, obstruction, or any other irritating symptom. On the sixth day of the course two of the four participants that had not dived due to otological symptoms stated that they could dive; so, on the sixth day the diving program continued with 26 participants. A mean of 8.2±1.6 (min: 5, max: 10) dives were performed. The participants stated that a mean of 7.9±2.0 (min: 3, max: 10) dives were comfortable and free of ear pain, obstruction, or any other irritating symptom.

On the seventh day of the course, the two participants who could not dive on the sixth day due to otological symptoms stated that they could dive. However, as one was diagnosed with an acute central perforation at the lower quadrant of the right tympanic membrane on otolaryngological examination, he was excluded from the diving program. He was hospitalized and underwent perforation repair with vector paper under local anesthesia. On the seventh day, the diving program was continued with 27 participants. A mean of 7.3±2.1 (min: 4, max: 10) dives were performed. Participants stated that a mean of 6.6±2.8 (min: 2, max: 10) dives were comfortable and free of ear pain, obstruction, or any other irritating symptom.

On the eighth day of the course, a participant suffered respiratory difficulty. A chest X-ray revealed a pneumotic consolidation in the lower lobe of the right lung, and the participant was excluded from the diving program. Furthermore, the diving program of seven subjects were cancelled, including one with tympanic membrane perforation, four participants with acute serous otitis media whom stated that they could not tolerate diving in the eighth day, and a participant that received therapy for pneumonia. So, on the eighth day the diving program was completed with 22 participants.

On the eighth day a mean of 8.3±1.7 (min: 4, max: 12) dives were performed. Participants stated that a mean of 7.6±2.6 (min: 1, max: 12) dives were comfortable and free of ear pain, obstruction, or any other irritating symptom (Tables 1 and 2).

**Table 1.** Mean daily number of comfortable dives

| Day | N | Number of dives | p |
|---|---|---|---|
| **Day 1** | 29 | 6,14±3,482 (0-15) | |
| **Day 2** | 29 | 8,34±4,295 (0-20) | 0.001 |
| **Day 3** | 29 | 7,76±3,842 (1-20) | 0.025 |
| **Day 5** | 24 | 7,96±3,210 (2-15) | 0.008 |
| **Day 6** | 26 | 7,92±2,038 (3-10) | 0.018 |
| **Day 7** | 27 | 6,63±2,844 (2-10) | 0.261 |
| **Day 8** | 22 | 7,64±2,629 (1-12) | 0.036 |

Number of dives as mean± SD (min-max); p: comparison with day 1

An assessment of the otological symptoms of the participants on the diving days revealed that on the first day 16 (55%) participants had otological symptoms, whereas 13 (45%) participants had no symptoms. The number of participants with otological symptoms was 6 (21%) on the second day; 6 (21%) on the third day; 4 (14%) on the fifth day; 3 (10%) on the sixth day; 5 (17%) on the seventh day; and 4 (14%) on the eighth day.

**Table 2.** Health problems encountered during the course

| | N | % |
|---|---|---|
| **No pathological condition** | 20 | 68.9 |
| **Acute serous otitis media on the third day** | 6 | 20.9 |
| **Pneumotic consolidation in the lower lobe of the left lung** | 1 | 3.4 |
| **Tympanic membrane perforation on the seventh day** | 1 | 3.4 |
| **Pneumotic consolidation in the lower lobe of the right lung** | 1 | 3.4 |
| **Total** | 29 | 100.0 |

An analysis of the ability of solving otological problems with the Valsalva maneuver revealed that the problem was solved in 10 (63%) of those with otological symptoms on the first day; 3 (50%) on the second day; 4 (67%) on the third day; 2 (50%) on the fifth day; 0 (0%) on the sixth day; 3 (60%) on the seventh day; and 1 (25%) on the eighth day (Table 3).

**Table 3.** Daily rates of occurrence and solution of otological symptoms during diving activity

| Day | Symptom present | | Symptom absent | | Valsalva maneuver solution rate | |
|---|---|---|---|---|---|---|
| | N | % | N | % | N | % |
| **Day 1** | 16 | 55 | 13 | 45 | 10 | 63 |
| **Day 2** | 6 | 21 | 23 | 79 | 3 | 50 |
| **Day 3** | 6 | 21 | 23 | 79 | 4 | 67 |
| **Day 4** | No diving activity * | | | | | |
| **Day 5** | 4 | 14 | 25 | 86 | 2 | 50 |
| **Day 6** | 3 | 10 | 26 | 89 | 0 | 0 |
| **Day 7** | 5 | 17 | 24 | 83 | 3 | 60 |
| **Day 8** | 4 | 14 | 25 | 86 | 1 | 25 |

The difference between the diving days with respect to diving comfort in terms of freedom from otological symptoms during the 10-day free diving course was also analyzed. There were no significant differences between the days ($p>0.05$) (Table 4).

The effect of smoking on otological symptoms during dives was also statistically analyzed. No statistically significant results were found with regard to smoking and the frequency of otological symptoms on any of the seven diving days ($p>0.05$). Moreover, all participants were questioned about palpitations for ruling out cardiac pathological conditions, diving mask-related eye pain, and tooth pain considered as a sign of barotrauma. These three symptoms were not present in any participant.

