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Aerobic Capacity and Chest Pain in Novice Scuba Divers

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Abstract: Aerobic power indicates the maximum amount of Oxygen intake that a person uses during strenuous physical activities under the sea. Accordingly, the significance of aerobic power in divers who spend much time under the water must be addressed. In order to investigate the matter, this study examines the correlation of aerobic power with increasing diving depth of divers and its relationship with their chest pain. The statistical population includes 70 students from a diving class of a Diving School in Bandar Anzali. The group consists of 20 male subjects randomly selected according to Morgan's table, aged 18 to 25, with no history of health issues, smoking, and professional sports activities. The results indicated a significant relationship between aerobic power and diving depth until the onset of chest pain; a significant inverse relationship between aerobic capacity and the intensity of chest pain; and a significant relationship was observed between aerobic capacity and duration of chest pain. These results are in favor of the effect of aerobic capacity in prevention of chest pain in divers.

Keywords: Cardiorespiratory Fitness, Aerobic Power, Deep Diving, Chest Pain.

1. Introduction

History shows that Alexander the Great not only sent divers to destroy the enemy's impediment in the anchorage but also took advantage of diving to monitor their progress during wars. The significance of diving lies in humans' need for military leadership, conducting underwater services, underwater commerce, and expanding the gates of knowledge through searching and discovering underwater secrets.

No one knows exactly when humans discovered that they could stay underwater for a particular period by holding their breath; however, diving as a profession has existed for more than 5,000 years. Due to human beings' basic need for oxygen, they cannot stay underwater for long. Without professional means and instruments, man has a chance of dramatic incidents. Unfortunately, humans react significantly to pressure increases as the diver goes deeper, and there is a chance of chest pain and lung failure (Kooyman & Ponganis, 1997).

It is obvious that diving is a physiologically demanding exercise. Divers must not have any history of medical issues, especially respiratory and cardiovascular illnesses, since they are the major players during diving. Therefore, respiratory and cardiovascular fitness are critical notions for professional divers (Matuszak & Cooper, 2018).

Cardiorespiratory fitness, also called cardiorespiratory endurance and cardiovascular fitness, is the heart's ability to pump oxygen-rich blood to the muscles, and subsequently, muscles can perform sufficiently. The best indicator for evaluating cardio-respiratory fitness is measuring the maximum oxygen consumption (Vo2max); For example, a person whose maximum oxygen consumption is 65 milliliters per kilogram in a minute has a higher cardio-respiratory fitness than a person whose maximum oxygen consumption is 50 milliliters per kilogram in minute. The maximum capacity of oxygen consumption during exercise is called maximum oxygen consumption. Terms such as aerobic capacity, aerobic power, maximum absorbed oxygen, and cardio-respiratory endurance capacity are also used in the same sense. It would be logical if vo2max values are higher in endurance sports than speed or power sports (Gaini, Rajabi 2018).

General physical fitness is a sign of a person's health and healthy lifestyle. The physical fitness required for each job is different, especially for military personnel, who should be higher than anyone else. In this regard, the IRGC Navy after the imposed Iran–Iraq War, understood the fact that military divers need to be professionally trained to acquire cardiorespiratory and overall physical fitness and endurance in order to survive during operations. In so doing IRGC Navy planned new rehearsal to increase the navy diver cardiorespiratory fitness to carry out tactical operations, to perform salvage operations and repair welding, and to identify and collect scientific research information in deep see water (Deputy A. Nedsa, 1378).

In doing so, the goal of the researcher is to answer this question: will divers with higher aerobic fitness have chest pain in deep diving (as the depth increases) or not?

2. Materials and Methods

Measuring the body's ability to consume oxygen during sports activity is a common method for evaluating cardio-respiratory fitness (Eddington & Wadgerton 1993, p. 2).

The best laboratory test to measure cardiorespiratory endurance is the direct measurement of oxygen consumption through step-by-step exercise tests until reaching the maximum capacity. These tests are usually performed using a stationary bike or a treadmill. The subject performs light activity increasingly to the maximum intensity of the activity, and in all stages, the oxygen consumption is measured by gas measuring devices.

Along with the increase in activity intensity, oxygen consumption also increases until it reaches a constant value. The maximum amount of oxygen used in this stage is the maximum amount of oxygen consumed by a person. Although the measurement of oxygen consumption in a direct way (using respiratory gas analyzers) is the most accurate measurement, due to the high cost and impracticality of this method in different situations, it is often used to estimate oxygen consumption indirectly through heart rate response to exercise, distance covered or the elapsed time is used in various field and laboratory tests.

