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ORIGINAL

Hearing injuries due to atmospheric pressure changes in air and water survival training instructors

Lesiones auditivas por cambios de presión atmosférica en instructores de entrenamiento para supervivencia en aire y agua

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ABSTRACT

Under normal atmospheric conditions, the individual has an optimal state of health, but these conditions alter their physiology and can cause damage to health. Hence, sudden changes in atmospheric pressure generate hearing manifestations and/or injuries because the pressure inside the ear must be equal to that outside. The objective of this study was to determine the prevalence of hearing injuries caused by sudden changes in atmospheric pressure in air and water survival training instructors, during the period 2012-2022. Epidemiological, descriptive cross-sectional research. To collect the information, a documentary review of the clinical records and the work plan was carried out. The population and sample were made up of the 20 instructors of the Department of Physiological Training (DAF). Results: the male sex predominated (85 %), the average age and seniority were 36 ± 4,68 and 12 ± 6,59 years respectively, with a work exposure of 6 hours per week. In addition, 15 cases of hearing loss and 01 case of decompression illness with hearing injury were diagnosed, a prevalence of 0,8 cases per year, which indicates that one instructor annually suffers from hearing injury due to Barotrauma. This is why the main prevention measure is in the organization of work, limiting the number and duration of dives. Therefore, it is recommended to implement a hearing conservation program and comply with the morbidity registry of occupational diseases and accidents of the DAF instructor staff related to changes in atmospheric pressure.

Keywords: Atmospheric Pressure; Hearing Diseases; Barotrauma; Decompression Sickness.

RESUMEN

El individuo en condiciones atmosféricas normales posee un estado de salud óptimo, dichas condiciones alteran su fisiología pudiendo generar daños a la salud. De allí, que los cambios bruscos de presión atmosférica generan manifestaciones y/o lesiones auditivas, debido a que la presión interna del oído debe ser igual a la del exterior. El objetivo de este estudio fue determinar la prevalencia de lesiones auditivas ocasionadas por cambios bruscos de presión atmosférica en instructores de entrenamiento para supervivencia en aire y agua, durante el periodo 2012-2022. Investigación de tipo epidemiológica, descriptiva de corte transversal. Para la recolección de la información se realizó revisión documental de las historias clínicas y el plan de trabajo. La población y muestra se conformó con los 20 instructores del Departamento de Adiestramiento Fisiológico (DAF). Resultados: sexo masculino predominó (85 %), la edad y antigüedad promedio fue 36± 4,68 y 12± 6,59 años respectivamente, con una exposición laboral de 6 horas semanales. Además, se diagnosticaron 15 casos de hipoacusia y 01 caso de enfermedad por descompresión con lesión auditiva, una prevalencia de 0,8 casos por año, lo cual indica que un instructor anualmente padece de lesión auditiva por Barotraumatismo. Es por ello, que la principal medida de prevención está en la organización del trabajo, limitando el número y duración de las inmersiones. Por lo que se recomienda implementar un programa de conservación auditiva y

cumplir con el registro de morbilidad de las enfermedades y accidentes laborales del personal de instructores del DAF relacionados con cambios de presión atmosférica.

Palabras clave: Presión Atmosférica; Enfermedades Auditivas; Barotrauma; Enfermedad de Descompresión.

INTRODUCTION

From ancient times, humans have been compared with a perfect machine; however, the human body is designed to operate under specific conditions, such as the bipedal position, exposure to certain ranges of atmospheric pressure, oxygen concentration, among others. These conditions have not always been respected by technological advancements, diving, and aviation, leading to the manifestation of certain limitations that humans have under specific circumstances. Therefore, in order to contribute to the safety of such activities, it is imperative to know, comprehend, and be trained in these human limitations to prevent health damage, particularly of an auditive nature arising from sudden changes in atmospheric pressure.[1]

In this context, the term barotrauma can be defined as the damage caused to any tissue by a sudden change in pressure difference, between the air space inside the body and the gas or liquid surrounding the individual. It can also occur when someone transitions from a higher-pressure environment to a lower-pressure one, as is the case when ascending suddenly during the practice of scuba diving.[2]

Similarly, it can be caused by compression or decompression. In the first case, air spaces in the organism surrounded by soft tissues (and, therefore, subject to an increase in ambient pressure, according to Pascal's principle) will experience a volume reduction (as well predicted by Boyle's law: by doubling ambient pressure, the gas volume is reduced by half). It is important to note that decompression barotrauma occurs more rarely than compression barotrauma, but its consequences are usually more severe.[1]

