The Effects of a Training Program on Some Physiological Variables Before and After Diving in Scuba Divers

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Abstract:

The current research aimed to identify the effect of diving training programs on some physiological variables of divers, using an experimental approach on a sample selected purposively from divers in Sharm El-Sheikh city, registered with the Egyptian Diving Federation for the training season (2023-2024), comprising 15 divers. The researcher applied the proposed program to the research sample for a period of 8 weeks. The most important findings of the study are as follows: There were statistically significant differences between pre-dive and post-dive measurements at a significance level of 0.05 for the experimental group (before diving) in all physiological variables. There were percentages of change between pre-dive and post-dive measurements for the experimental group before diving in all physiological tests, ranging from a high value to a low value. There were no significant differences between pre-dive and post-dive measurements for the experimental group after diving in some physiological variables, attributed to the training program. There were weak percentages of change in all physiological tests under study. Based on these results, it can be concluded that the training program significantly affected the physiological variables of the divers, which could contribute to improving their performance and health during and after diving.

Keywords: Diving exercises – Physiological Variables – Scuba Divers

Introduction:

Scuba diving is considered one of the most enjoyable and beautiful water sports that many people practice. In fact, in some coastal countries, it has become a popular sport. It is the window that allows divers to see the world beneath the seas (Eichhorn & Leyk, 2015).

Some may not consider scuba diving to be a strenuous sport, as the body is weightless underwater and the physical exertion required is typically of moderate intensity, allowing the average individual to engage in diving (Buzzacott, et al., 2014).

The marine environment beneath the surface during diving results in unexpected changes (such as currents, waves, and underwater animals), in addition to the increasing respiratory resistance faced by the diver's breathing apparatus at greater depths, causing stress on internal body systems (Carturan, et al., 2002; Anegg, et al., 2002).

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Diving can be hazardous even at depths that seem harmless. The high pressure outside the body can seriously affect the diver's health. Medical assessment of fitness for diving is a fundamental requirement for diving at any dive center. To efficiently evaluate and advise potential divers, specialists must be able to assess the individual's physical and physiological condition to determine their ability to dive and the associated health risks, thus identifying whether the individual is fit to dive (McLellan, et al., 2010; Bove, 2011).

Some recreational divers may have underlying health factors that are affected by diving, putting their health at risk due to the increased pressure outside the body and its impact on internal organs (Eichhorn & Leyk, 2015).

The Egyptian Diving and Rescue Federation (CMAS) in 2012 and the Professional Association of Diving Instructors (PADI) in 2006 recommended increasing attention to the sport of diving due to its various fields such as sports, military, scientific, commercial, domestic and international tourism, which constitute an important source of income for the Arab Republic of Egypt. The changes associated with pressure variations underwater due to diving are a result of the hydrostatic pressure forces experienced by the diver's body, which are generated by the weight of the water and are equal in all directions at a certain depth. It increases at a rate of 1 kg/cm² for every 9.75 meters depth in saltwater and 1 kg/cm² for every 10 meters depth in freshwater. Therefore, diving requires specific functional and physical capabilities that qualify practitioners for continuous effective work in the underwater environment, in addition to the automatic nervous system's ability to quickly respond to pressure changes underwater (Carturan, et al., 2002; CMAS, 2012; Eichhorn & Leyk, 2015).

The mutual influence of the aquatic environment during underwater diving poses a significant challenge to the heart, blood vessels, and some physiological changes. Therefore, the surrounding environment plays a major role in the process of motor control. It allows for control of motor direction in terms of shape, range, direction, and timing (Tso, et al., 2022; Carl, et al., 2004).

Diver training is a process of skill development and physical and physiological performance enhancement in the use of diving equipment and techniques, enabling divers to dive safely. Sports and technical training programs have significantly improved diving, including VO2 max variables (Babatabar et al., 2023).

Based on the findings of studies highlighting the importance of physically conditioning divers to prepare them for diving, the researcher concludes that it is a priority to train divers as they endure high physical and physiological pressures. This necessitates their physical preparation to cope with their physiological systems, which respond to exertion by the blood during diving, through a structured training program.

Aim:

The current research aims to investigate the impact of diving training on some physiological variables of divers.

Hypothesis:

There are statistically significant differences between pre-diving and post-diving measurements for the physiological variables of the divers in both research groups.

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Methods:

Approach:

The researcher used the experimental approach (two-group design) with pre- and post-measurements.

Participants:

The researcher selected the research sample purposively from divers registered with the Egyptian Diving Federation for the sports season 2023/2024, totaling 15 players. Five players were randomly selected for the pilot study, resulting in an actual research sample of 10 players divided into two experimental groups, each comprising 5 players.

