EFFECTS OF SCUBA DIVING ON MIDDLE EAR PRESSURE

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I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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To My Family and Instructors

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

EFFECTS OF SCUBA DIVING ON MIDDLE EAR PRESSURE

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Since; the self-contained underwater breathing apparatus (scuba) was developed; the growth in the recreational diving population leaded an increase in diving-related injuries, mostly about the ear barotraumas. Previous findings show that inexperienced divers are more predisposed to ear barotraumas. This study was performed to see the dive related alterations of the middle ear pressure and the compliance of the tympanic membrane due to experience (experienced - skin divers and/or underwater rugby players and inexperienced -not use to skin diving or such water sports) and depth (3m and 12m) in 22 novice divers with normal pre-dive audiometry, tympanometry, and otorhinolaryngologic examination. Pre dive otologic inspections were taken and pre dive / post dive tympanograms were measured for each depth. In 8 ears of the 5 inexperienced divers either hyperemia or hemotympany were observed in the second day's (12m) otoscopic inspections. In the first post dive tympanometric measurements; middle ear pressure changes were observed in 19 ears of 14 divers. The compliance was not changed in 5 ears of 3 divers and increased in the reminder. In the second tympanometric measurements, 12 ears of the 8 divers showed negative middle ear pressure and compliance was not changed in 10 ears of 5 divers and increased in the reminder. Due to experience and middle ear pressure changes of each day; no meaningful, statistically significant correlation was found.

Also no meaningful correlations were found neither for experience and compliance. A correlation of .542 between experience status and otologic inspection prior to 12m depth dives was a contradiction to the hypothesis “there would not be any significant difference between experienced and well trained inexperienced groups” as the otologic variations such as hyperemia or hemotympany were only seen in inexperienced novices. Again; the correlation of **.**571 showed that 3m depth dives had grater frequency of middle ear pressure changes than 12m depth dives. Similarly; due to the compliance correlation of **.**516, 3m depth dives had a grater frequency of compliance increases than 12m depth dives. These results however should be reconsidered as the 3m depth was the first open water dive day and 12m depth was the next day which the novices could use to the open water conditions.

Keywords: Middle Ear Pressure, Compliance, Scuba Diving

ÖZ

SCUBA DALIŞININ ORTA KULAK BASINCI ÜZERİNE ETKİLERİ

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Scuba dalışının bulunmasıyla dalıcı sayısının artması, dalış kazalarında özellikle de kulak barotravmalarında artışa yol açmıştır. Özellikle deneyimsiz dalıcıların kulak barotravmalarına yatkınlığı bilinmektedir. Bu çalışma dalış öncesi normal odyometri, timpanometri ve kbb değerine sahip 22 yeni dalıcıda dalışa bağlı orta kulak basıncı ve kompliyans değişimlerini deneyim durumuna (serbest dalış yapan ve yapmayanlar) ve dalış derinliğine (3m ve 12m) göre ortaya koymak amacıyla yapılmıştır. Her derinlik için dalış öncesi otolojik muayene ile dalış öncesi ve sonrasında timpanogram değerlendirmeleri yapılmıştır, 12m dalışından once yapılan otoskopik muayenede 5 deneyimsiz dalıcının 8 kulağında hiperemi ya da hemotimpani görülmüştür. Ilk dalış sonrası timpanometrik değerlendirmede14 dalıcının 19 kulağında orta kulak basınç değişimi görülmüş, 3 dalıcının 5 kulağında kompliyans değişimi olmazken kalanlarda artış saptanmıştır. Ikinci timpanometrik değerlendirmede; 8 dalıcının 12 kulağında negative basınç görülmüş, 5 dalıcının 10 kulağında kompliyans değişimi olmazken kalanlarda artış saptanmıştır. Deneyime gore orta kulak basınç değişimleri ya da kompliyans açısından istatistiksel anlamlı korelasyon bulunamamıştır. Deneyim durumu ve 12m dalışı öncesinde yapılan otoskopik muayene bulguları arasındaki .542 korelasyon “iyi eğitilmiş grupta

deneyimli ve deneyimsizler arasında önemli bir fark olmayacaktır" hipoteziyle ters düşmektedir çünkü hemotimpani yada hiperemi gibi otolojik bulgular yalnızca deneyimsiz gurupta ortaya çıkmıştır. Aynı şekilde .571 korelasyon 3m dalışlarında 12m dalışlarına gore daha yüksek oranda basınç değişimi olduğunu göstermektedir. Benzeri şekilde .516 kompliyans korelasyonu da 3m dalışlarında 12m dalışlarına gore daha yüksek oranda kompliyans değişimi olduğunu göstermektedir. Bu sonuçlar 3m dalışının ilk açık deniz dalışı oluşu ve 12m dalışının hemen ertesi gün yapılması nedeniyle yeni dalıcıların açık deniz şartlarına alışabileceği göz önünde bulundurularak değerlendirilmelir.

Anahtar Kelimeler: Orta Kulak Basıncı, Kompliyans, Scuba Dalışı

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CHAPTER 1

INTRODUCTION

Since; the self-contained underwater breathing apparatus (scuba) was developed by Jacques Cousteau and Emile Gagnon in France in 1943, there has been an incredible growth in the recreational diving population. In the world there are more than 10,000,000 divers and almost 500,000 divers are trained and certified each year (Basut, 2005). Unfortunately, this has made an increase in diving-related injuries, mostly about the ears and sinuses barotraumas (Roydhouse, 1980). Barotraumas in scuba divers results from the difference between internal physiologic pressure and surrounding water pressure. Pressure increases linearly at a rate of 1 atm (760 mmHg) for every 10 m of sea water. Boyle's Law (the volume of a gas varies inversely with pressure if temperature is held constant) relates to all forms of barotraumas (Brylske, 1997).

Most sport dives take place at a depth of 18–40 m, where the pressure level is equivalent to about 3 to 5 atm of absolute pressure. In typical recreational diving, a hose connects a tank of compressed air to a pressure regulator placed in the mouth and the diver breathes through the regulator; which senses change in depth and delivers air at ambient pressure. This means pressure will be equalized in the lungs easily; however, in the closed cavities like paranasal sinuses or middle ear cavity, the effects of Boyle's Law will still be valid (TSSF 1* diver course notes).Due to their etiologies, otolaryngeal problems of scuba diving transpire in two categories as barotrauma related problems like outer ear barotraumas, middle ear barotraumas, inner ear barotraumas, Para nasal sinuses barotraumas, alternobaric vertigo, facial baroparesis and barotrauma unrelated problems like otitis externa (bacterial proliferation due to moisture and high temperature generally because of clearing the preventive earwax in the outer ear) and inner ear decompression sickness. Barotrauma related problems except alternobaric vertigo (AV) are generally seen during descent, while AV is seen during ascent.

Barotrauma is defined as tissue damage resulting which occurs when a gas-filled body space, like middle ear cavity fails to equalize its internal pressure to ambient pressure (Melamed, 1992; Moore, 1999). To avoid this, air-filled spaces must be equalized to ambient descending hyperbaric pressure; otherwise blood and tissue fluids will be forced into the air-filled spaces until the equalization is realized.

Many inexperienced divers continue to descend despite ear pressure and pain, in order not to separate form the other divers. This will cause ineffective pressure equalization as the Eustachian tubes irreversibly block with a pressure differential of approximately 1.4 m depth. Diving at a shallow depth; as the greatest change in volume occurs near the water's surface, is not preventive. Indeed, the eardrum may rupture in as little as 1.2 m of water if pressure is not equalized (Becker, 2001).

Pressure equalization mistakes during descent are common to both middle-ear and inner-ear barotraumas. Methods for equalizing pressure in the ear include Valsalva, Frenzel, Toynbee, Lowry, Edmonds, and BTV (béance tubaire voluntaire) maneuvers. The jaw thrust technique involves forcefully exhaling through the nose into the mask and is often successful in equalizing middle-ear pressure (Clenney, 1996).

In divers who have difficulty in equalizing pressure, barotraumas can be minimized by equalizing pressure in the ears at the water's surface, descending slowly and feet-first along a line to control the rate of descent, equalizing the ears at every breath (preferably using the jaw thrust–nose exhalation technique), and descending head-down after reaching a depth of about 6–8 m. (Becker, 2001)

The outer ear barotraumas (Vascular congestion, hemorrhagic vesiculation, or tympanic membrane rupture) are commonly due to occlusion with an earplug, earwax, or a tight-fitting wetsuit hood (Divers Alert Network)

Middle-ear barotraumas occur mostly during descent and result from failure to actively open the normally closed Eustachian tube. Injury may be minimal edema of the middle ear mucosa, hemorrhagic streaking along the malleus, or the middle ear may fill with blood or the tympanic membrane may rupture (Farmer, 1993). Symptoms include the acute onset of pain, vertigo and conductive hearing loss that lateralizes to the affected side; in severe cases usually during ascent, increased pressure in the middle ear can cause reversible weakness of the facial nerve and facial baroparesis (Molvaer, 1987). Expanding air in the middle ear during ascent passively opens the Eustachian tube.