The authors, Hamilton and Bhattacharyya, emphasize that injuries or damage occurring in the organism during or after a barometric change (pressure changes) in air or water occur more frequently at the level of the auditory system. This can result in a blockage in one or both ears, along with discomfort, vertigo, intense pain, rupture of the tympanic membrane with bleeding, and even severe hearing loss. The most common causes are associated with diving, flight cabins, hyperbaric and hypobaric chambers, or during an explosion.[3]

On the other hand, the Aerospace Medical Center of Chile, in its manual on Basic Concepts of Aviation Physiology,[4] reports the existence of other damages resulting from barometric changes known as "Dysbarisms". These encompass all those pathophysiological phenomena that the human organism can undergo due to the effects of changes in gases within the body subjected to variations in barometric pressure. An example is the release of nitrogen bubbles from organic liquids that can be located in joints or nearby areas, causing inflammation and pain. Likewise, the manual from the Aerospace Medicine Center of Chile in 2004 classified dysbarisms into those caused by mechanical effect of volume variation of trapped gases and decompression sickness.

This manual indicates that a worker exposed to an increase in barometric pressure in any space with the presence of gas may suffer barotrauma, which is very frequent in the ears, principally causing injuries to the outer ear (including the tympanic membrane and middle ear) when the external ear canal is occluded with plugs, helmets, or due to the presence of earwax. The likelihood of injury increases when the worker has an upper respiratory tract pathology that causes dysfunction of the Eustachian tubes (ET), due to the middle ear normally communicates with the outside through the ET, whose function is to equalize air pressure on each side of the tympanic membrane. This is achieved through the opening of the ET to allow the passage of air.[4]

There are some previous studies that have assessed the impact of pressure on professional divers. In Mexico, a study between 2002-2007 evaluated 298 divers, finding that 56 of them experienced barotrauma, with an average diving depth of 14,7±2,1 meters during 3,6±1,4 hours daily.[5] In Spain, another study between 2008-2010 assessed 233 divers, where 89,2 % presented decompression symptoms, and 19,7 % had mild hearing loss associated with years of experience.[6] More recently, in Chile, a study conducted in 2016 evaluated 12 professional divers, finding that 9 presented mild auditory alterations, but there was no association with years of practice or hours of immersion.[7] Similarly, in Chile, another study conducted in 2018 assessed 125 divers, finding that 86 % of them submerged to depths greater than 30 meters, and 80 % reported episodes of decompression, with a prevalence of hearing loss of 54,4 %.[8] These previous studies suggest a relationship between occupational factors such as diving depth and time with manifestations like barotrauma and auditory alterations in divers.[5,6,7,8]

On another note, in Venezuela, as a result of a resolution issued by the Ministry of the People's Power for Transport (Resolution No. 032) in 2022, regarding general guidelines to regulate underwater inspections of ships, its Article 8 establishes the requirements that private companies, operators of underwater diving activities, must comply with: a) Documents: Designation by the National Institute of Aquatic Spaces (INEA), work authorization, protocol to follow, risk analysis, and a Quality Management System (QMS) b) Equipment:

Live video with recording capability, communication, surface-supplied air equipment (…) c) Personnel: They must have a diving supervisor, two divers with surface-supplied air, a diving assistant, and a console operator diver, among others.[9]

Similarly, the Law on Marinas and Related Activities (2014) stipulates in Articles 166 and 167 of the Chapter IV, concerning underwater activities, that the National Institute of Aquatic Spaces (INEA) is the entity responsible for regulating, controlling, and supervising these diving activities as well as their certification. While military personnel are exempt from certain laws, they are still subject to the principles outlined in the Organic Law on Prevention, Working Conditions, and Working Environment (LOPCYMAT) (2005), which ensures the health and safety of workers (divers). In another context, the Regulation of Hygiene and Safety Conditions at Work, in the chapter IV regarding Divers with Supplied Atmosphere, establishes the necessary measures for diving works and operations in Articles 718 and following.[10,11,12]

Likewise, at the level of the institution under study, in the Center for Physiological Training and Aerospace Medicine (CAFMA), there are established norms in the Directive on examinations and procedures governing the health sector in Bolivarian military aviation (Directive AV/D 3-22. Series 3 common activities of personnel (2011)), for the exposure of instructors in the hypobaric chamber and in the pool. Among the most crucial regulations, it is stipulated that crew members and passengers should refrain from heavy exercises or work for a period of forty-eight (48) hours after the flight in the low-pressure chamber. It is also emphasized that one should not enter the hypobaric chamber if the instructor reports any symptoms related to the respiratory tract, and individuals should wait 15 days before engaging in activities involving sudden changes in atmospheric pressure again.[13]

The current topic is deemed highly significant for the health of CAFMA workers, particularly in the Department of Physiological Training (DAF), as it will facilitate the identification of the prevalence of hearing injuries resulting from sudden pressure changes and their correlation with personnel's exposure time, whether it comes from lack of knowledge or non-compliance with recommended rest intervals between one immersion and another. Furthermore, the realization of annual medical checkups is crucial, not just for the military and civilian population in aeronautics but also for instructors to enhance the quality of life for these workers.