The researcher ensured the normality and homogeneity of the curve among the research sample by analyzing the results obtained from the data collection tools used in the study on that sample. All results indicate conformity to the normal curve, as shown in Table (1).

Table (1): Descriptive Data of Participants (n=15).

Variables	Measurement	Mean	SD (±)	Median	Kurtosis	Skewness
Height	Cm	163.111	1.778	136.50	-0.775	-0.656
Weight	Kg	63.277	1.637	63.50	-1.234	-0.407
Age	Year	15.416	0.691	15.75	-0.207	-1.446

From Table (1), it is evident that the skewness coefficients for the research sample in terms of height, weight, and age ranged from -1.234 as the lowest value to -0.207 as the highest value. Additionally, the kurtosis coefficients for the research sample in terms of height, weight, and age ranged from -1.446 as the lowest value to -0.656 as the highest value. All of these values fall within the range of ±3, indicating that the research sample is homogeneous and conforms to the normal curve.

Data Collection Tools:

The researcher used the following tools:

- A stadiometer for measuring height in centimeters.
- A calibrated medical scale for measuring weight in kilograms.
- A sphygmomanometer for measuring blood pressure.
- A metronome for adjusting step timing.
- A centrifuge for separating blood components (3 speeds) with a maximum speed of 3000 revolutions per minute.

Tests and Measurements:

1. Measurements for sample characterization (height – weight - age)

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2. Functional measurements and tests (pulse rate by a physician - blood pressure by a physician. - maximum oxygen consumption (VO2max) using the Ruffier test).

The Recommended Training Program:

- The researcher prepared expert opinion survey forms regarding the components of the proposed training program.
- The researcher transcribed the expert opinions regarding the components of the training program.

Designing the Training Program:

- The training program was implemented during the preparation period.
- Provision of necessary tools for program execution.
- Gradual increase in exercise intensity along with appropriate rest intervals.
- Reduction in the volume of general exercises while increasing focus on specific exercises.
- Intensification of exercises by increasing speed, strength, and power, with emphasis on speed-strength.
- Emphasis on warm-up process to prepare the body for high-intensity physical loads.
- Focus on recovery process through stretching exercises and breathing exercises.
- Regulation of training load intensity using heart rate equation.
- Duration of the training program = 8 weeks.
- Number of training units per week = 4 units.
- Total number of training units throughout the program = 4 × 8 = 32 units.
- A ratio of (2:1) will be used to determine the load cycle.
- Duration of each training unit = 120 minutes.
- Average duration of training units per week = 120 × 4 = 480 minutes.
- Average number of weeks = 2 weeks.
- Number of weeks less than the maximum = 3 weeks.
- Maximum number of weeks = 3 weeks.

Regulating the training load intensity using heart rate.

The researcher used the Target Heart Rate equation to determine and guide the intensity of the training load based on the average resting heart rate of the primary research sample, which was determined by:

- Maximum Heart Rate (HR Max) = 220 - Age
- Heart Rate Reserve (HRR) = Maximum Heart Rate - Resting Heart Rate
- Maximum Heart Rate = 220 - 16 = 204 beats/minute.
- Resting Heart Rate = 70 beats/minute.
- Heart Rate Reserve = 204 - 70 = 134 beats/minute.
- Target Heart Rate = (Target Percentage × Heart Rate Reserve) + Resting Heart Rate

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- Training Load Levels:
- Maximum Load (90-100%).
- Less than Maximum Load (75-89%).
- Moderate Load (65-74%).
- Positive Rest (35-55%).
- Target Heart Rate at 90-100% = (134 × 100) / 100 + 70 = 190 beats/minute.
- Target Heart Rate at 89-75% = (134 × 75) / 100 + 70 = 170 beats/minute.
- Target Heart Rate at 74-65% = (134 × 65) / 100 + 70 = 157 beats/minute.
- Target Heart Rate at 55-35% = (134 × 35) / 100 + 70 = 116 beats/minute.

(Anderson, 2004)

Main Study:

Pre-measurements:

The pre-measurements of functional variables under investigation were taken on 25-26/11/2023. The functional measurements were conducted under the supervision of the researcher and the responsible physician according to the following protocol.

- Measurement of systolic and diastolic blood pressure at rest by the specialized physician.
- Measurement of resting heart rate by direct palpation of the radial artery using the fingers at the wrist. The radial artery is located on the palmar aspect of the wrist directly at the base of the thumb. The heart rate was measured for 15 seconds, then multiplied by 4 to obtain the heart rate per minute.
- Measurement of maximum oxygen consumption (absolute and relative).
- Measurement of post-exercise heart rate immediately after exertion.

