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Evaluating the Effects of Differences in Diving Experience on Some Respiratory Dynamic Functions of Divers

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Abstract:

*The current research aims to study the effects of diving for different years on some dynamic respiratory functions of divers. The researchers used the descriptive (survey) approach***.** *The researchers purposefully chose (30) persons divided into divers (n=20) and non-divers (n=10). Divers were subdivided into (5-6) years of diving experience (n=10) and (9-10) years of diving experience (n=10). Non-divers (n=10) are not involved in diving nor any other athletic activity. Results indicated statistically significant differences among the three groups of non-divers, divers (5-6 years) and divers (9-10 years) on dynamic respiratory measurements immediately after diving in favor of non-divers, indicating a negative effect of professional diving for long years on respiratory functions.*

Key Words: *Respiratory Dynamic Functions - Divers- Diving Experience.*

I. Introduction:

Underwater diving has expanded from a hobby to a sport then to an entire industry. Divers are affected by several pressures on their bodies and these pressures induce different effects on various body systems like the cardiovascular system, the pulmonary system, the neurological system, the muscular system, the brain and the skeleton (Whatane 2018).

A common problem in the respiratory system of divers during exposure to diving pressure is fatigue in breathing muscles (rips and neck muscles) due to double effort exerted by these muscles to widen lungs for good breath in addition to pressure on the chest (Tetzlaff& Thomas 2017).

This increased pressure occurs simultaneously with increases in gas density. These two issues decrease functional efficiency of human respiratory system as it decreases with the increase of depth and under

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water gas density. This increases difficulty of breathing through respiratory paths in addition to increasing the diver's respiratory effort, leading to exerting extra effort (Edmonds et al. 2015). The increase in pressure over these systems leads to similar increase in diving side-effects (Whayne 2018).

During diving, the increase of pressure leads to increases in gas density. So, to get the same breathing volume deep under water, the diver needs to exert more effort by breathing muscles. Breathing capacity on 30 m depth (4 barometric pressure) is half its value on sea level (1 barometric pressure). This increases resistance in breathing pathways on the trachea and bronchial tubes (Shopov 2019).

Working under high pressure negatively affects lung functions of workers due to breathing air dryness and increased density. This increases effort exerted by lung muscles due to resistance in the trachea and bronchial tubes (Poopol et al 2019).

There are many physical and chemical changes that accompany diving and can alternate the mechanics of breathing and lung blood circulation while the lungs are trying to maintain sufficient gas exchange under high pressure. Diving to far depths for prolonged periods of time may lead to negative effects on lung function due to greater exposure to such conditions accompanying diving as these conditions may damage bronchial tubes and dehydrate the lining materials of small alveoli (Shopov2019; Edmonds et al 2015).

Increased oxygen load happens as a result of repeated diving for several consecutive years on different depths for prolonged times due to increased molecular pressure of this gas in breathing air in addition to being dry with high density. All these factors cause non-bacterial inflammations as a result of damaging the surfactant, a gelatinous material that protect the inside walls of small alveoli and gives it flexibility to prevent them from closing during gas exchange. This may lead to dehydration and increased density of this material. Due to repeated diving for longer times, alveoli become unable to repair and rehydrate this material. This leads to full dehydration and vanishing of this material leading to difficulty of getting air into alveoli during gas exchange as some of its air pathways are blocked. As a result, respiratory system functions decrease. This is consistent with Tetxlaff& Thomas (2017), Mirasoglu&Aktas (2019), Konarski et al (2013) and Edmonds et al. (2015) who indicated that the increase of molecular pressure during diving may adversely affect the function of respiratory system as hyperoxygenation resulting from the increased molecular pressure of oxygen causes oxidative stress in lung tissues in addition to bronchial inflammation as a result of repeated exposure to such conditions. The same is true for nitrogen. While surfacing, pressure decreases leading nitrogen to get out of blood vessels tissues as these tissues usually carry silent nitrogen bubbles to get into the lungs to be released outside the diver's body. This may have adverse effects on lung function (Mirasoglu&Aktas 2019).

The increased periods of diving may increase the negative side-effects of dynamic measurements of breathing. This is clear with professional and commercial divers due to the effects of increased depths and longer periods of work on lung functions as these diving activities are completely different from other types of athletic or recreational diving. Accordingly, this research is trying to identify the respiratory response resulting from exposure to under water pressure and if there are any differences in these responses to to the number of years in this career so that we can identify any changes in the diver's respiratory system as a result of physical loads during exposure to different pressures while diving.