Inner-ear barotraumas; that are produced by transmission of pressure changes within the middle ear to the cochlea by round and oval windows; occur infrequently but may lead to persistent hearing loss, tinnitus, and dizziness. Three mechanisms of the inner ear injury are; hemorrhage, labyrinthine membrane tear, and perilymph fistula through the round or oval window (Parell, 1985). A forceful Valsalva maneuver may suddenly open the Eustachian tube with high-pressure air in the middle ear, causing outward movement of the stapes footplate and inward movement of the round-window membrane.

Decompression sickness is caused by the release of inert gas bubbles (usually nitrogen) into the bloodstream and tissues after ambient pressure are reduced (Dick, 1985; Melamed, 1992). According to Dalton's law, the partial pressures of gasses in the breathing mixture increase in proportion to the ambient pressure, at depth (Brylske, 1997). Against the actively metabolized oxygen, nitrogen is inert and dissolves in body tissues until saturation, proportional to the ambient pressure as defined by Henry's law. If ambient pressure is released too quickly, the dissolved nitrogen gas cannot remain in solution and will form air bubbles within the blood, interstitial fluids and tissues *(*Brylske, 1997). The tendency of bubble formation depends on the depth, duration at depth and the rate of ascent, which means releasing the ambient pressure.

Decompression sickness (DCS) was used to be classified into type I "symptoms are usually mild and may manifest as fatigue or malaise or may be more specific, involving the muscles, joints and skin" and type II "more severe symptoms which can affect the lungs, vestibular apparatus and the nervous system" (Greer, 1992). Today, DCS is classified into affected organs or systems.

The incidence of DCS among recreational scuba divers is estimated to be one case per 5,000 to 10,000 dives. Diving within the limits of dive tables is no guarantee against DCS, as more than 50 percent of cases of decompression sickness occur after no-decompression dives. In addition to the dive profile and rate of ascent, other factors including hypothermia, fatigue, increased age, dehydration, alcohol intake, female gender, obesity and patent foramen ovale may influence the risk DCS (Knauth, 1997).

Inner ear decompression sickness presents with acute vertigo, nausea, emesis, nystagmus and tinnitus. The pathophysiology is unclear; one mechanism might be bubble rupture of the intraosseous membranes in the semicircular canals. In many cases, inner ear decompression sickness is clinically indistinguishable from otic barotraumas. The dive profile and timing of symptoms might help to clarify the diagnosis (Farmer, 1993).

Many questions still exist regarding divers with tympanostomy tubes, ear perforation, and history of ossicular reconstruction, stapedectomy, or mastoidectomy operations. Comments are anecdotal and based on personal diving experience, observation, and discussion with divers.

Previous findings show that inexperienced divers are more predisposed to ear barotraumas, therefore; training should be very important for the prevention. (Divers Alert Network)

Korıwchak and Werkhaven (1991) indicated that the middle ear barotraumas were not associated with diver age, sex, experience, otolaryngologic history, or medications, rather were associated with poor underwater visibility, difficulty clearing ears during ascent, and hearing loss after surfacing. However; the experience groups had same underwater conditions in our study.

1.1 Statement of the Problem

The most common diving related injuries are known as ear and sinus barotraumas (Divers Alert Network, 2000). Middle ear pressure and compliance variations show the effects of diving to the ears, because unless there is a problem in equalizing the ears; middle ear pressure should normally be same with ambient pressure (Shupak, 1991).

Injuries of ears are mostly reported in inexperienced novice divers.

This study was performed to see the dive related alterations of the middle ear pressure and the compliance of the tympanic membrane due to experience (experienced - skin divers and/or underwater rugby players and inexperienced -not use to skin diving or such water sports) and depth (3m and 12m) in novice divers.

1.2 Significance of the Study

This study was significant for comparison of the middle ear pressure changes (important indicator for the dysfunction of Eustachian tube and thus predisposition for injuries) and tympanic membrane compliance in groups such as experienced (skin divers and/or underwater rugby players) – inexperienced (not use to skin diving or such water sports) novice divers; and shallower (3m depth) – deeper (12m depth) dives.

1.3 Purpose of the Study

The purposes of the study were:

A) Comparing experienced (skin divers and/or underwater rugby players) and inexperienced divers’ post dive middle ear status and

B) Effects of diving depth on middle ear pressure and tympanic membrane compliance which might be related with middle ear barotraumas by timpanometry.

1.4 Hypothesis

It was hypnotized that; there would be no significant difference in post dive middle ear status by means of middle ear pressure changes and tympanic membrane compliance between the experienced (skin divers and/or underwater rugby players) and inexperienced (not use to skin diving or such water sports) novice divers, as the same training conditions were maintained for the both groups.

Also; no meaningful variation of middle ear pressure changes and tympanic membrane compliance between diving depths of 3m and 12 m was postulated for this study.

For all groups; post dive tympanic membrane compliance (elasticity) increases due to forces that occur during scuba diving; were expected.

1.5 Definition of Terms

Absolute pressure is the result when atmospheric pressure is added to gauge pressure.

Alternobaric vertigo is a condition in which the sense of balance is impaired. It is caused by unequal pressure in the middle ear, as may be experienced by divers during ascent.

Ambient pressure is the surrounding pressure.

Atmospheric pressure is the pressure exerted by the atmosphere.

Barotitis media (middle ear barotrauma) is soreness or bleeding in the middle ear. It is caused by a difference between the air pressure in the middle ear and the air outside. This can occur with quick changes in altitude, in diving, or in pressure chambers. Symptoms are pain, ringing in the ear (tinnitus), trouble hearing, and dizziness (vertigo).

Barotrauma refers to tissue damage resulting from the direct effects of pressure; that occurs when a gas-filled body space (e.g., lungs, middle ear) fails to equalize its internal pressure to accommodate changes in ambient pressure (Melamed, 1992; Moore, 1999).

CMASS (Confédération Mondiale des Activité Subaquatiques) World Under Water Federation.

Decompression sickness (DCS) A painful, sometimes deadly condition caused by nitrogen bubbles forming in the body tissue. This sickness, most often found in deep-sea divers, caisson workers, and aviators, is caused by moving too quickly from areas of higher atmospheric pressures to lower pressures, as divers coming up from the bottom of the ocean too fast. Disorientation, severe pain, and fainting result. Treatment is to return the patient quickly to an environment of higher pressure and gradually reduce the pressure to allow the body time to adjust (decompression). Also called *bends, caisson disease.

Ear clearing (Valsalva Manoeuvre) Divers equalize the pressure on descent by holding the nose closed, closing their mouth and trying to blew gently through the nose. This increases the air pressure in the nasopharynx and forces air through the Eustachian tube to the middle ear.

Edmonds (first technique) Clearing the ears is to open the Eustachian tubes by wriggling the jaw from side to side or thrusting the jaw forward.

Edmonds (second technique) "sniff and blow" is where diver sucks the cheeks in with a sniff against the closed nostrils immediately followed by a valsalva.

Eustachian tube is a tube lined with mucous membrane that joins the nose-throat cavity (nasopharynx) and the inner ear (tympanic cavity). This tube allows air pressure in the inner ear to be equalized with the outside air pressure. When the air pressure change is sudden or extreme (such as in an airplane), causing the ears to stop up, swallowing will usually equalize the pressure. Also called *auditory tube.

Frenzel manoeuvre is like the Valsalva manoeuvre in that the diver blows air against the pinched nose, but the frenzel manoeuvre does not use the diaphragm to blow the air, into the eustachian tube, it uses the throat muscles to compress the air in the pharynx instead. The frenzel manoeuvre minimizes probability of round windows rupture, but requires more time to master.

Lowry technique is to swallow and blow at the same time. This is a Toynbee and valsalva combination.

Patent foramen ovale: Foramen ovale does not close to fossa ovale; thus become a risk for a diver to bypass blood with nitrogen bubbles to circulation again. It happens especially with valsalva maneuver.

Reversed ear is caused by blocking the outer ear (Auditory Canal may bleed to equalize pressure or Eustachian Tube blocking after start of dive.

Scuba (Self-contained underwater breathing apparatus) diving refers to pressured air respiration in ambient pressure while diving.

Toynbee Manoeuvre involves holding the nose and swallowing simultaneously. This usually causes the Eustachian tubes to open momentarily, allowing air to enter the middle ear. The tubes open only momentarily and it causes a negative pressure in the pharynx, so only smaller amounts of air are able to pass into the middle ear space, so is not as effective as Valsalva.

