THE EFFECTS OF DIVING ON PULMONARY FUNCTION

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ABSTRACT

Background: Diving as an occupation has its specific health problems. Respiratory system is one of the systems that can be affected by environmental changes associated with diving as increased hydrostatic pressure, increased breathing gas density, and increased partial pressure of gases e.g. oxygen and carbon dioxide.

Aim: To determine the effects of diving on pulmonary function and the extent of this problem among Iraqi divers.

Subjects & Methods: One hundred and twenty divers with 240 non-divers military personnel were interviewed according to special questionnaire and spirometry was performed for each of them.

Results: The values of all studied pulmonary function tests were found to be lower in divers as compared with non-divers (FEV_1, FVC, FEV_1%, F_{50}, F_{25}, MVV, and MEF) with highly significant differences, except FET which was significantly higher in divers than in non-divers. These changes gave the features of obstructive airway disease.

Conclusions: Divers are at risk of some pulmonary function changes. The pattern of these changes is consistent with small airways obstruction and they could be related mostly to their diving activities. Other factors cannot be excluded. Further studies on such occupational group are recommended.

INTRODUCTION

Respiratory system is affected by changes in environmental conditions experienced in diving. The effects of increased pressure in diving are either induced by increase in hydrostatic pressure[1], or as a result of increased partial pressure of gases in the blood and tissues such as oxygen, nitrogen, and carbon dioxide[2]. As diving depth increases, the density of breathing gases increases as an almost linear function of the absolute pressure. Increased gas density and the diving breathing apparatus may adversely affect ventilation in a mechanical way limiting the diver's ability to ventilate his lungs and increase the work required for breathing[3], reducing gas exchange through reducing gas-in-gas diffusion[4], and induced insufficient pulmonary ventilation[5]. During vertical immersion, there is a reduction of vital capacity, total lung capacity, and functional residual capacity but no effect on tidal volume[3]. These changes are mostly caused by hydrostatic effect[6]. Hyperoxic condition in diving reduced Forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC) with forced mid expiratory flow rate (MEF), which subsequently leads to airway obstruction development in future[7]. Four years follow up of divers shows a significant reduction in FEV_1 which occurs following the first year of diving. Forced mid expiratory flow rate was also reduced after one year of diving, which indicates the development of air flow limitation in relation to diving exposure[8]. No study had been carried out before on Iraqi divers to show the effect of diving on pulmonary function. Therefore, this cross-sectional comparative study which was carried out in 1999 aims to determine the impact of diving on the pulmonary function in Iraqi divers in Basrah.

SUBJECTS AND METHODS

Subjects

The study group consisted of 120 divers who were selected from the Unit of Frogmen and Special task in Iraqi Navy. Two divers were excluded because they were considered unfit for the study when they gave a history of asthma. The comparative group composed of 240 non-divers military personnel from the Iraqi Navy. Both groups were matched for military rank, age, years of service, residence, and smoking habit.

Methods

Interviewing was performed according to a special questionnaire form which covers the following aspects; personal characteristics *(rank, age, years of service, smoking, residence)*, history of factors that can affect the respiratory system *(such as asthma, lung trauma, or jobs other than diving)*, and

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professional history of diving *(such as duration of diving, sea or fresh water diving, maximum depth of diving, type of apparatus and breathing gas, history of underwater accident)*. Height and weight were measured. Physical examination was done, divers with any positive symptom or sign related to respiratory system were referred to a specialist to confirm the diagnosis.
Spirometry was performed in the morning (9-12 am) using the spirometer type micro medical manual revision 1.0 August 1997, micro medical Ltd, England.

RESULTS

Table-1 shows the distribution of personal characteristics of both the study and comparative groups. No significant differences were found between the two groups

Table 1. ***Distribution of personal characteristics***.