Aim:

The current research aims to study the effects of diving for different years on some dynamic respiratory functions of divers.

Hypothesis:

There are statistically significant differences in the dynamic respiratory functions after diving among Divers (9-10 years – 5-6 years) and non-divers (sedentary persons).

Approach:

The researchers used the descriptive (survey) approach.

Participants:

Research community included (30) persons including divers (certified by the international diving federation) and non-divers (sedentary persons). The researchers purposefully chose (30) persons divided into divers (n=20) and non-divers (n=10). Divers were subdivided into (5-6) years of diving experience (n=10) and (9-10) years of diving experience (n=10). Non-divers (n=10) are not involved in diving nor any other athletic activity.

Data Collection Tools:

According to review of related literature (Poolpol el. al.2019; Shopov,2019;Mirasoglu et al 2018; Tetzlaff& Thomas 2017; Cheng 2017; Voortman et al. 2016; Pougnet et al. 2014; Chong et al. 2008), the following respiratory variables were chosen to be investigated:

- Forced Vital Capacity (FVC)
- Forced Exhale Volume after 1 sec (FEV1)
- Percentage of Forced Exhale Volume after 1 sec (FEV1%)
- Peak Exhale Flow (PEF)

Main Study:

Before the study, the researchers verified the following:

- Explaining this study objective to participants.
- All participant signed written consent for their participation.
- All assistants are familiar with methods of measurement and recording data.
- All conditions are suitable for obtaining best results.
- All tools and equipment are valid.

Main measurements were taken at the airlock of department of diving – The Arab Academy for Sciences, Technology and Maritime Transport – Alexandria. All participants performed dry diving (25 m) for 22 minutes using US Navy Dive Schedules to identify max time for this depth.

Statistical Treatment:

The researchers used SPSS Software to calculate the following: Mean – F value – LSD – variance percentage (%).

II. Results:

Table (1): Variance Analysis among the three groups (non-divers – 5-6 years divers – 9-10 years divers) on dynamic respiratory functions

S	Variables	Source of variance	Freedom degree	Sum of squares	Mean of squares	F
1	FVC	Intra-groups	2	2.114	1.057	27.103
		Inter-group	27	1.053	0.039	
		Sum	29	3.167		
2	FEV1	Intra-groups	2	2.556	1.278	31.171
		Inter-group	27	1.107	0.041	
		Sum	29	3.663		
3	FEV1%	Intra-groups	2	737.066	368.533	24.040
		Inter-group	27	413.910	15.33	
		Sum	29	1150.976		
4	PEF	Intra-groups	2	23.302	11.651	35.521
		Inter-group	27	8.856	0.328	
		Sum	29	32.158		

(F) Table value on freedom degrees of 2, 27 and P ≤0.05 = 3.35.

Table (1) showed difference significance among the three groups (non-divers – 5-6 years divers – 9-10 years divers) on dynamic respiratory functions. Results clearly indicated statistically significant differences among the three groups.

Table (2): Least Significant Difference (LSD) among the three groups (non-divers – 5-6 years divers – 9-10 years divers) on dynamic respiratory functions.

S	Variables	Groups	Means	Means differences			LSD
				Non-divers	Divers 5-6 years	Divers 9-10 years	
1	FVC	Non-divers	4.690		0.360*	0.550*	0.181
		Divers 5-6 years	4.330			0.190*	
		Divers 9-10 years	4.140				
2	FEV1	Non-divers	4.350		0.380*	0.660*	0.169
		Divers 5-6 years	3.970			0.280*	
		Divers 9-10 years	3.690				
3	FEV1%	Non-divers	92.330		8.860*	11.660*	3.601
		Divers 5-6 years	83.470			2.800*	
		Divers 9-10 years	80.670				
4	PEF	Non-divers	10.120		0.590*	1.270*	0.529
		Divers 5-6 years	9.530			0.680*	
		Divers 9-10 years	8.850				

Table (2) showed least significant differences (LSD) among the three groups (non-divers – 5-6 years divers – 9-10 years divers) on dynamic respiratory functions.

Table (3): Variance Rate among the three groups (non-divers – 5-6 years divers – 9-10 years divers) on dynamic respiratory functions.