TSSF Türkiye Sualtı Sporları Federasyonu – Turkish Underwater Federation

Tympanic membrane compliance: Elasticity or adaptation of eardrum due to pressure changes.

Tympanometry: Middle ear pressure is measured by placing a probe into the outer ear. The probe contains a sound source, a microphone and a pump connected with a manometer. When the sound entered to the ear, it will be partially absorbed by the middle ear system and partially reflected from the tympanic membrane. In case of equal pressure in outer and middle ear; absorption and compliance, thus hearing will be maximized and impedance will be minimized. By the pump of the probe, outer ear pressure will be changed and the sound reflected from the tympanic membrane will be measured by the microphone. This method is called as tympanometry. Tympanogram means the results obtained by a graph.

Vertigo is a loss of the sense of balance.

1.6 Assumptions of the study

i. It is assumed that the participants of the study understood the purpose of the study.
ii. It is assumed that the participants followed the safety rules of ear clearing correctly.
iii. Divers used no decongestants for opening the Eustachian tube during the study days.
iv. All participants were well trained in 2m and 5m depth pools for 3 days.
v. It is assumed that all participants dived to the designated depths.

1.7 Limitations of the Study

i. This study was limited with 22 novice scuba divers.
ii. This study was limited with 44 dives (22 to 3m; 22 to 12 m).
iii. Mastoid pneumatization and other pathologic or physiologic statuses of the applicants were not inspected.
iv. Only 24 hours of relaxation period was given to the divers between 3m and 12 m depth dives.
v. Due to the alignment of the subjects there were time differences in post dive tympanometric measurements.

CHAPTER II

LITERATURE REVIEW

The purpose of this chapter is to review the literature on the occurrence mechanism of ear barotraumas and relevant studies on middle ear pressure and compliance chances because of diving.

Chapter II includes 2 main parts; a) Relevant physics, anatomy and physiology
b) Previous studies related with middle ear pressure and compliance.

2.1 Relevant Physics Anatomy and Physiology

The principles of Barotraumas in scuba divers results from the difference between internal physiologic pressure and surrounding water pressure. Due to Boyle's Law; the volume of a gas varies inversely with pressure if temperature is held constant ($P_1V_1= P_2V_2$) Pressure increases linearly at a rate of 1 atm for every 10 m (33 ft) of sea water (Brylske, 1997).

As, air is compressible and denser and most of the air is concentrated within 9654 m above the surface, only a 0.5 atm change can occur at a height of 5486 m. This disparity between water and air pressure explains why barotraumas occur more frequently during diving than flying.

The volume of gas in seawater decreases by half during descent to (or doubles during ascent from) a depth of 10 m.

The middle ear pressure should be equal to the ambient pressure in normal conditions. The increasing pressure while diving should be equalized by the Eustachian tube. (TSSF 1* Diver Course Notes)

