Impact of Aerobic Training Upon Physical Fitness of Firefighters in Cairo City.

Hala M. Ezz. El Deen*, Sherif M. Eissa and Mohamed M. Amin*****

*Physical Therapy Department for Cardiopulmonary Disorders and Geriatrics, Faculty of Physical Therapy, Cairo University

**Physical Therapy Department for Cardiopulmonary Disorders and Geriatrics, Faculty of Physical Therapy, Misr University for Science and Technology.

*** National Heart Institute

ABSTRACT

Background: *Exposure to environmental pollution, particularly smoke inhalation, during fire fighting may result in development of cardiopulmonary disorders in firefighters. Firemen are often at high risk for heart attacks, respiratory injuries and present with a wide variety of complications primarily because they get little or no exercise while on duty. The present work was conducted to study the influence of aerobic training upon the improvement of the physical fitness among firefighters in Cairo. The maximum oxygen consumption, maximum voluntary ventilation, resting blood pressure, and peak heart rate were chosen as acceptable predictors for the firefighters' physical fitness.* ***Subjects and methods:*** *Forty active firefighters were participated in this study, their ages ranged from 30- 47 years. The subjects were assigned into two groups the trained one enrolled into an aerobic program for two months, while the control one followed their habitual daily activities without any physical interventions.* ***Results:*** *revealed improvement in the selected physical fitness parameters of the firefighters in the training group, as measured by improvement of the MVV, VO_2 max, blood pressure, and peak heart rate after two months of aerobic training.*

INTRODUCTION

Firemen are often at high risk for heart attacks primarily because they get little or no exercise while on duty[11]. Exposure to environmental pollution during fire fighting may result in development of respiratory disorders[23,22].

Accident, traumas and poisoning are the most frequent causes of health impairments among firemen, determined by the nature of their occupation. Their work is directly related with the exposure to various harmful chemical and physical factors, involving at the same time mental stress during rescue and fire fighting actions[36,34,35].

Firefighters remain in close proximity to smoke with sustained periods of exposure[18]. Smoke inhalation is a well-recognized cause of early respiratory injury and may account for up to 75% of fire-related deaths and present with a wide variety of complications and findings[3,12].

A number of recent time series mortality studies have provided evidence of positive associations between air pollutions and all cause mortality, cardiovascular mortality, respiratory mortality, or even more specific causes such as pneumonia and chronic obstructive lung disease mortality[37,10,32].

Exposure at firehouses, where fire fighters spend long periods of time, may also pose a health risk. Diesel exhaust from running trucks in closed building can expose firefighters to high level of emission particulate that are probably carcinogenic[28]. Fire companies located in old buildings containing deteriorating asbestos containing insulation may produce harmful levels of exposure[5,6,13].

Smoke inhalation injury can be characterized according to the time period post-injury. The first 36 hours involves treatment of the initial hypoxic insult, carbon monoxide and cyanide toxicity, early airway edema, bronchorrhea, and bronchoconstriction[30,31]. Mucosal sloughing, tracheobronchitis, increased lung water, and impaired gas exchange characterize day's 1- 5-post exposure[8]. The final stage is the inflammation- infection stage, in which the risk of nosochomial pneumonia increases markedly, coinciding with further impairment of lung function[17,15]. Short-term changes, including reductions in Spirometric parameters and increased airway reactivity, have been described commonly after firefighting[2,14].

Physical activity was defined as working capacity divided by body weight. The working capacity is defined as the cumulated work performed during the symptoms limited exercise test[7]. Functional capacity or working capacity is best measured by value of VO_{2max}[42]. Physical performance, maximal oxygen uptake and exercise test duration represent the strongest predictors of mortality[19,4].

The American College of Sports Medicine (ACSM) defines aerobic exercise as "any activity that uses large muscle groups, can be maintained continuously, and is rhythmic in nature." It is a type of exercise that overloads the heart and lungs and causes them to work harder than at rest. Find something you enjoy doing that keeps your heart rate elevated for a continuous time period and get moving to a healthier life[25,29].