S	Variables	Groups	Means	Variance Rate		
				Non-divers	Divers 5-6 years	Divers 9-10 years
1	FVC	Non-divers	4.690		7.676	11.727
		Divers 5-6 years	4.330			4.388
		Divers 9-10 years	4.140			
2	FEV1	Non-divers	4.350		8.736	15.172
		Divers 5-6 years	3.970			7.053
		Divers 9-10 years	3.690			
3	FEV1%	Non-divers	92.330		9.596	12.629
		Divers 5-6 years	83.470			3.354
		Divers 9-10 years	80.670			
4	PEF	Non-divers	10.120		5.830	12.549
		Divers 5-6 years	9.530			7.135
		Divers 9-10 years	8.850			

Table (3) showed variance rate among the three groups (non-divers – 5-6 years divers – 9-10 years divers) on dynamic respiratory functions.

III. Discussion:

Table (1) indicated statistically significant differences among the three groups (non-divers – 5-6 years divers – 9-10 years divers) on dynamic respiratory functions after diving. This led the researchers to perform LSD analysis as seen in tables (2) and (3) as results indicated that least significant differences on forced vital capacity (FVC) between non-divers and divers (5-6 years) was (7.676%) in favor of non-divers and between divers (5-6 years) and divers (9-10 years) was (4.388%) in favor of divers (5-6 years) while least significant differences between non-divers and divers (9-10 years) was (11.727%) on favor of non-divers. This indicates that diving for longer years adversely affects the respiratory system in FVC.

Considering forced exhale volume after one second (FEV1), it was clear that least significant difference between non-divers and divers (5-6 years) was (8.736%) in favor of non-divers and between divers (5-6 years) and divers (9-10 years) was (7.053%) in favor of divers (5-6 years) while least significant differences between non-divers and divers (9-10 years) was (15.172%) on favor of non-divers. This indicates that diving for longer years adversely affects the respiratory system in FEV1.

Considering percentage of forced exhale volume after one second (FEV1%), it was clear that least significant difference between non-divers and divers (5-6 years) was (9.596%) in favor of non-divers and between divers (5-6 years) and divers (9-10 years) was (3.354%) in favor of divers (5-6 years) while least significant differences between non-divers and divers (9-10 years) was (12.629%) on favor of non-divers. This indicates that diving for longer years adversely affects the respiratory system in FEV1%.

Considering peak exhale flow (PEF), it was clear that least significant difference between non-divers and divers (5-6 years) was (5.830%) in favor of non-divers and between divers (5-6 years) and divers (9-10 years) was (7.135%) in favor of divers (5-6 years) while least significant differences between non-divers and divers (9-10 years) was (12.549%) on favor of non-divers. This indicates that diving for longer years adversely affects the respiratory system in PEF.

The researchers think that these differences among the three groups after dry diving in airlock under (4 bar) on 25 m depth for 22 minutes are due to the pressure on lungs to increase breathing rate due to the effort exerted under (4 bar). Under these conditions, breathing faces several factors like the increase in gas density as the increase in depth simultaneously increases the density of breathing air molecules. This means that participants exerted extra effort during inhale and exhale due to the increase of air pathways resistance in the trachea, bronchial tubes and alveoli. This indicates that training experience is vital in organizing breathing during diving to limit adverse effects on the respiratory system. This explains who professional divers keep diving for several years in spite of its adverse effects on the respiratory system. This is consistent with Mirasoglu et al. (2018) who indicated that breathing muscles contractions resulting from diving pressure may lead to temporary decrease in lung functions immediately after diving, but they return to normal the next day. But this is not contradicted with the fact that diving for long periods may lead to chronic decreases in lung dynamic respiratory functions due to repeated exposure to several physiological effects related to diving. Therefore, it is important to expose divers to annual medical evaluation to evaluate their dynamics function of lungs.

Breathing pressurized air under high pressure leads to breathing effort due to resistance of air pathways in the respiratory system as a result of increased density and dehydration of breathing air. This decrease breathing capacity during physical effort, compared with breathing under (1 bar) on sea level. Repeated exposure to these conditions may lead to blocking some of the micro air pathways in the respiratory system (Pougnet et al. 2019).