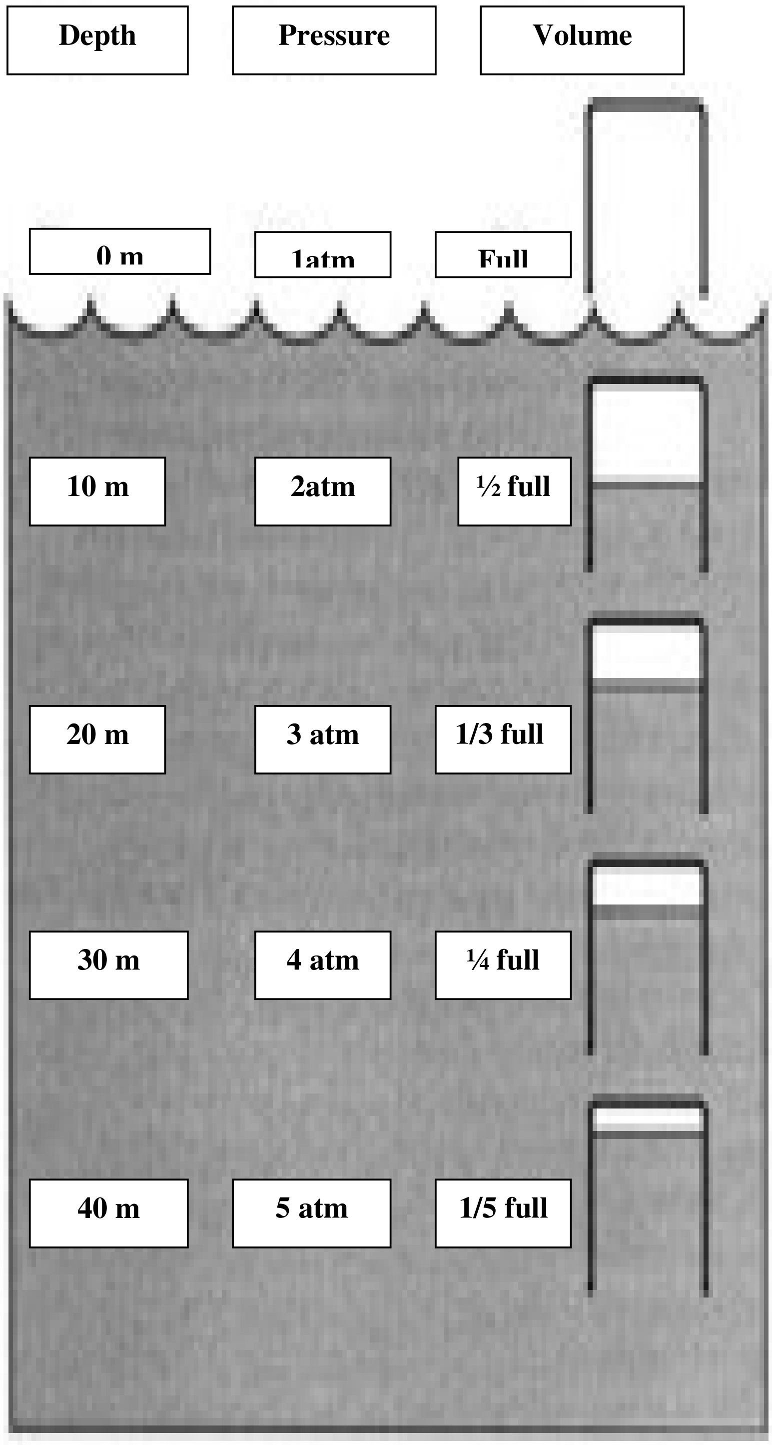

Figure 1: Volume Changes for Each 10m of Sea Water

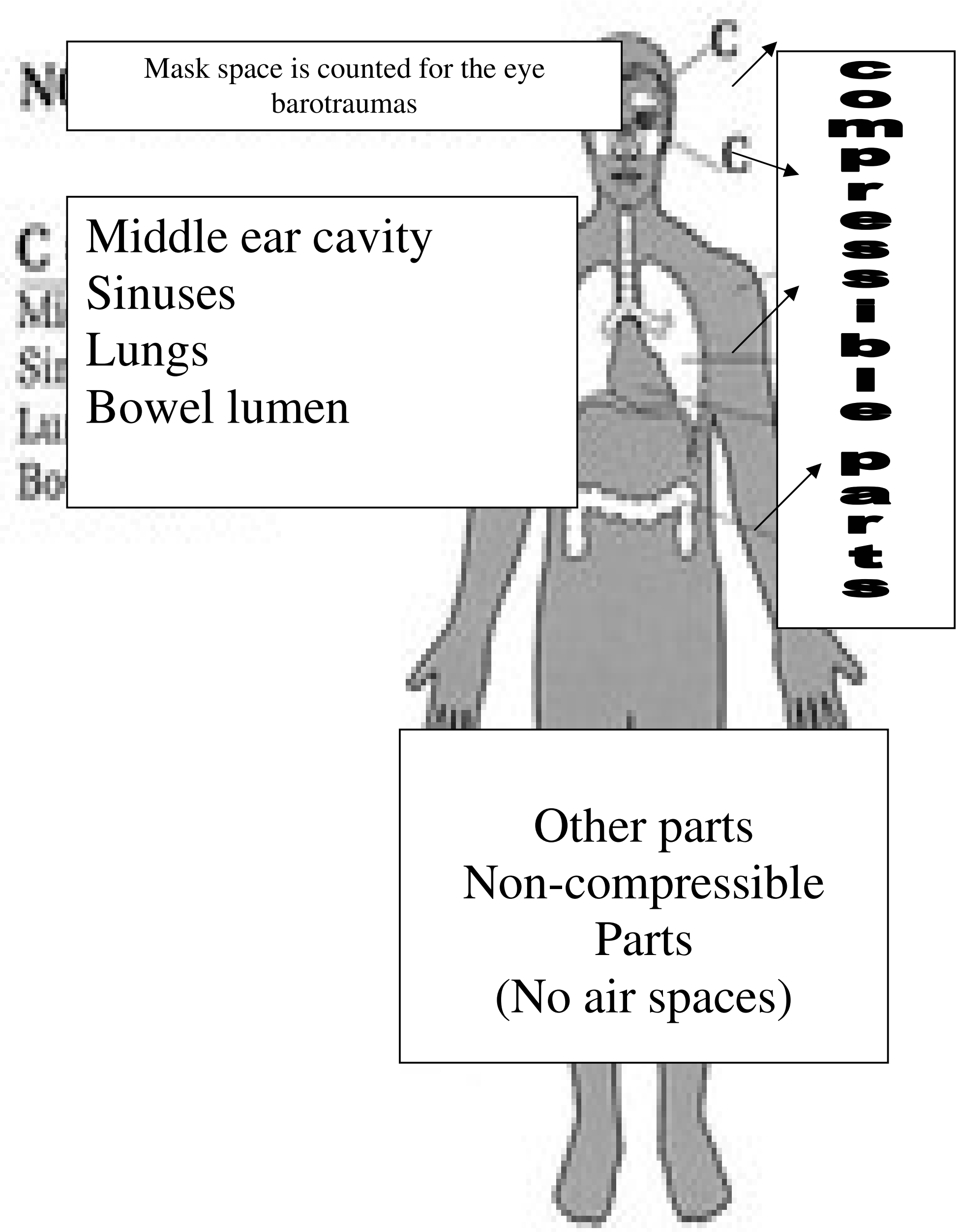

Figure 2: Compressible Parts of the Human Body

The ear is the organ of hearing and balance and divided into three parts:

- **The outer Ear** - consists of the lobe or Pinna, the Auditory Canal and ends with the Tympanic Membrane (ear drum)
- **The middle ear** - contains ossicles. malleus, incus, stapes, in that order, connecting the Tympanic Membrane with the Oval Window.
- **The inner ear -** contains three Semi-Circular Canals for balance (Vestibular Canals) with the Oval Window, the Round Window, Cochlea and Eustachian tube which connects inner ear with naso-pharynx.

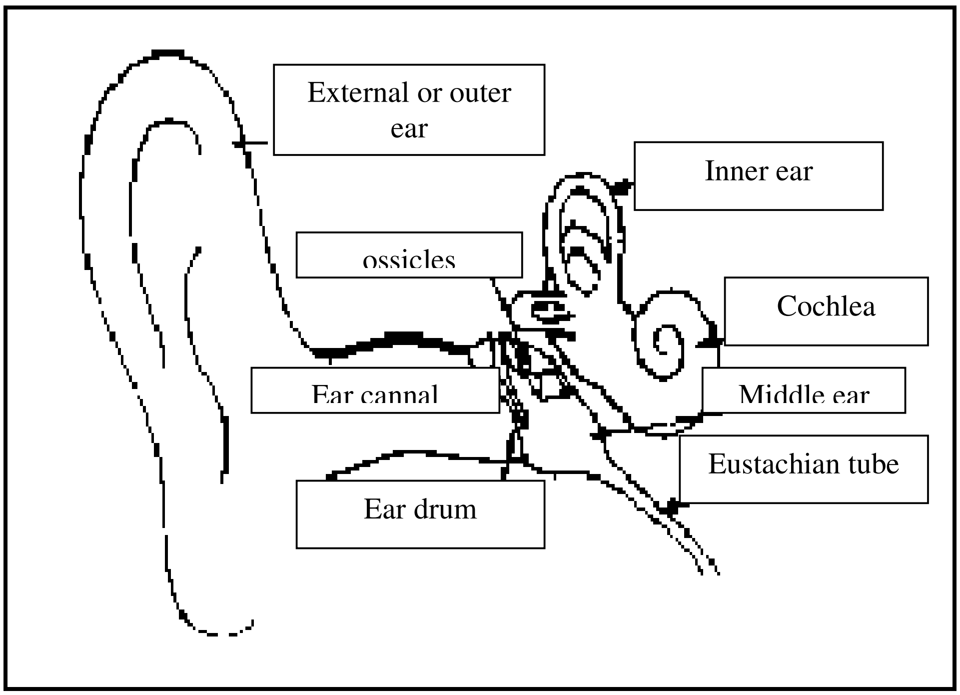

Figure 3: **Anatomy of the Human Ear**

The sound vibration felt by the tympanic membrane, is transmitted and amplified through the ossicles to the oval window of the cochlea. The cochlea and 3 semi circular canals are filled with perilymph transmitting vibrations through the cochlea to the nerves in order to be converted to nerve signals to be transferred to the brain. The round window and the oval window works in harmony to allow movement of perilymph inside the cochlea, (while the oval window moves in, the round window moves out). The ossicles; three tiny bones that connect the ear drum to the cochlea, are; the Malleus, Incus and Stapes.

Approximately 1.5cm length of a normally closed eustachian tube; is located in the back of the nasopharynx at nearly nostril level; with a highly variable patency. There are several factors that affect tubal patency and tolerance to pressure changes: Both the Eustachian tube angle and the shape can affect the ability to pressurize the middle ear. Individuals with larger pneumatization in the mastoid sinuses will be less tolerant to pressure changes due to the volume change in the middle ear will be greater for a given amount of descent. Allergies, trauma, infection and thyroid disorders might be the other possible factors of disruption in normal tubal function.

The nasopharynx end of the Eustachian tube is normally closed. With a positive pressure in nasopharynx, m. tensor veli palatini, m. levator veli palatini and m. salpingopharyngeus contract and the tube opens. By the increasing pressure of descent, the Eustachian tube works like a valve and stays closed. If the difference between middle ear pressure and ambient pressure is more than 80-120cm H_2O, “trapdoor effect” will occur and the tube could not be opened. In order to equalize the pressure diver should ascent up to the point that pain is disappeared. In case of ascent; as the middle ear volume increases, the Eustachian tube easily opens to evacuate the trapped air.

For individuals with ear pressurizing difficulty, the position in the water column is very important. It is well known that the head-down position during descent can make middle ear equalization more difficult. Less well known is the reason for this effect.

The soft tissues around the membranous Eustachian tube and gravity have some roles in normal functioning. Soft tissue is the most probable candidate for positional obstruction. It is advised for the new learners to begin descent slowly, and always in the head up position. Divers with prior ear problems should also correspond the same position. Half of the Eustachian tube is surrounded by bone; where the other half is open to the pressure changes of the ambient pressure. This membranous half is partially surrounded by a "C" shaped cartilage. During swallowing, muscles of the soft palate pull on the Eustachian tube. This traction opens the tube while closing the nasopharynx. The act of swallowing often causes a clicking or crackling sound made by the moist tissues of the Eustachian tube pop open. The pressure outside the ear must be same with the inside pressure otherwise the result will be the pain. If the pressure difference increases the tympanic membrane may stretch and perforate which will cause pain, dizziness, nausea and some bleeding from the ear.

Middle ear barotraumas are the most frequently seen diving injuries which occur much more commonly in the novice divers as a direct result of improper middle ear equalization techniques.

There are nine different techniques of equalization on assessing the effectiveness of middle ear pressurization.

It is always recommended that individuals should practice pressurization of their middle ears prior to diving in order to test their Eustachian tubes patency, and to perform middle ear pressurization before beginning actual descent to cushion the ears against trauma. It might be useful to learn a technique for assessing the adequacy of pressurization known as "watch the nose inflate" (Watch the Schnazolla). This can be observed if one pinches the nasal passages (nares) closed, with pinching fingers held low on the nose. A strong pressurization effort will cause the tissues above the occluding fingertips to balloon outward. This is an indication of the inflation effort to the Eustachian tubes. In order to optimize technique this can be practiced in the mirror. Pressurizing the nose is not quite the same as inflating the middle ear, however if the diver reports no evidence of a popping or crackling sensation the instructor should check the pressure of the nose.

The most basic and simplest techniques in diving are the yawn, swallow, jaw thrust and the head tilt. These techniques of equalizing middle ears are useful for individuals with widely patent Eustachian tubes, who never have problems with equalization. These techniques are not recommended for the novice divers.

The first dive in a swimming pool is generally significant for ear barotraumas due to poor ear clearing technique, novice distraction and poor buoyancy control.

Pressurization techniques below should always be used in novice divers for prevention of the middle ear squeeze.

THE VALSALVA MANEUVER (pressurization)

Antonio Valsalva , first recorded a technique for pressurization of the middle ears in the 1700's. With this technique, gradients of 6-10' of seawater can be achieved by blowing out the closed nostrils while muscles are kept tight and retracted.