Character	Divers (n=120)		Non-divers (n=240)		P-value
	No.	*%*	*No.*	*%*	
Age (years)					
19 – 30	68	56.7	136	56.7	NS
31 – 42	52	43.3	104	43.3	
Years of service					
≤ 3 – 12	71	59.2	141	59.2	NS
13 – 25+	49	40.8	99	40.8	
Residence					
Urban	98	81.7	210	87.5	NS
Rural	22	18.3	30	12.5	
Smoking					
Smokers	62	51.7	107	44.6	NS
Non-smokers	58	48.3	133	55.4	
Weight (Kg)	67.1 ± 11.7		68.7 ± 10.8		NS
Height (cm)	171.3 ± 6.4		170.8 ± 9.6		

Table-2 displays the mean values of the pulmonary function tests of both divers and non-divers. The values of FEV_1, FVC, FEV_1%, PEF, F_{50}, F_{25}, MVV and MEF were significantly lower for divers as compared with the non-divers group (P<0.01). On the other hand, the FET was significantly higher for the divers group compared with the non-divers group (P<0.01).

Table 2. ***Mean values of pulmonary function tests of the study groups.***

Indicator	Divers Mean ± SD	Non-divers Mean ± SD	P-value
FEV_1	**3.68 ±0.54**	4.01±0.33	**<0.01**
FVC	**4.40 ±0.6**	4.67±0.46	**<0.01**
FEV_1%	**83.5 ±7.77**	86.2±4.87	**<0.01**
PEF	**440.3 ±110.4**	503.6±103.6	**<0.01**
F_{25}	**1.8 ±0.69**	2.14 ±0.66	**<0.01**
F_{50}	**4.4 ±1.2**	5.3 ±1.2	**<0.01**
MVV	**138.4 ±20.3**	152 ±30.2	**<0.01**
MEF	**3.83 ±1.2**	4.45 ±0.97	**<0.01**
FET	4.42 ±1.48	**3.9 ±1.43**	**<0.01**

FEV1 (Forced Expiratory Volume in one second), FVC (Forced Vital Capacity), PEF (Peaked Expiratory Flow), F25 (Forced expiratory volume in a quarter of a second), F50 (Forced expiratory volume in a half of a second), MVV (Maximum Voluntary Ventilation), MEF (Mid Expiratory Flow rate, FET (Forced Expiratory Time). Table-3 shows the relation between smoking and the pulmonary function tests in both divers and the non-divers comparison group. FEV_1 was significantly lower in divers than that among the comparison group regardless of smoking habit (P<0.01). However no significant difference in

the value of FEV_1 could be detected in relation to smoking in both divers and non-divers (P>0.05). The same result was true for FVC and PEF except that in comparison group, the PEF was significantly lower in smokers than non-smokers.

Table 3. ***The mean values of selected pulmonary function tests among the study groups in relation to smoking.***

Smoking	FEV_1			FVC			PEF		
	Divers	*Non-divers*	*p-value*	*Divers*	*Non-divers*	*p-value*	*Divers*	*Non-divers*	*p-value*
+	**3.65±0.57**	3.97±0.43	**<0.01**	**4.39±0.61**	4.63±0.49	**<0.01**	**430.04±122.7**	482.5±105.9	**<0.01**
-	**3.75±0.52**	4.04±0.35	**<0.01**	**4.46±0.62**	4.67±0.44	**<0.05**	**450.65±95.3**	520.8±98.3	**<0.01**
P-value	>0.05	>0.05		>0.05	>0.05		>0.05	**<0.01**	

Table-4 shows the distribution of smokers among the study groups according to number of cigarettes smoked per day. The percentage of those who smoke more than 15 cigarettes per day was more among divers than non-divers with a significant difference between the two groups.

Table 4. ***The distribution of smokers among the study groups according to number of cigarettes/ day.***

No. of cigarettes/day	Divers		Non-divers	
	No.	*%*	*No.*	*%*
None	58	48.3	133	55.4
1 - 14	16	13.3	50	20.8
15+	46	**38.4***	57	**23.8**
Total	120	100	240	100

*P-value <0.05

As shown in Table-5, there is no significant difference between the two groups regarding the duration of smoking.

Table 5. ***The distribution of smokers among the study groups according to duration of smoking.***

Duration (years)	Divers		Non-divers	
	No.	*%*	*No.*	*%*
None	58	48.3	133	55.4
≤ 6	24	20.0	35	14.6
6+	38	31.7*	72	30.0
Total	120	100	240	100

*P-value >0.05

Table-6 shows the prevalence of abnormal values of selected pulmonary function tests. The percentage of the divers with lower values of FEV_1% was 8.3% in comparison with 0% in non-divers. Whereas 59.2% of divers had lower value of F_{50} in comparison with 38.3 in non-divers with a highly significant difference. Regarding F_{25}, 61.7% of divers had low value compared to 47.5% of non-divers with a high significant difference.