The mission of these workers is of utmost importance as their main purpose is to provide flight physiology training to pilots and crew members of Military Aviation. This extends to other components of the National Bolivarian Armed Force, foreign armed forces, and other organizations and institutions according to the schedule outlined by the Department of Physiological Training (DAF). The overarching aim is to prevent risks and effectively address situations that may arise during these missions. Several research studies have underscored that diving accidents can have adverse effects on the ear due to pressure changes.[5,6,7,8]

As per the aforementioned, the primary objective of this investigation was to determine the prevalence of hearing injuries caused by sudden changes in atmospheric pressure in in air and water survival training instructors in the Aragua region, Venezuela, covering the period from 2012 to 2022. Additionally, the following specific objectives were delineated: to characterize the sociodemographic and work-related aspects of the study population; to identify the manifestations and types of reported hearing injuries concerning exposure to pressure changes; and to calculate the frequency of occurrence of these hearing injuries in instructors during the analyzed period.

METHODS

An epidemiological, descriptive cross-sectional study was conducted, utilizing secondary data obtained from the review of clinical records and employment records of instructors at a survival training center in Aragua, Venezuela, spanning the years 2012-2022. The population was made up of all instructors (n=20) affiliated with the Department of Physiological Training (DAF) at the center throughout the study duration.

Following the acquisition of informed consent and authorization from the medical and planning departments, variables related to sociodemographic, occupational, and auditory manifestations were gathered from clinical records. These variables, such as sex, age, labor seniority, weekly exposure hours, and records of auditory signs and symptoms associated with pressure changes, were input into a Microsoft Excel database for subsequent analysis.

Measures of central tendency, dispersion, and prevalence were computed. The prevalence was determined by assessing the proportion of cases with hearing injuries relative to the total number of instructors during the study period.

RESULTS

Table 1 illustrates that the predominant sex is male (85 %), the age group between 30 and 39 years constitutes 50 % of the studied sample, ranging in age from 22 and 45 years, with a mean of 36 years, and a standard deviation of +/- 4,68 years.

In terms of labor seniority, the average is 12 years +/- 6,59 years, with 65 % of instructors having a service ranging from 1 to 10 years in the position. Likewise, the working hours adhered to by these instructors, according

to the work plan, are 06 hours of weekly exposure. However, it is observed that the recommendation for a 15-day break from immersion after exposure to the hypobaric chamber is often not followed.

Table 1. Sociodemographic and occupational characterization of air and water survival training instructors for the period 2012-2022. Aragua, Venezuela. (n=20)

Sociodemographic and Occupational Characteristics	Nº of instructors	Percentage (%)
Sex		
Male	17	85
Female	3	15
Age group (years)		
20-29	3	15
30-39	10	50
40-50	7	35
Range: 22-45 years		
Mean: 36 years +/- 4,68 years		
Seniority (years)		
< 10 YEARS	13	65
11-20	6	30
21-30	1	5
Range: 1-27 years		
Mean: 12 years +/- 6,59 years		
Working week, Air/ Water (hours/week)	6 hrs/ week.	

Source: Clinical records (2010 - 2022).

Table 2 illustrates the auditory manifestations resulting from atmospheric pressure changes in the studied population over the 10-year period. In descending order of frequency, there were 15 cases of otalgia (75 %), 9 cases of tinnitus (ringing in ears) (45 %), and 1 case of otorrhagia (5 %). Meanwhile, the most frequently diagnosed hearing injury was unilateral or bilateral hearing loss, accounting for a total of 15 cases (75 %), followed by 1 case of decompression sickness with hearing injury (5 %). This sums up a total of 41 manifestations and hearing injuries reported in the 20 instructors during the study period.

Table 2. Auditory manifestations and injuries caused by changes in atmospheric pressure (Barotrauma) in air and water survival training instructors for the period 2012-2022. Aragua, Venezuela. (n=20)

Years	Frequency (n°)				
	Manifestations			Hearing injuries	
	Otalgia	Tinnitus	Otorrhagia	Uni- or bilateral hearing loss	Decompression sickness with auditory injury
2012	3			4	
2013		2		1	
2014	4	2		2	
2015	1	1		3	
2016	2			2	
2017	1	1	1	3	1
2018		1			
2019	2	2			
2020				No record	
2021				No record	
2022	2				
TOTAL	15	9	1	15	1

Source: Clinical records (2012-2022).