However there are some disadvantages in this technique, such as prolonged effort can cause venous engorgement of the tissues around the Eustachian tubes or a decrease in venous return to the heart thus can lower blood pressure in prolonged effort.

Diving with an ear plug will cause an unchanging trapped air pressure between the plug and tympanic membrane. In this case if the Eustachian tube is opened, tympanic membrane will be forced to stretch out and might be perforated. During a normal dive, in case of performing valsalva maneuver difficulties; if the Eustachian tube is opened, pressure increase in round window perforates its membrane implosively (to the side of inner ear) and if the tube is closed, then the increased intracranial pressure might perforate the round window membrane explosively. However Valsalva maneuver seems to be the easiest technique for a student.

THE FRENZEL MANEUVER (preferred pressurization)

Herman Frenzel taught this technique to dive bomber pilots during the Second World War. The technique is to close off the vocal cords, as lifting a heavy weight. The nostrils are pinched closed and an effort is made to make a "K" or guttural "guh" sound to make the back 1/3 of the tongue will rise and to elevate the "Adams Apple". Novices might practice the technique by watching the nose inflate and by watching the "Adams Apple" move up and down.

This technique is actually preferred as it can be done anytime during the respiratory cycle and does not inhibit venous return to the heart.

THE TOYNBEE MANEUVER

This technique is to pinch nostrils shut while swallowing. The muscles in the back of the throat pull open the Eustachian tube and allow air to equalize if a gradient is present. This technique is not recommended for rapid descent, if the Eustachian tube does not equalize on first effort.

BEANCE TUBAIRE VOLONTAIRE (BTV)

The French Navy developed a technique for middle ear equalization called "Voluntary Tubal Opening" in the 1950's. This technique is difficult to teach and only approximately 30% of those taught can perform it reliably. Muscles of the soft palate are contracted while upper throat muscles are employed to pull the Eustachian tube open (similar to the events that happen in the back of your throat at the end of a yawn).

THE ROYDHOUSE MANEUVER

Noel Roydhouse; a Sports Medicine Physician from New Zealand has provided an additional clue to the Voluntary Tubal Opening for contracting the muscles in their proper order in the back of the throat.

The instructions are: - to contract the palate lifters (the levator palatini) and - to contract the palate tensor muscles, (tensor palatini). This rises up and tilts forward the uvula, the small protuberance hanging down from the soft palate in the back of your throat which can be seen in the mirror.

Often a jaw thrust can help make this maneuver more effective, if the “blowing smoke rings" technique was ever mastered.

THE EDMONDS TECHNIQUE (pressurization)

Carl Edmonds; an Australian lecturer defined a technique of pressurization by either the Valsalva or the Frenzel maneuver which can be combined with jaw thrust or head tilt to more effectively open the Eustachian tube.

THE LOWRY TECHNIQUE (pressurization)

A pressurization maneuver is combined with a swallow. The technique is very effective once it is mastered but coordination and practice is required to pinch nostrils, build up pressure and swallow at the same time.

THE TWITCH (pressurization)

Generation of pressure is again by either Valsalva or Frenzel Technique but instead of swallowing as in the Toynbee Maneuver, the head is suddenly "twitched" sideways.

These methods should be started from the surface and repeated every 1-2 meters. If the pressure cannot be equalized at once, divers should go up 1-2 meters to try once more.

Novice divers generally have some troubles with ear clearing techniques due to the lack of basic understanding, anatomy or pathophysiology play secondary roles. Nasal anatomical problems such as a deviated nasal septum, intranasal polyps, or obstructed sinuses should be inspected by medical doctors. (http://faculty.washington.edu/chay/MEbaro.html)

2.2 Previous Studies Related with Middle Ear Pressure and Compliance

Green and Rothrock (1993) reported the first prospective evaluation of middle ear barotraumas in experienced recreational scuba divers. In this pilot study, tympanometric and otoscopic evaluations were performed daily on two experienced scuba divers engaged in multi-day repetitive diving. Middle ear pressures decreased in proportion to diving frequency, demonstrating Eustachian tube dysfunction which promptly reversed upon cessation of diving Otoscopic evidence of traumatic injury to the middle ear occurred in proportion to diving frequency, and also readily reversed upon cessation of diving. Tympanic membrane compliance remained normal, often despite pronounced otoscopic abnormalities.

Taylor (2003) surveyed an international, cross-sectional, descriptive postal of experienced, seven hundred nine recreational scuba divers belonging to diving clubs in Australia and the United States. In the survey, mild barotraumas were common. Ear, sinus, and tooth "squeeze" had been experienced by 369 (52.1%), 245 (34.6%), and 66 (9.2%) divers, respectively. Tympanic membrane (TM) rupture, round/oval window rupture, and subcutaneous emphysema had been experienced by 38 (5.4%), 8 (1.1%), and 5 (0.7%) divers, respectively.

Paaske(1991) made an assessment of the strain on the tympanic membrane caused by diving was performed using impedance measurement of the middle ear in 21 untrained young men going through a scuba-diving training program. Tympanometry was carried out just before and after diving. In 104 dives at depths from 2 to 12 m results showed a significant increase in middle ear compliance on diving. The increase in compliance was significant at different depths, was transient, and fell to the initial level between the dives. However, the strain exerted on the tympanic membrane and middle ear from barotraumas due to diving resulted in a reversible impairment of the recoiling capacity of the elastic fibrils of the tympanic membrane.

Uzun (2005) studied the evaluation of pre dive parameters related to Eustachian tube dysfunction for symptomatic middle ear barotraumas in 31 divers (774 total dives) with normal pre dive audiometry, tympanometry, and general and otorhinolaryngologic examination. After an occurrence of middle ear barotraumas, in 19 ears (31%) of 14 divers (45%) at one time or another, pre dive data on smoking, mild septal deviation, otitis media history, rhinosinusitis history, Valsalva, Toynbee, and nine-step inflation/deflation tympanometric test, as well as degree of mastoid pneumatization were registered for calculation of predictive value in relation to the barotraumas within 24 hours of diving. (Barotraumas that occurred during an upper respiratory tract infection were excluded). The rate of tubal dysfunction measured by the nine-step test and a mastoid pneumatization below average were significantly higher in divers ($p < 0.05$) as well as in ears ($p < 0.005$) with barotraumas. Positive and negative predictive values of both parameters for subsequent barotraumas were between 69% and 76%.

Alternobaric vertigo in sport SCUBA divers and the risk factors were studied by Uzun , Yagiz , Taş , Adalı , Inan , Koten and Karasalihoglu (2003). The Eustachian tube function and the incidence of alternobaric vertigo (AV) in 29 sport self-contained underwater breathing apparatus (SCUBA) divers with, or without, some possible risk factors for AV were investigated. Divers with normal audiological and otoscopic pre-dive findings, the nine-step inflation/deflation tympanometric test and Toynbee test for evaluation of Eustachian tube function, and the Valsalva maneuver for patency were used. In 1086 dives, four divers (14 %) experienced AV during five dives (0.46 %), (one diver experienced AV two times). It was found that having an otitis media history or Eustachian tube dysfunction determined with the nine-step inflation/deflation tympanometric test before diving, or difficulty in clearing ears during diving could be important risk factors for AV in sport SCUBA divers ($p<.05$).

Uzun , Adalı , Koten , Yağız , Aydın , Çakır and Karasalihoglu (2000) indicated an inverse relationship between sizes of mastoid pneumatization and risk of symptomatic ME barotraumas in sport scuba divers. Twenty-four sports scuba divers (48 ears), with normal otolaryngologic examination, were included in the study. Size of mastoid pneumatization was measured by simplified rectangular dimension method on a mastoid x-ray taken at Schuller's view. Divers were counseled to refer to the investigators if any symptoms occurred during and/or after diving. All symptomatic ears were examined within 24 hours of diving by the same investigator, who was blinded to the degree of pneumatization. Middle ear barotrauma occurred in 15 ears (31%) of 11 divers (46%). Findings showed that with increasing degree of pneumatization, there was a decreasing risk of symptomatic barotrauma ($P <.001$). No barotrauma occurred in ears with a pneumatization greater than 34.7 cm^2. However, barotrauma occurred in all 3 ears with a pneumatization degree smaller than 13.6 cm^2.

Uzun, Adalı, Taş, Koten, Karasalihoğlu and Devren (1999) used the nine-step inflation/deflation test as a predictor of middle ear barotrauma in sports scuba divers to investigate the predictive value and efficiency of tympanometric tests of Eustachian tube function (Valsalva test, Toynbee test and nine-step inflation/deflation test) in predicting ME barotrauma in 44 ears of 22 sports scuba divers who had normal audiometry, tympanometry and otorhinolaryngological examination without previous history of ear disease. %). It was indicated that the nine-step inflation/deflation test is a reliable method of predicting middle ear barotrauma sufferers, especially when applied with the Toynbee test.