2.1. Instruments

After the necessary examinations based on the subjects' physical health, the participants sign a consent form, which includes the necessary explanations about the test and its possible risks and discomforts. Also, 2-3 days before the start of the main test, the subjects should refrain from doing any intense physical activity or diving. In addition, the subjects are taught about the diving pressure chamber and how they should communicate and cooperate with the researcher while inside the chamber. A meeting is held with colleagues who help the researcher use their opinions and suggestions and coordinate the necessary steps. For a better result of the primary test, the subjects wear shoes and diving clothes with a thickness of 3 mm on the treadmill and inside the pressure chamber.

2.1.1. Common Methods of Measuring Aerobic Power (Vo2max)

In general, the best indicator of endurance fitness is maximum oxygen consumption (vo2max). Measuring the body's ability to consume oxygen during sports activity is used as a common method to evaluate cardio-respiratory fitness (Eddington and Wadgerton 1993, p. 2). In general, evaluation of aerobic capacity is possible in two ways: laboratory method and field method.

2.1.1.1. Laboratory Methods

The general capacity of athletes is assessed in the laboratory by walking and jogging on a treadmill, riding a stationary bicycle ergometer, rowing through a rowing ergometer, and finally, swimming in a pool where the speed of movement or water circulation can be controlled and measured. The measurement principles are the same in different devices, but there is a slight difference of up to ten percent in the maximum amount of oxygen consumed in these devices (Khodadad 1369).

The heart is measured and estimated at the end of the activity (Eddington & Edgerton 1993, p. 2). The most common tests for indirect estimation of maximum oxygen consumption in the laboratory are Bruce and Balk tests on treadmills, Astrand-Rhyming test on ergometer bicycles, and a variety of staircase tests in the form of maximum and subtests (Gaini, Rajabi 1388).

2.1.1.2 Field Methods

One of the most common field tests for estimating aerobic capacity and cardiovascular endurance is running and walking. In addition to measuring cardiac endurance, blood circulation and breathing, these tests also evaluate muscular endurance. The reason for this can be the intervention of most of the skeletal muscles in the execution of the test.

Running tests are very useful when the number of people is large, and it is necessary to evaluate all of them in a short period of time. However, in order to gain credibility, objectivity, and trust, the subjects should do aerobic sports and practice for the test. The important point is that the distances, times, and recording methods should be used in a standard way (Morrow et al. 1995).

2.1.1.2.1 Cooper's 12-Minute Run Test

Kent A. G. Copper, in 1968, while studying Dr. Berno Black's research and with the cooperation of several other physiologists, prepared and organized the two 12-minute tests, which provide a relatively good measurement of maximum oxygen consumption. Cooper's 12-minute running test was designed and determined for the first time in 1968 for US Air Force employees who were 30 years old (Dabbagh, 1379).

Cooper created standards for male participants that showed their readiness at excellent, good, average, weak, and very weak levels. Implementing this test is simple. It only requires determining how far you can run or walk in 12 minutes.

Cooper and Balk have found a high correlation between the maximum oxygen consumption measured by the treadmill during the mentioned test. Balk found that the results obtained from both methods were +10% of the true values, and Cooper obtained a correlation of 0.897, which is very high. We remind that running for at least 12 minutes gives the assurance that most of the work was done aerobically instead of anaerobically (Saboktakin and Mirfatah, 1368)

2.2. Statistical Society

The statistical population of this research includes 70 students of the diving class of Hazrat Seyyed Al-Shuhada Ranger and Diving School in Bandar Anzali, whose physical training (aerobic) and diving are part of their current semester courses. The criteria for selecting the sample from the research community based on public health according to the checklist for checking the general health status, the absence of respiratory and heart diseases, kidney, anemia, diabetes, no history of chemical injury, drug use, and current treatment, no history of past professional sports activities and history smoking.

2.3. Statistical Analysis

Descriptive statistics, including mean, standard deviation, confidence level, and Pearson correlation coefficient, are used for statistical description and analysis. The data is analyzed using the SPSS computer program. The statistical calculation is also determined at the $p \leq 0.05$ level. The predictive power of this formula is (98%). In this formula, the duration of physical activity is expressed in minutes and beats, and VO2 MAX is expressed as (ML/KG/MIN). If the correlation is significant, the regression equation is also used (Delavar, 2019).