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Regarding the results obtained from calculating the prevalence of hearing injuries caused by changes in atmospheric pressure in air and water survival training instructors, it is determined that:

Prevalence of Hearing Injuries = (16 cases in 10 years) / 20 = 0,8

The prevalence rate of hearing injuries among Physiological Training instructors was 0,8 over the span of 10 years. This indicates that, on average, one instructor from the DAF experienced a hearing injury due to barotrauma annually.

DISCUSSION

The health effects caused by changes in barometric pressure in certain professions vary. That is the case of aviators, where the increase in altitude results in a decrease in atmospheric pressure, leading to associated cellular hypoxia. Meanwhile, in divers or submariners, the opposite occurs, tissues near air-filled spaces of the body, such as the ears, paranasal sinuses, tooth roots, and lungs, can be damaged if the body cannot equalize the pressure between itself and the surrounding water; as water pressure increases, the volume of air in the body decreases, causing health damages in these areas.[1]

In the present research, the sociodemographic and occupational characterization revealed a predominance of male subjects (85 %). Regarding age, the range was from 22 to 45 years, with an average of 36 years ± 4,68 years. The age group between 30 and 39 years represented 50 % of the cases. About 65 % of the instructors had an average labor seniority of 12 ± 6,59 years, and a weekly working hours of 6 hours. These results align with findings by Padilla et al.[5] and Barra and Gallegos[7] regarding sex, age range, and average labor seniority. In this way, they are consistent with what these authors reported regarding compliance with the working hours, with at least 50 % of their population working 5 hours or less per week.

Regarding the identification of auditory manifestations and injuries, a total of 41 cases were found, including otalgia, tinnitus, otorrhagia, hypoacusis (uni- or bilateral), and decompression sickness with hearing injury. These findings are consistent with those obtained by González et al,[6] who reported that pressure changes in diving and aviation personnel can lead to tinnitus and hypoacusis as the main sequelae, which may later contraindicate their occupational activity.

Similarly, in a study aiming to identify the auditory system alterations in military professional divers, Templado[14] found that the most frequent symptoms were otalgia (53,33 %), tinnitus (20 %), nausea (20 %), imbalance and instability (20 %), and hearing acuity decline. These results do not coincide with those of the present investigation, where otalgia was present in 75 %, tinnitus in 45 %, with no mention of nausea or imbalance and instability, but hearing acuity decline was present in 75 %. These differences are possibly a consequence of non-compliance with the no-diving period after exposure in the hyperbaric chamber in the current study.

On the other hand, in relation to the prevalence of hearing injuries associated with changes in atmospheric pressure, it differs from the study by Garrido et al,[8] as they reported lower values (0,54), while in the present study, it was 0,8. This difference is possibly due to the non-compliance with the rules for diving after the exposure in the hypobaric chamber and/or the number of instructors required for weekly training. Therefore, the main preventive measure consists of organizing work, limiting the number and duration of dives.

The professional diving safety manual, published in the information sheet FD-14 by the Institute of Occupational Health and Safety, states that the maximum daily duration of underwater stays is set at 3 hours (180 minutes). Regarding the limitation of continuous and successive dives, only one continuous or successive dive can be carried out per day, with a minimum of 12 hours between the end of one dive and the start of the first one on the following day. Only in the case of dives where the depth does not exceed 10 meters throughout the day, the underwater stay can be of 5 hours (300 minutes). After completing a dive that has required decompression, personnel who have performed it will not be subjected to physical work on the surface that accelerates blood circulation for the next 2 hours.

CONCLUSIONS

The conclusion of this research is that there is a high prevalence (0,8) of hearing injuries caused by sudden changes in atmospheric pressure among the personnel of air and water survival training instructors in the studied context.

According to the aforementioned, the following recommendations are proposed: to design and implement a hearing conservation program for all DAF instructor personnel who are exposed to atmospheric pressure changes. This program should include regular annual medical evaluations and audiometric tests. Additionally, it is proposed to establish a morbidity record to maintain an adequate report of diseases and occupational accidents related to atmospheric pressure changes among DAF instructors. Furthermore, it is advisable to increase the number of personnel trained as physiological training instructors. This measure aims to optimize the overall organization of work, thereby reducing the risks associated with the activities conducted by these instructors.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHORSHIP CONTRIBUTION

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