**Table 4.** Daily rates of ontological symptoms by smoking status

| Day | Smoking | Otological symptoms | | Total | p |
|---|---|---|---|---|---|
| | | Yes | No | | |
| **Day 1** | Yes | 1 | 0 | 1 | 0.359 |
| | No | 15 | 13 | 28 | |
| | Total | 16 | 13 | 29 | |
| **Day 2** | Yes | 1 | 0 | 1 | 0.207 |
| | No | 5 | 23 | 28 | |
| | Total | 6 | 23 | 29 | |
| **Day 3** | Yes | 1 | 0 | 1 | 0.207 |
| | No | 5 | 23 | 28 | |
| | Total | 6 | 23 | 29 | |
| **Day 5** | Yes | 0 | 0 | 0 | 0.091 |
| | No | 4 | 20 | 24 | |
| | Total | 4 | 20 | 24 | |
| **Day 6** | Yes | 1 | 0 | 1 | 0.087 |
| | No | 2 | 24 | 26 | |
| | Total | 3 | 24 | 26 | |
| **Day 7** | Yes | 1 | 0 | 1 | 0.158 |
| | No | 4 | 22 | 26 | |
| | Total | 5 | 22 | 27 | |
| **Day 8** | Yes | 0 | 0 | 0 | 0.228 |
| | No | 4 | 18 | 22 | |
| | Total | 4 | 18 | 22 | |

## DISCUSSION

Ears are the most severely affected organs by braotrauma. Divers avoid injury by equalizing air pressure in the middle ear using their eustachian tubes. They keep middle ear pressure equal to ambient pressure (2).

In our study the rate of otological symptoms was 55% on the first day of the course program, but it dropped to 14% at the 8th day. However, an analysis of the tolerability of otological symptoms by the Valsalva maneuver revealed that although the participants could ease their otological symptoms at a rate of 63% on the first day of the course, only 25% of the otological complaints could be compensated for at the 8th day. This indicates that compensability of otological symptoms may be limited on consecutive diving days. Furthermore, the study displayed a significantly higher rate of comfortable diving on subsequent days of the diving course compared with the first day.

Although comfortable diving rates were higher than that of the first day, tolerability or controllability of otological complaints were lower in consecutive diving days. In a study comprising 23 participants, exposure to repeated pressure in freshwater dives for three consecutive days caused a negative shift in middle ear peak pressure. The same study also showed that the less experienced divers had significantly higher middle ear peak pressure and higher-pressure differences. Middle ear pressure values were found to be less in those who had been diving

for two years. A higher middle ear pressure was linked to a higher prevalence of barotrauma (13).

In another study, a total of 437 dives were performed by 28 participants in a six-day camping program. A positive change in middle ear pressure was more prominent on the third day compared to the first. Divers with barotrauma displayed significantly lower tympanometric peak pressure compared to divers with normal otoscopic findings. This study concluded that repeated, multi-day dives promoted middle ear pressure equilization and significantly lowered peak pressure (excess pressure) in the tympanogram. The deepest changes were reported among divers with low or moderate experience (14). We diagnosed otitis media effusion of different levels in six participants on the third day of the course program. Participants with serous otitis media had their conditions progressed despite treatment on consecutive diving days. This shows us that in divers with serous otitis media, diving activity should definitely be paused in addition to initiating treatment.

Some epidemiological evidences have revealed the middle ear mucociliary system to play a significant role in clearing middle ear effusions. However, it is already known that exposure to tobacco smoking plays an important role in the persistence of middle ear effusion among patients with normal mucociliary function. In a study comprising 33 patients, smokers had significantly lower mucociliary function in the middle ear (15). Another study demonstrated that tobacco smoking negatively affected eustachian tube functions (16). While the acute effect of smoking is on the mucociliary system, the chronic effect is on hearing. A patient's inability to perform the Valsalva maneuver is not significantly associated with smoking(17). Many studies have shown that the amount and duration of smoking (>5 years) are correlated with hearing loss, especially in sensorineural type (18,19,20). Herein, we could not detect any significant effect of smoking on otological symptoms through altered middle ear functions while diving on any of the eight diving days.

It has been shown that, repetitive, multi-day diving led to significantly decreased compliance and increased regular tympanometry peak pressure (overpressure) in the middle ear and that the most profound changes were observed in less and intermediately experienced scuba divers (14). In another study that investigated the influence of repetitive scuba diving in fresh water on middle ear mucosa, it was found that middle ear barotrauma prevalence increased with the cumulative number of dives per day. The major risk factors were diving depth and diving experience (21).

Studies on this subject are concerned with scuba divers. In our study, free diving took place. Technically, free divers are faster exposed to pressure, but much shorter. Therefore, the fast and effective use of the Valsalva maneuver may be more important. In our study, we relate the reduction of otologic complaints with repetitive dives to a good training in Valsalva and to the increase in experience with repetitive dives. As far as we can establish, this is a first study on the effect of Vvalsalva maneuver on otolaryngeal complaints in freedivers.

The limitation to the study is the absence of tympanometric assessment in addition to otological examination on diving days. Furthermore, performing tympanometric assessments before and immediately after diving, and comparing differences in-between, different results may be attained. Studies using tube manometers for a detailed assessment of eustachian tube suggest that knowledge and experience in this field may be increased.

In conclusion, diving-related health problems of divers can be more rapidly and effectively managed by assessing detailed physical examination findings and providing necessary treatment and equipment. We think that evaluation of eustachian dysfunction before diving will play an effective role in preventing otological complications during and after dives. Otological symptoms can be more effectively managed by instructing divers on how and when to perform necessary maneuvers in an appropriate manner.

## Conflict of Interest

The authors declare no conflicts of interest and do not have any financial disclosures. No competing interests were declared

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