Sheridan, Hetherington and Hull (1998) described three cases (a hemorrhage in the inner ear, a tear of the labyrinthine membrane, or a perilymphatic fistula) of inner ear barotraumas in scuba divers. Against the older literature it was suggested that scuba divers who completely recovered from inner (or middle) ear barotrauma might Return to diving with caution and care.

One thousand and one disorders of the ear, nose and sinuses in 650 SCUBA divers were analyzed for anatomical distribution and causation by Roydhouse (1980). The outer, middle and inner ears made up 64.6% with a surprising 23.9% being related to the lower jaw, its teeth, attached muscles and the temporo-mandibular joint. Of the remaining, 3.1% were related to the nose, 6.6% to the sinuses and there was a miscellaneous group of 1.8%. Most outer ear infections seemed to be self-inflicted whilst the middle ear conditions were due to dysfunction of the eustachian tube.

Korıwchak and Werkhaven (1991) indicated that the middle ear barotrauma is the most common health hazard of scuba diving. To investigate the overall incidence of middle ear barotrauma, a prospective incidence study of 51 novice divers and 46 experienced divers was conducted. Otoscopy was performed on the divers before and immediately following a single dive. The overall incidence of mild barotrauma was 40%, and the incidence of severe barotrauma was 27%. No tympanic membrane perforations were found. The most common presenting symptoms were difficulty clearing ears during descent, ear pressure, and ear pain. Barotrauma was not associated with diver age, sex, experience, otolaryngologic history, or medications. Barotrauma was associated with poor underwater visibility, difficulty clearing ears during ascent, and hearing loss after surfacing.

Aktaş and Kutlu (2000); studied the relationship between traumatic tympanic membrane perforations and pneumatization of the mastoid. A total of 25 male patients with tympanic membrane perforations resulting from blast injury (n = 7), slap (n = 17), and football hit (n = 1) and 20 healthy male volunteers without any ear problem had temporal bone computed tomographic scans in the axial plane, parallel to the infraorbitomeatal line, with 2 mm slice thickness and 2-mm intervals using bone algorithm with a ProSpeed Spiral tomography machine. It was found that the level of mastoid pneumatization has no statistically significant effect on tympanic membrane pathologies due to blast or other injuries.

Zulkaflay (1996) examined hearing loss in diving amongst Navy divers. An audiometric survey was performed on a group of 120 divers and 166 non divers from the Royal Malaysian Naval Base between July to December 1991. The results of this survey revealed that insidious development of high frequency sensorineural hearing loss may be associated with diving. At frequencies 4000, 6000 and 8000 Hz the divers had higher mean hearing levels than non divers and their hearing at those frequencies seemed to deteriorate faster. The etiology of this insidious hearing loss is multifactorial and may be related to inner ear barotrauma, decompression sickness or noise-induced deafness.

Kozuka and Nakashima (1997) reviewed the records of 136 patients who had inner ear disorders including hearing loss and vertigo caused by pressure change. And divided them into three groups, according to the etiology: group A, change in atmospheric pressure (diving, airplane travel, etc.); group B, rapid change in ear pressure in normal atmosphere (nose blowing, heavy lifting, etc.); and group C, blast injury. A flat initial audiogram was the most common type in groups A and B. In group C, high-tone hearing loss was the most common type of audiogram. These results correspond to findings previously reported in animal experiments. Exploratory tympanotomy was performed more than 12 days after the pressure change in 16 patients. Although the vertigo disappeared after surgery, hearing did not improve.

Miyazawa, Ueda and, Yanagita (1996) studied Eustachian tube (ET) function by means of sonotubometry and tubotympano-aerodynamography (TTAG) prior to and following exposure to hypobaric or hyperbaric conditions. Forty normal adults were subjected to hypobaric pressure. Fifty adults who underwent hyperbaric oxygen

(HBO) therapy also were studied. Following hypobaric exposure, 14 of 80 ears (17.5%) exhibited middle ear barotrauma. Following hyperbaric exposure, 34 of 100 ears (34%) exhibited middle ear barotrauma. Dysfunction of the ET, characterized by altered active and passive opening capacity, was more prevalent following exposure to extremes in atmospheric pressure compared to baseline.

Bernstein (1996) reviewed the role of allergy in Eustachian tube blockage and otitis media with effusion. They suggested that the observed relationship between allergy and otitis media with effusion was caused by mediators of inflammation and cytokines and colony-stimulating factors released by mucosal mast cells and other inflammatory and epithelial cells in the nose and nasopharynx. These mediators produce blockage of the Eustachian tube through a number of mechanisms, which may include local injury or vascular- or neural-mediated changes in the Eustachian tube opening pressure and in middle ear perfusion.

Shupak, Attias , Aviv and, Melamed (1995) described middle ear negative pressure and effusions after oxygen diving in thirty-four oxygen divers with normal otoscopic and tympanometric evaluation. The symptoms were documented, and pneumatic otoscopy and tympanometry were repeated immediately after the completion of a 3 h, 15 feet oxygen dive, and 7 h later on awakening from the night's sleep. Most divers had positive otoscopic findings the morning after the dive, all of which cleared within 4 h of rising. The generalized nature of oxygen-induced middle ear under-aeration, combined with the dynamics of the symptoms and signs observed, made middle ear barotrauma, tympanic cavity oxygen absorption, and middle ear epithelial oxygen toxicity all unlikely explanations.

Brown, Jones and Krohmer (1992) determined the efficacy and safety of decongestant prophylaxis among first-time underwater divers in the prevention of barotitis media (middle ear squeeze) in one hundred twenty volunteer scuba divers under the supervision of certified instructors in Panama City. After randomization, each subject received a 60-mg tablet of pseudoephedrine or placebo 30 minutes before diving. A total of 116 subjects met the inclusion criteria and completed the study; 60 received 60 mg pseudoephedrine, and 56 received placebo. The pseudoephedrine group had smaller Teed scores after diving than did the control subjects (P = .003).

Nishihara, Gyo and Yanagihara (1992) experimented transmission of change in the atmospheric pressure of the external ear to the perilymph. In guinea pigs, the middle ear and perilymphatic pressures were simultaneously registered in response to pressure change in the external ear canal. In the first experiment, pressure was slowly loaded in the ear canal in the range of 200 mm H_2O to -200 mm H_2O. Pressure transmission to the perilymph was smaller when the bulla was open to the outside than when it was closed. It was significantly impaired by disruption of the ossicular chain and especially by closure of the round window. The data indicate that air volume in the middle ear cavity plays an important role in transmission of slowly changing atmospheric pressures. In the second experiment, the eustachian tube was closed and the pressure was changed in the range of 1000 mm H_2O to -1000 mm H_2O. The middle ear and perilymphatic pressures increased or decreased corresponding to the loading pressure in the range of 400 mm H_2O and -200 mm H_2O. Beyond these levels, response rate of the middle ear pressure decreased and perilymphatic pressure declined in spite of further increase in loading pressure. The increase in pressure difference between the middle ear and the inner ear might cause disruption of the round and/or oval windows.

Shupak , Sharoni , Ostfeld and Doweck (1991) documented and quantified middle ear pressure equalization failure during simulated dives among diving candidates who had otherwise met the otologic criteria for diving fitness. Forty-two candidates for regular naval diving activity were included in the study. Tympanograms of both ears at 1 and 1.1 absolute atmospheres were taken inside a pressure chamber with the subjects in two positions: seated and supine. The results suggested that successful auto inflation at surface ambient pressure does not necessarily reflect middle ear pressure equalization ability during descent in a dive.

Ivarsson and Lundgren (1977) studied the effects of head-out immersion on active and passive middle ear pressure equilibration in three otologically normal scuba divers. Results were compared with the equilibration capacity recorded in the non immersed sitting and supine positions. Head-out immersion had only a minor effect on the ability to equilibrate the middle ear pressure actively during descent; passive ear clearing during ascent was slightly more difficult compared with this capacity in the sitting non immersed position. In the supine position ear clearing was significantly more difficult during both ascent and descent.

Schuchman and Joachims (1985) studied tympanometric assessment of Eustachian tube function of divers. The Eustachian tube swallow test (ETST) was performed on both ears of 62 otologically normal young adult participants in a scuba diving course. There was no relation between the subjects' performance on the ETST and the otoscopic evidence of barotrauma after an actual dive. The ETST was of no practical value in screening prospective divers.