VO2MAX=14/8-(1/379×T) + (0/451×T^2) - (0/012 ×T^3)

The Cooper's test is performed at a predetermined time (according to the syllabus table). Subjects are prohibited from eating food except water to the extent necessary for at least 2 hours before the test. Before starting the main test, after wearing diving clothes and shoes, the subjects warm up with stretching and stretching movements for 15 minutes. They had to run on the treadmill for 3 to 5 minutes at low speed and without incline to understand running coordination. Immediately after warming up, the main test begins on the tape recorder. The primary test for diagnosing aerobic capacity is the Bruce protocol under the supervision of a doctor (Pollack-Wilmore, 2019).
After recording the aerobic capacity of all the subjects, each of them enters the pressure chamber individually, and pressure begins to increase gradually to reach the deep-sea pressure. Therefore, the chest pain threshold of each of the subjects is recorded by showing their hand through the pressure chamber. In the next step, each subject should stay in the pressure chamber for at least 15 minutes after feeling and starting the chest pain so that the extent of the pain can be felt and expressed. Then, after leaving the pressure room, each subject fills out a questionnaire based on the pain level within 15 minutes of stopping at the depth of pain onset. Finally, the subjects should report to the researcher the duration of pain relief from the chest area without using painkillers (interview).

3. Results

The results obtained from this research conducted on Navy beginner divers with an average age of 21.8-21.2+ are as follows.
- A significant relationship was observed between aerobic power and diving depth until the onset of chest pain in beginner IRCG Navy divers.
- A significant inverse relationship was observed between aerobic capacity and the intensity of chest pain in beginner IRCG Navy divers at the depth of onset of pain.
- A significant relationship was observed between aerobic capacity and duration of chest pain in beginner IRCG Navy divers after deep diving.
The average depth of onset of pain in 15 subjects of this research was 4026.6 cm and their standard deviation was 407.0 cm. The lowest depth of pain onset is 3400 cm and the highest is 4900 cm.
The average duration of pain in 15 subjects of this study was 42.6 minutes and their standard deviation was 32.7 minutes. The minimum duration of pain is 5 minutes and the maximum is 100 minutes.
The average aerobic power of 15 subjects of this research was 58.57 mg/kg/min and their standard deviation was 4.99 mg/kg/min. The lowest aerobic capacity is 49.02 mg/kg/min and the highest is 67.05 mg/kg/min.
Considering that the use of parametric statistics requires the normality of the data distribution, so the Kolmogorov-Smirnov test was used to test this assumption.

Table 1. Data normality table

		power aerobic	Period Time Elimination the pain	intensity deep pain Beginning the pain	depth Beginning the pain
	Number	15	15	15	15
Average	Normality **of** (1,2) **parameters**	58.5733	41.667	2.267	4026.667
The standard deviation		4.99735	32.7014	.7037	407.8982
absolute	Maximum differences	.177	.205	.251	.162
Positive		.086	.205	.248	.162
negative		-.177	-.131	-.251	-.086
	Kolmograph-) SmirnovZ (	.684	.797	.973	.627

significance level(P)	.737	.557	300	.826

4. Discussion and Conclusion:

According to diving physiology, the weight of the water above the diver's head exerts pressure on the compressible tissues of the body and organs, which are called air cavities, include the lungs, ears, and sinuses.

As a result of changing the depth of diving, the pressure around the diver changes a lot. When divers go under water, the pressure around them increases tremendously. To prevent the lungs from collapsing, air must also be delivered under high pressure into the lungs, and this exposes the blood in the lungs to extremely high pressures of bubble gases, which is called hyperbolism. If this pressure exceeds a certain limit, it may cause extreme changes in the body's physiology (Masoumi, 2010).

In diving, breathing begins with the full capacity of the lungs before submerging in the water. At great depth, the mechanical limits of chest wall compression and diaphragm stretching are obtained. However, the pressure balance is achieved through the redistribution of the large volume of extra thoracic blood to the normal intrathoracic blood volume (Hawazadeh, 2010).

The result of testing the first hypothesis shows that there is a significant relationship between aerobic capacity and the depth of onset of pain in the chest area of beginner divers, which is in line with the research conducted by Masoumi (2010), Hawazadeh (2010), Gaini (2011), Sonström (1984).), Tirosello, Lawrence, Kubitz and Salazar (1991), Dishman (1998), quoted by Jamshidian (2011), Liner and Anderson (2008), Tet Zalaf et al. (1998), Yan Bai (2011), Mohajer Shirvani and colleagues (2012), is consistent.