Table 6. ***Prevalence of abnormal values of selected pulmonary function tests among the studied groups.***

Parameter	Divers (n=120)		Non-divers (n=240)		P-value
	No.	*%*	*No.*	*%*	
FEV_1% < 75	10	**8.3**	0	0	**<0.001***
F_{50} < 4.8	71	**59.2**	92	38.3	**< 0.01**
F_{25} < 2	74	**61.7**	114	47.5	**< 0.01**

*Fisher Exact Test was used for calculation of P-value

DISCUSSION

The matching process was attained in this study, so bias related to age, years of service, place of residence was minimized to a negligible extent. Regarding weight and height, they were nearly similarly distributed in divers and the comparison group. Therefore, the difference in pulmonary functions between divers and the comparison group cannot be attributed to these anthropometric measurements. All the pulmonary function tests, which were measured in the study, showed significantly different values between the divers and the comparison group. Such differences reflect changes in lung volume and flow rates among divers. The values of FEV_1, FVC, FEV_1%, PEF, F_{25}, F_{50}, MEF, and MVV were significantly lower in divers compared to non-divers. The FET value was significantly higher in divers compared to non-divers. Such findings i.e. limitation of pulmonary function in divers could reflect the effect of factors related to diving profession like exposure to changing pressure, changing gas density, underwater trauma or other hazards. These findings generally agreed with the findings of other researchers elsewhere[7,9,10]. Skogstad et al[11] in 2002 reported a significant reduction in the values of FEV_1 and MEF among divers over a 6-year follow up period. On the other hand, Bartheleny et al[12] in 1990 noticed an increase in the FVC and decreases in all other expiratory flow rates (FEV_1, F_{50}, and F_{25}). Davey et al[13] suggested that the increase in vital capacity mainly occurs in the younger divers below 30 years of age; in addition the FEV_1 may not increase in proportion, so the FEV_1% may be reduced by diving. Watt[14] showed consistent FVC reduction with increased duration of service in diving. Since smoking is well known to affect the respiratory system leading to chronic obstructive airway disease[15], the relation of pulmonary function to smoking and diving was studied to exclude or confirm possible variation in pulmonary function between divers and non-divers that could be attributed to difference in smoking habit. The results showed that there was no significant difference in percentage of smokers among divers and non-divers groups (Table-1), therefore, it can be assumed that the variation in pulmonary function between divers and non-divers would unlikely be due to smoking since no significant difference was noticed in some pulmonary functions (FEVI, FVC) in relation to smoking in both divers and non-divers (Table-3). However, divers group tended to include more heavy smokers than non-divers group (Table-4) a condition which could have contributed to the observed differences in pulmonary functions, so a synergistic effect of smoking and diving on pulmonary function cannot be excluded but difficult to quantify. Previous studies had pointed out to such a possibility and suggested that smoking divers versus non smokers and heavy smokers versus light smokers were at greater risk of pulmonary impairment[7,12,16]. Therefore, divers seemed to have higher risk than non-divers with respect to limitation in respiratory function but smoking divers are at even greater additional risk of such limitation. The pattern and prevalence of abnormal values of selected pulmonary function tests (FEV_1%, F_{50}%, and F_{25}%) in divers compared to non-divers, suggest an effect towards obstructive airway disease. The reduction in the values of these indicators is useful as a follow-up or monitoring test. The results are in line with findings of other studies[9,17-19]. These changes may reflect some sort of structural changes in the fibro-elastic properties of small airways, and that the obstructive disease could occur in subjects with long diving experience[17,18], gas change effect, hyperoxia[14,20], and capillary diffusion deterioration[4,8] or pulmonary edema that was reported to be associated with diving which probably occurs due to pressure changes caused by emersion and failure of the blood gas barrier[21,22].

In conclusion, divers are at risk of some pulmonary changes mostly affecting small airways conductance. These changes are mainly related to diving activities but other factors such as smoking, short stature or low body weight could not be excluded. Therefore, continuous studies on diving health assessment, annual check-up of divers, adding pulmonary function tests to the pre-employment checking, and special attention is to be paid for the types of breathing apparatus used in diving, are highly recommended.

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