Öktem, Karakullukçu, Cansız and Aktaş (2000) determined the changes in elasticity of the tympanic membranes on 36 divers with different levels of experience in 123 dives due to depth of the dives and experience of the divers. Tympanometric measurements were taken by means of ear canal volume, middle ear pressure and compliance. No differences were observed for the ear canal and middle ear pressure, but the increase in compliance was statistically significant even in shallow dives ($p<0.001$). Due to the results they suggested that the pressure changes and related mild barotraumas between two sides of tympanic membrane might cause and increase in the elasticity of tympanic membrane.

CHAPTER III

METHOD AND PROCEDURES

Design of the study was performed: a) for comparison of the experienced and inexperienced groups' post-dive middle ear pressure and compliance alterations and b) for finding the various depths' (3m and 12m) effects on middle ear pressure and compliance changes on the same groups.

This chapter exposes the methods and procedures used to collect and analyze data to examine the effects of training, experience and diving depth to the middle ear pressure and compliance changes after scuba diving.

3.1 Selection of Participants

In an open water scuba diving course; 22 beginners with normal pre-dive audiometry, tympanometry, and general and otorhinolaryngologic examination were included to this study.

Totally 11 of them were experienced in under water rugby and free dive, other 11 beginners were inexperienced; however, both groups were well trained for ear clearing in 2m and 5m depth pools for 3 days. All participants were taught to dive on feet down position and to equalize the middle ear pressure by valsalva maneuver. The pool training session was ended one week before the open water dives.

A questionnaire was applied for the previous problems about ear problems such as Eustachian tube dysfunction, septum deviation, nasal pathologies and allergic rhinitis. No problems were established due to the questionnaire.

Written informed constents to participation were obtained from all subjects.

3.2 Instrument

All participants' pre dive rhinotolaryngeal inspections were taken by medical reports and self established questionnaire about Eustachian tube dysfunction, septum deviation, nasal pathologies and allergic rhinitis were received at the beginning of the study.

At the first day of the course; skin diving and mask clearing techniques were given to the participants at the 2m depth pool.

At the second day; scuba diving techniques especially feet down descent and valsalva maneuver for ear clearing were taught at the 5m depth pool.

At the fourth day; second day's procedure was repeated. No middle ear problems were reported after the pool practices.

One week after the last pool practice, open water dives were performed in two days. In the first day, 3m depth dives and in the second day 12m depth dives were realized. Each diving date, pre dive otologic inspections were taken by a medical doctor and pre dive / post dive tympanograms were measured by a medical technician from 19 Mayıs University Hospital**.**

Table 1: Schedule of the Study

1^{st} day	2^{nd} day	4^{th} day	11^{th} day (3m depth dives)	12^{th} day (12m depth dives)
Skin diving and mask clearing techniques were given to the participants at the 2m depth pool	Scuba diving techniques especially feet down descent and valsalva maneuver for ear clearing were taught at the 5m depth pool	Second day's procedure was repeated. No middle ear problems were reported after the pool practices	pre dive autologic inspections were taken pre dive tympanometries were measured post dive tympanometries were measured	pre dive autologic inspections were taken pre dive tympanometries were measured post dive tympanometries were measured

Tympanometry was measured by Impedance Audiometer AZ_7 and XYT Recorder model AG_3 Interacoustics electro acoustic impedance apparatus. An appropriate probe was placed into the ear and external ear pressure was increased to +200mm H_2O; than was decreased to -400 mm H_2O to see the middle-ear pressure and compliance curves in tympanogram.

3.3 Data Analysis

All data were stored in the computer and the statistical sciences for social sciences version 13.0 (SPSS) was used to threat the data.

In order to determine any significant difference of middle ear pressures changes between experienced and inexperienced groups; 3m and 12m depth dives paired samples correlations and Pearson product correlations (r) were calculated to determine the degree of middle ear pressures changes related to experience and diving depths.

CHAPTER IV

RESULTS

4. 1. General Characteristics of the Participants

General characteristics of the participants were 11 experienced (skin divers and/or underwater rugby players) and 11 inexperienced (not use to skin diving or such water sports) participants both males and females aged between 15 and 50. All of them were medically reported as they were fit for diving.

In all participants, the first otologic inspections before the 3m depth dives were normal.

In table 2 general characteristics of the participants were demonstrated.

Table 2: General Characteristics of the Participants

SAMPLE	AGE	HEIGHT(cm)	WEIGHT(kg)	GENDER	EXPRERIANCE
S1	29	180	81	M	IN EXPERIENCED
S2	45	180	103	M	IN EXPERIENCED
S3	50	167	84	M	SKIN
S4	28	187	95	M	IN EXPERIENCED
S5	21	175	58	M	SKIN
S6	39	175	85	M	IN EXPERIENCED
S7	15	180	75	M	IN EXPERIENCED
S8	42	180	75	M	IN EXPERIENCED
S9	20	178	60	M	IN EXPERIENCED
S10	25	180	82	M	SKIN
S11	22	175	68	M	IN EXPERIENCED
S12	22	179	60	M	IN EXPERIENCED
S13	31	185	85	M	UW RUGBY
S14	34	166	85	F	SCUBA
S16	20	172	55	F	UW RUGBY
S17	23	173	68	F	SKIN
S18	27	174	65	F	UW RUGBY
S19	20	170	48	F	IN EXPERIENCED
S20	20	158	58	F	UW RUGBY
S21	24	154	50	F	IN EXPERIENCED
S22	27	174	68	F	UW RUGBY

Table 3: Results of the Otoscopic Inspections and Tympanometric Measurements

SAMPLE	EXPERIENCE STATUS	OTOLOGIC INSPECTION BEFORE 3M DEPTH FIRST DIVE	OTOLOGIC INSPECTION BEFORE 12M DEPTH SECOND DIVE	FIRST (3M) TYMPANO-METRIC RESULTS OF ME PRESSURE	SECOND (12M) TYMPANO-METRIC RESULTS OF ME PRESSURE	(3M) TYMPANO-METRIC RESULTS OF ME COMPLIANCE	(12M) TYMPANO-METRIC RESULTS OF ME COMPLIANCE
S1	INEXP.	N	N	l- as is / r(+) p	r-l as is	R + L+	R+L+
S2	INEXP.	N	LEFT HYPEREMIC	r-l (+)p	r-l as is	R+L+	R+L+
S3	INEXP.	N	RIGHT – LEFT HEMOTYMPANIC	l as is / r (-) p	l as is / r (-) p	R-L+	R-L-
S4	INEXP.	N	RIGHT – LEFT HYPEREMIC	r as is / l (+)p	r-l as is	R+ L+	R-L-
S5	INEXP.	N	N	r-l as is	r-l as is	R-L-	R-L-
S6	INEXP.	N	N	r-l as is	r-l as is	R+ L -	R+L+
S7	INEXP.	N	RIGHT – LEFT HEMOTYMPANIC	r-l (+) p	r-l as is	R+L+	R+L+
S8	INEXP.	N	N	r-l as is	r-l as is	R-L+	R-L-
S9	INEXP.	N	RIGHT HEMOTYMPAN	l(-)p / r as is	l(-)p / r as is	R+L+	R+L+
S10	INEXP.	N	NO	r/l (-) p	r/l (-) p	R+L+	R+L+
S11	INEXP.	N	N	r-l as is	r-l as is	R+L+	R+L+
S12	SCUBA	N	N	r/l (-) p	r/l (-) p	R+L+	R+L+
S13	SKIN	N	N	l (-) p / r as is	r-l as is	R+L-	R-L-
S14	SKIN	N	N	l as is / r(+)p	r-l as is	R+L+	R+L+
S15	SKIN	N	N	r-l as is	r-l as is	R+L+	R+L+
S16	SKIN	N	N	r-l as is	r-l as is	R+L+	R+L+
S17	SKIN	N	N	r(+)p /l as is	r/l (-) p	R+L+	R+L+
S18	UWR	N	N	l as is / r (-) p	l as is / r (-) p	R+L+	R+L+
S19	UWR	N	N	r-l as is	r-l as is	R+L+	R+L+
S20	UWR	N	N	l(-)p / r as is	l(-)p / r as is	R+L+	R+L+
S21	UWR	N	N	r/l (-) p	r/l (-) p	R+L+	R+L+
S22	UWR	N	N	r-l as is	r-l as is	R+L+	R+L+

In 8 ears of the 5 inexperienced divers (22.7% of total and 45.4% of inexperienced group); either hyperemia or hemotympany were observed in the second day's otoscopic inspections (next day of the first 3m depth dive just before the second 12m depth dives) but not reported as injured by the participants.

In the first post dive tympanometric measurements; 25 ears showed no meaningful middle ear pressure changes, 8 ears showed positive pressure and 11 ears showed negative pressure due to valsalva maneuver or inequality of the ambient pressure. Thus, middle ear pressure changes were observed in 19 ears of 14 divers (63.6%).