Among the effects of high aerobic capacity on the body can be improved respiratory system performance, reduction of stress-anxiety-depression, more energy, less fatigue, higher work capacity and more respiratory efficiency and less pulmonary ventilation, increasing muscle strength and flexibility in respiratory muscles and improvement of immune system function (Gaini, 2011).

Lung compression due to depth pressure, which will reduce the remaining lung volume from the normal level (less than 25% of the total lung volume), becomes more visible at a depth greater than normal, i.e. more than 33 meters (100 feet). It seems that the reason for the onset of pain in the divers of the present study is the pressure changes at depth on their respiratory system, which caused the lungs to fall together and reduce the remaining volume of their lungs. Therefore, it seems that according to Gaini's research (2013), the better the divers who have better respiratory system performance, they have more efficient respiratory system.

Of course, these divers were placed in the conditions of a pressure chamber and a depth of more than 33 meters, for the first time, and this issue can cause anxiety and stress in them. The subjects who had higher aerobic capacity had less anxiety and stress, and higher lung ventilation, they experienced the onset of pain at a greater depth.

The result of the second hypothesis test shows that there is an inverse and negative relationship between aerobic capacity and chest pain intensity during a 10-minute stop at the depth of pain onset. In this regard, it can be stated that according to the researches of Gaini (2013) and Hawazadeh (2014), the signs of high aerobic capacity are increased muscle strength, endurance and flexibility, due to the increase in the volume of mitochondria, which causes more oxygen to be received by the muscle, and increases blood circulation in the capillaries of skeletal muscles.

High aerobic capacity will also increase the strength and endurance of ligaments and tendons, reduce fatigue and improve the respiratory system. It seems that divers who have higher aerobic capacity have better respiratory system performance due to higher strength, endurance and flexibility of respiratory muscles, which in turn causes a higher volume of residual air to remain in the lungs after exhalation to prevent the lungs from collapsing.

In general, this research shows that a diver who does aerobic exercises can dive at a greater depth by increasing the performance of his respiratory system in terms of higher efficiency capacity and greater respiratory efficiency. Also, by increasing the strength, endurance and flexibility of the respiratory muscles due to aerobic exercises, which will increase the volume of the mitochondria of the muscles and deliver more oxygen to the breathing muscles of the diver, he can have a higher volume of air remaining in the lungs after exhalation. Accordingly, the intensity of pain will decrease due to deep pressure.

Finally, high aerobic capacity is an asset for beginner divers that reduces the duration of pain after it occurs due to going deeper. Also, by increasing their aerobic capacity, beginner divers can overcome the pain caused by stress and anxiety resulting from various unpredictable environments and situations in diving, and by reducing stress and anxiety, they can reduce the duration of pain to a minimum.

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ظرفیت هوازی و درد قفسه سینه در غواصان مبتدی

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چکیده: قدرت هوازی نشان دهنده حداکثر میزان اکسیژن دریافتی است که فرد در حین فعالیت‌های بدنی شدید در زیر دریا از آن استفاده می‌کند. بر این اساس، اهمیت قدرت هوازی در غواصانی که زمان زیادی را در زیر آب می‌گذرانند باید مورد توجه قرار گیرد. به منظور بررسی موضوع، این مطالعه به بررسی همبستگی قدرت هوازی با افزایش عمق غواصی غواصان و ارتباط آن با درد قفسه سینه آنها می‌پردازد. جامعه آماری شامل ۷۰ نفر از دانشجویان کلاس غواصی یکی از آموزشگاه‌های غواصی بندرانزلی می‌باشد. این گروه متشکل از ۲۰ آزمودنی مرد است که به طور تصادفی بر اساس جدول مورگان انتخاب شدند، در رده سنی ۱۸ تا ۲۵ سال، بدون سابقه مسائل بهداشتی، استعمال دخانیات و فعالیت‌های ورزشی حرفه‌ای بودند. نتایج نشان داد که بین قدرت هوازی و عمق شیرجه تا شروع درد قفسه سینه رابطه معناداری وجود دارد. همچنین رابطه معکوس معنادار بین ظرفیت هوازی و شدت درد قفسه سینه وجود دارد. و در نهایت بین ظرفیت هوازی و طول مدت درد قفسه سینه رابطه معنی داری مشاهده شد. این نتایج نشان از تاثیر ظرفیت هوازی در پیشگیری از درد قفسه سینه در غواصان می‌باشد.

واژه‌های کلیدی: آمادگی قلبی تنفسی، قدرت هوازی، غواصی عمیق، درد قفسه سینه.

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