Main Application:

The recommended training program was applied from 28-11-2023 to 27-1-2024 for (8) weeks.

Post-measurements:

The post-measurements of functional variables under investigation were taken on 28-29/11/ 2024 following the same protocol of pre-measurements.

Statistical Treatment:

The researcher used SPSS Software to calculate the following: Mean – SD (±) – Median – Skewness – Kurtosis – Correlation Coefficient – (t) test – Improvement Rate.

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Results:

Table (2): Difference Significance Between Pre- and Post-measurements of Physiological Variables in The First (pre-diving) Experimental Group (n=5).

Variables	Measurement	Pre-		Post-		Means Difference	(t)	Change rate%
		Mean	SD(±)	Mean	SD(±)			
HR (rest)	bpm	72.50	1.267	68.50	0.849	4.00	9.49*	5.517
HR (exertion)	bpm	186.60	1.429	180.70	0.984	5.90	13.76*	3.16
Blood Pressure (Systolic)	Mm/HG	123.70	1.159	118.70	0.984	5.00	8.96*	4.042
Blood Pressure (Diastolic)	Mm/HG	85.40	1.07	80.70	0.674	4.70	18.05*	5.503
VO2 max (Absolute)	L/Min	3.41	0.110	4.03	0.133	0.62	15.95*	18.181
VO2 max (Relative)	ML/Kg/Min	31.607	1.201	36.017	1.841	4.41	6.54*	13.95

(t) tabulated value on P ≤0.05 = 2.26

Table (2) shows statistically significant differences between the pre-measurement and post-measurement of the first experimental group before diving in all the physiological variables under investigation. The calculated (t) values ranged from 6.54 as the lowest value to 18.05 as the highest value, all of which were greater than the tabulated t-values at the 0.05 significance level.

Table (3): Difference Significance Between Pre- and Post-measurements of Physiological Variables in The Second (post-diving) Experimental Group (n=5).

Variables	Measurement	Pre-		Post-		Means Difference	(t)	Change rate%
		Mean	SD(±)	Mean	SD(±)			
HR (rest)	bpm	72.00	1.00	71.333	0.577	0.666	2.00	0.925
HR (exertion)	bpm	184.333	0.577	183.333	1.154	3.00	4.00	0.55
Blood Pressure (Systolic)	Mm/HG	122.23	1.15	121.67	0.58	0.67	2.00	0.54
Blood Pressure (Diastolic)	Mm/HG	84.67	1.15	83.33	1.53	1.33	4.00	1.54
VO2 max (Absolute)	L/Min	3.37	0.06	3.60	0.17	0.23	2.65	6.93
VO2 max (Relative)	ML/Kg/Min	29.09	1.04	29.96	1.55	0.87	1.68	2.99

(t) tabulated value on P ≤0.05 = 2.26

Table (3) indicates the absence of differences between the pre-measurement and post-measurement of the second experimental group in some physiological variables. This is attributed to the injury of some players during the implementation period of the training program, as they did not complete the designated time for the training program. The calculated "t" values ranged from 1.68 as the lowest value to 4.00 as the highest value at the 0.05 significance level.

Discussion:

Table (2) demonstrates statistically significant differences between the pre-measurement and post-measurement of the experimental group (pre-diving) in all the physiological variables under investigation, favoring the post-measurement. The calculated (t) values ranged from 6.54 as the lowest value to 18.05 as the highest value, all of which were greater than the tabulated "t" values at the 0.05 significance level. There were also percentages of change between the pre-measurement and post-measurement of the first experimental group before diving in all physiological tests under study. The percentages of change ranged from 3.16% as the lowest value

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in the post-exercise heart rate test to 18.181% as the highest value in the maximum oxygen consumption test.

The researcher attributes this positive effect to the proposed training program. Regarding the heart rate, the researcher attributes the decrease in heart rate to the positive impact of the proposed training program, which led to an improvement in cardiac muscle efficiency, an increase in the amount of blood pumped per heartbeat, and an increase in cardiac output. This is consistent with the study by Babatabar et al. (2023).

The physiology of the lungs undergoes significant changes during underwater diving, where immersion and increased pressure surrounding the body lead to profound effects on both the cardiovascular and respiratory systems. Blood pooling, increased respiratory gas pressures, and variations in gas volumes, along with changes in surrounding pressure, put the heart and lungs under pressure. Normal physiological function and physical fitness of the cardiovascular and respiratory systems are essential requirements for safely dealing with the challenges of the underwater environment during free diving or scuba diving (Tetzlaff, 2023; Shalaby et al., 2021).