The compliance was not changed in 5 ears of 3 divers (13.63%) and increased in the reminder.

In the second tympanometric measurements, 12 ears of the 8 divers (36.4 %) showed negative middle ear pressure and the remainder showed no difference. Again, compliance was not changed in 10 ears of 5 divers (22.72%) and increased in the reminder.

Compliance was not changed in 15 ears of 8 divers (18.18%) and increased in the reminder for the total dives.

Table 4: Paired Samples Correlations due to Experience and Depths

Pair 1 Experience & otologic inspection before 12m depth dives,

Pair 2 Experience & middle ear pressure after 3m depth dives,

Pair 3 Experience & middle ear pressure after 12m depth dives,

Pair 4 Middle ear pressure results of 3m depth dives and middle ear pressure results of 12m depth dives,

Pair 5 Experience & compliance for 3m,

Pair 6 Experience & compliance for 12m,

Pair 7 Otologic inspection before 12m depth dives & compliance for 3m,

Pair 8 Otologic inspection before 12m depth dives & compliance for 12m,

Pair 9 Compliance for 3m & 12m.

Table 4: Paired Samples Correlations due to Experience and Depths

		N	Correlation	Sig.
Pair 1	experience & otologic inspection(otoscopy) before 12m depth dives	22	.542	.009
Pair 2	experience & middle ear pressure after 3m depth dives	22	.000	1.000
Pair 3	experience & middle ear pressure after 12m depth dives	22	-.189	.400
Pair 4	middle ear pressure results of 3m depth dives and middle ear pressure results of 12m depth dives	22	.571	.005
Pair 5	Experience &compliance for 3m	22	.316	.152
Pair 6	Experience &compliance for 12m	22	.408	.059
Pair 7	otologic inspection before 12m depth dives & compliance for 3m	22	.171	.445
Pair 8	otologic inspection before 12m depth dives & compliance for 12m	22	-.155	.491
Pair 9	compliance for 3m & 12m	22	.516	.014

As can be seen from the table; there is a correlation of **.542** between experience status and second day's otologic inspection.

Due to experience and middle ear pressure changes of each day; no meaningful, statistically significant correlation was found.

Also no meaningful correlations were found neither for experience and compliance nor for otologic inspection and compliance.

Table 5: Pearson Correlations due to Experience and Depth

		Exp.	Otoscopy	Comp3m	Comp12m	MEpres.3m	MEpres.12m
experience	Pearson Correlation	1	-.542(**)	.316	.408	.000	.189
	Sig. (2-tailed)		.009	.152	.059	1.000	.400
	N	22	22	22	22	22	22
Otoscopic results	Pearson Correlation	-.542(**)	1	.171	-.155	.410	.041
	Sig. (2-tailed)	.009		.445	.491	.058	.856
	N	22	22	22	22	22	22
Compliance for 3m	Pearson Correlation	.316	.171	1	.516(*)	.090	.239
	Sig. (2-tailed)	.152	.445		.014	.692	.284
	N	22	22	22	22	22	22
Compliance for 12m	Pearson Correlation	.408	-.155	.516(*)	1	-.039	.251
	Sig. (2-tailed)	.059	.491	.014		.865	.260
	N	22	22	22	22	22	22
ME pressure for 3m	Pearson Correlation	.000	.410	.090	-.039	1	.571(**)
	Sig. (2-tailed)	1.000	.058	.692	.865		.005
	N	22	22	22	22	22	22
ME pressure for 12m	Pearson Correlation	.189	.041	.239	.251	.571(**)	1
	Sig. (2-tailed)	.400	.856	.284	.260	.005	
	N	22	22	22	22	22	22

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

CHAPTER V

DISCUSSION

This study was designed to substantiate the preventive effect of training ear clearing techniques on middle ear barotraumas by means of middle ear pressure and compliance changes. Also due to the design; relations of diving depths with middle ear pressure, compliance and otologic changes were observed.

Totally 2 groups (experienced and inexperienced for 3m, and 12m depths) of pre dive inspections and pre - post dive tympanometric measures had been taken for 22 participants. Both groups were well trained for ear clearing in 2m and 5m depth pools for 3 days one week before the open water dives (feet down position – valsalva maneuver). A questionnaire was established for the previous problems about ear problems such as Eustachian tube dysfunction, septum deviation, nasal pathologies and allergic rhinitis. All participants' pre dive rhinotolaryngeal inspections were taken by medical reports.

Due to the results of the study a correlation of **.542** between experience status and otologic inspection prior to 12m depth dives was found. This is a contradiction to the hypothesis "there would not be any significant difference between experienced and well trained inexperienced groups" as the otologic variations such as hyperemia or hemotympany were only seen in inexperienced (not use to skin diving or such underwater sports) novices.

Again; contrast to the hypothesis " there would be no significant differences in middle ear pressure variations between diving depths", the correlation of **.571** showed that 3m depth dives had grater frequency of middle ear pressure changes than 12m depth dives.

Similarly; due to the compliance correlation of **.516,** 3m depth dives had a grater frequency of compliance increases than 12m depth dives.
These results however should be reconsidered as the 3m depth was the first open water dive day and 12m depth was the next day which the novices could use to the open water conditions. Thus; only 24 hours of relaxation period between two dives can be considered as a limitation for this study.

Due to experience and tympanometric measures both for middle ear pressure and compliance of diving depths; no meaningful, statistically significant correlation was found.

Against the hypothesis; correlation of experience was transpired due to the results of the study. This situation could be ripened because of the difference between pool and open water conditions. Though, all participants were taught the insistent ear clearing techniques, especially valsalva maneuver, poor visibility and currents might have frightened the inexperienced divers.

Also number of the dives was not sufficient for such a study.

Some other anatomical and physiological factors such as mastoid pneumatization were not examined, also there would be some other difficulties different than self established responses for the questionnaire of ear clearing problems such as Eustachian tube dysfunction, septum deviation, nasal pathologies and allergic rhinitis; thus the possible effects of such conditions were not taken into consideration. However all participant had succeeded in the previous 3 days of pool session and no injuries had been reported.

An assessment of the strain on the tympanic membrane caused by diving was performed using impedance measurement of the middle ear in 21 untrained young men going through a scuba-diving training program (Paaske, 1991). Tympanometry was carried out just before and after diving. In 104 dives at depths from 2 to 12 m results showed a significant increase in middle ear compliance on diving.

The results of Paaske harmonizes with the results of this study results.

Korıwchak and Werkhaven (1991) indicated that barotraumas were associated with poor underwater visibility, not with experience.

The similar underwater conditions were present for this study, however all barotraumas were seen in the inexperienced group.

Green and Rothrock (1993) reported the first prospective evaluation of middle ear barotraumas in experienced recreational scuba divers. In this pilot study, tympanometric and otoscopic evaluations were performed daily on two experienced scuba divers engaged in multi-day repetitive diving. Middle ear pressures decreased in proportion to diving frequency, demonstrating Eustachian tube dysfunction which promptly reversed upon cessation of diving Otoscopic evidence of traumatic injury to the middle ear occurred in proportion to diving frequency, and also readily reversed upon cessation of diving. Tympanic membrane compliance remained normal, often despite pronounced otoscopic abnormalities.

Due to otoscopic abnormalities of 5 divers in this study; 3 of them had compliance increases for both ears and both diving depths, while 2 of them had compliance increases for both ears only for 3m depth dives and no changes for 12m depth dives.

Öktem, Karakullukçu, Cansız and Aktaş (2000) determined the changes in elasticity of the tympanic membranes on 36 divers with different levels of experience in 123 dives due to depth of the dives and experience of the divers, by means of ear canal volume, middle ear pressure and compliance. No differences were observed for the ear canal and middle ear pressure, but the increase in compliance was statistically significant even in shallow dives ($p<0.001$). The otoscopic barotrauma diagnosis was 8.3% (3of 36 divers).

Due to the results of this study, the increase in compliance was also statistically significant, 81.2% of divers had increase in compliance, no significant changes of middle ear pressure were found and the otoscopic barotrauma diagnosis was 22.7% (5of 22 divers).

CHAPTER VI

CONCLUSION

As a conclusion; it appeared that experience (skin diving or under water rugby) have had a grater importance than training's preventive effect (which should not be underestimated for a novice diver), however, scuba courses are opened to all population who are medically reported as fit for scuba diving. So training still keeps its magnitude for the novices' prevention.

Better open water conditions (such as clear visibility, calm and warm water) might be recommended for the elementary dives to prevent the novices. Nevertheless, in any worse conditions anxiety could not be controlled, thus, ear clearing problems could be seen in experienced accepted divers.

As predicted at the beginning of the study, increase in compliance was significant for all groups and depths.

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