Tetzlaff& Thomas (2017) indicated that functions of the diver's lung may be adversely affected by several factors including gas density, gas molecular pressure and pressure of diver's lungs either for short or long periods. In addition, lung functions may be damaged even after one dive.

Bennett & Elliott (2004) indicated that when analyzing lung volume, inhale/exhale effort during breathing and during max ventilation under (1, 3 and 6) bar in the airlock, it was clear that breathing mechanical work rate during max ventilation decreases with the increase of air pathways resistance under high pressure as a major portion of breathing pulmonary pressure and exhale load are exhausted in useless work as a result of increasing dynamic pressure of air pathways in the chest. In addition, max effort obtained by breathing decreases by the end of exercise. This may be due to energy depletion in respiratory muscles as a result pf exerting high effort different from (1 bar) condition as density and molecular pressure of breathing gas increases. This is consistent with Tetzlaff& Thomas (2017) and Mirasoglu et al (2018) who indicated temporary decrease in divers' lung function immediately after the dive.

Results of dynamic functions of breathing after the dive came in favor of non-divers. The researchers think that this is due to the fact that divers' lungs suffer severe pressures under water leading to increases in gas molecular pressure, humidity, dehydration and density of breathing air used in diving. These adverse effects on the respiratory system lead to blocking some air pathways. This is consistent with Poopol et al. (2019), Tetzlaff& Thomson (2017), Shopov (2019) and Mirasoglu et al. (2018). Results of divers (5-6 years) were also better than divers (9-10 years) and this indicates that the increase of diving period deepens the adverse side-effects of diving of dynamic breathing measurements.

Pougnet al. (2014), Tetzlaff& Thomson (2017) and Pougnet et al. (2019) indicated that decrease rate and adverse effects of functional efficiency of divers' lungs decrease with the increase of practicing years. They indicated that fast decrease appears during the first year of diving (1-3 years) as the respiratory system could not adapt with severe pressures of diving and the accompanying factors, but with the increase of deep diving experience the respiratory system adapts with working under such conditions as the diver becomes more economic in exerting breathing effort. This decreases the speed of adverse effects on respiratory functions of divers due to under water physical work on the contrary fast decrease at the beginning of practicing diving.

These results are consistent with Poopol et al. (2019), Tetzlaff& Thomas (2017), Shopov (2019), Mirsoglu et al. (2018) and Cheng (2017) who indicated that diving for long periods has negative effects on the efficiency of breathing dynamic functions.

Diving induces hemodynamic changes in the lungs leading to simultaneous increases of the respiratory system functions as a result of direct effects of diving. There are also accumulative long-term effects appearing in professional divers showing a decrease in FVC as the air micro-pathway becomes narrower (Cheng 2017).

These results are consistent with results of previous studies asserting the accumulative long-term effects of professional diving on decreasing pulmonary ventilation. The researchers concluded statistically significant differences among the three groups of non-divers, divers (5-6 years) and divers (9-10 years) on dynamic respiratory measurements immediately after diving in favor of non-divers, indicating a negative effect of professional diving for long years on respiratory functions.

IV. Conclusions:

According to this research aim, hypothesis, methods and results, the researchers concluded that:

1. Variance percentages of Forced Vital Capacity (FVC) among the three groups ranged from (4.388%) to (11.727%) in favor of non-divers followed by divers (5-6 years).
2. Variance percentages of Forced Exhale Volume (FEV1) among the three groups ranged from (7.053%) to (15.172%) in favor of non-divers followed by divers (5-6 years).
3. Variance percentages of Forced Exhale Volume percentage (FEV1%) among the three groups ranged from (3.354%) to (12.629%) in favor of non-divers followed by divers (5-6 years).
4. Variance percentages of Peak Exhale Flow (PEF) among the three groups ranged from (5.830%) to (12.549%) in favor of non-divers followed by divers (5-6 years).
5. Practicing diving for 9-10 years leads to decreasing the efficiency of lung dynamic functions.
6. The increase of practicing years helps decreasing the decrease rate of lung dynamic functions after exposure to diving pressures due to chronic adaptations of the respiratory system.

V. Recommendations:

According to these conclusions, the researchers recommend the following:

1. All professional divers should undergo annual medical evaluation through periodic application of respiratory tests under investigation.
2. Well-controlled training programs should be designed for improving the functional efficiency of divers' lungs.
3. Methods for protecting divers from the adverse effects of professional diving on the respiratory system should be studied.

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