Heart rate increases during physical activity, and this increase is associated with the intensity of the effort exerted. It tends to be lower in trained athletes compared to untrained individuals. As for systolic and diastolic blood pressure, and maximum oxygen consumption (absolute/relative), statistically significant differences were found between pre-exercise and post-exercise measurements, favoring the post-exercise measurements. The researcher believes that this positive effect can be attributed to the proposed training program, which is regulated scientifically. This is consistent with previous studies (Carturan et al. 2002, Anegg et al. 2002, McLellan et al. 2010, and Bove 2011).

If we track the evolution of lung volumes throughout the training cycle of the program, we will find statistically significant differences between the measurements, indicating adaptation of the respiratory system and achieving the purpose of the training program. As for the maximum oxygen consumption (VO2max), there are statistically significant differences among all seven measurements, indicating a noticeable improvement in this variable throughout the program, especially in the initial stage where progress tends to be faster (Richard J., Winsely, 2008).

It is evident from Table (3) that there are differences between the pre-dive and post-dive measurements for the second experimental group in some physiological variables, although these differences are not statistically significant. This is attributed to the training program, where the calculated "t" values ranged from 1.68 as the lowest value to 4.00 as the highest value, at a significance level of 0.05. The percentage of change between the pre-dive and post-dive measurements for the second experimental group in all physiological tests ranged from 0.54% as the lowest value in systolic blood pressure test to 6.93% as the highest value in the maximum absolute oxygen consumption test.

The researcher attributes this to the regularity of the divers in the proposed training sessions throughout the program implementation period, which was sufficient to induce an effect on the physiological variables. The improvement in training status leads to a decrease in heart rate during

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performance, indicating improved efficiency. This aligns with the findings of previous studies (Babatabar et al. 2023; Own 2004).

The program and its included exercises lead to improvements in circulation and increase the heart's ability to pump more blood with each beat during exercise and rest. This reduces the heart rate and gives the heart longer rest intervals between contractions and relaxations to increase its efficiency as a pump. In terms of dynamic evolution, we find that the changes were continuous throughout the program's measurement stages. However, this is attributed to the adaptation being faster at the beginning of the training, with subsequent adaptation occurring more slowly. (Richard. J., Winsely 2008)

The phenomenon of decreased blood pressure rate is a physiological phenomenon in athletes when it serves as evidence of increased training status. It confirms that adaptation to physical exertion occurs as a result of increased cardiac output. (Draper. N., Hodgson, C. 2008)

The risks of diving are evident through the combination of underwater environmental conditions and the physiological requirements of diving underwater. These include dynamic cardiovascular pressures encountered at depth, which involve increased hydrostatic pressure leading to central shifts in plasma volume, alongside cold-water stimuli resulting in involuntary responses. (Eichhorn & Leyk, 2015 Tso, et al. 2022)

As a result of the lack of improvement in the training status of the affected sample due to incomplete program completion, we find that the heart rate did not improve. Thus, the validity of the research hypothesis is confirmed through the previous presentation.

Conclusions:

According to these results, the researcher concludes the following:

- There were statistically significant differences between pre-dive and post-dive measurements at a significance level of 0.05 for the experimental group (pre-dive) in all physiological variables under investigation, favoring the post-dive measurements.
- There were varying percentages of change between pre-dive and post-dive measurements for the first experimental group (pre-dive) in all physiological tests under investigation, ranging from 18.181% as the highest value in the maximal absolute oxygen consumption test to 3.16% as the lowest value in the post-exercise heart rate test.
- There were no significant differences between pre-dive and post-dive measurements at a significance level of 0.05 for the second experimental group (post-dive) in some physiological variables, attributed to the training program.
- There were weak percentage changes in all physiological tests under investigation, ranging from 0.54% as the lowest value in systolic blood pressure test to 6.93% as the highest value in the maximal absolute oxygen consumption test.
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Recommendations:

According to these conclusions, the researcher recommends the following:

- Enhancing training programs with exercises that help maintain physiological variables during diving.
- Conducting similar studies using different variables to assess the complete functional status of divers during diving.
- Conducting further similar studies on different samples.
- Emphasizing the importance of regulating the training program according to the age of divers and utilizing heart rate to control the intensity of the training program, which in turn affects the functional status of divers.
- Considering the level of physiological variables before and after diving due to their importance in a diver's ability to dive.

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