Numerous epidemiological surveys suggested that adequate, regular exercise could maintain or improve fitness, preserve good health, and enhance the quality of life in comparison to a more sedentary life style[1].

The present study was designed to monitor some of the cardiopulmonary capacity of firefighters of smoke inhalation in Cairo city and measured the changes in their physical endurance capacity after an aerobic training program.

SUBJECTS, MATERIAL AND METHODS

Subjects

Forty subjects volunteers active firefighters were recruited for the study from fire stations in Cairo (Heliopolis, Ataba, Dokki, and Abdeen Brigade Stations). Their mean age, weight and height were shown in table (1). All the participants were signed a consent form before they began the study.

Exclusion criteria included any present or past sever chronic cardiopulmonary diseases, severe exposure that led to hospital admission, body mass index more than 28 kg/m^2, smokers, persons with cutaneous burns and subjects who shared in fighting chemical fires.

After selection of the subjects, they were divided into two equal groups: training group (A), comprised 20 subjects, who underwent a specific aerobic training program for 2 months in addition to their habitual activities and duties. While the second group (B) considers a control one contain also 20 subjects who did not participate in any training program except their habitual activities and duties during the same duration of the study.

All participants in both groups underwent the following evaluations

1) Physical examination

a) Body mass index BMI: by measuring the weight and height (Seica Height-weight scale, Germany) to calculate the body mass index; by dividing the weight in kilograms by the square of the height in meters (kg/m^2)[20], to exclude obese one.

b) An average resting blood pressure: was calculated from the mean of the second and third of three consecutive measurements with a Reister Blood pressure sphygmomanometer, made in Germany, read to the nearest 2 mmHg, while the subject in the recumbent position for at least 10 minutes[16], to exclude those with high BP.

c) Questionnaire: A self-administered entry questionnaire submitted at baseline evaluation provided extensive information on common chest symptoms for each subject, which was repeated again at the end of the program.

2) Cardiopulmonary Exercise stress testing (CPET)

The cardiopulmonary exercise test unit (Zan Messgeraete GmbH, D- 97723 Oberthulba, Germany) was used to measure: $VO_{2\ max}$, Peak heart rate, blood pressure and spirometric test. The test was performed according to the following procedures:

a) Subjects preparation

* Clinical examination was performed by cardiologist to rule out contraindications for the test.
* A detailed explanation and instruction of the testing procedure was given firstly to each participant separately, that outlines risks and possible complications. These instructions include:

(1) Not to eat for three hours before test. Water may be taken as needed at any time.
(2) Dress light clothes & footwear appropriately for exercise.
(3) Avoid unusual physical efforts should be performed for at least 12 hours before testing.

*A resting standard 12-lead electrocardiogram (ECG) was obtained to record the resting pre-exercise ECG by allowing the subject to relax at least 10 minutes before recording.

b)Testing procedure

(I)- Spirometric test "maximum voluntary ventilation" (MVV)

The subject seated on the adjustable height chair and was connected to flow-sensor through rubber mouth piece, which was introduced to his mouth and enclosed firmly by his lips while the nose was closed by a nasal clip to prevent air leak. Subject was instructed not to move his trunk anteriorly or posteriorly during performing the test. Then the subject breathed as rapidly and deeply as possible and after 3 breaths this maneuver should be continued for at least 12 seconds, but no longer than 15 seconds to avoid fainting.

Spirometric measurement data were collected at baseline and then at the end of the study, and measurements were made in accordance with testing criteria of the American Thoracic Society (ATS) and corrected for temperature, pressure, and water saturation. A minimum of three acceptable tracings were recorded, with the subject in a sitting position, the maximum value used for data analysis[9,12].

(II)- Exercise test (CPET)

Subject seated on the cycle ergometer after being adjusted to the height of subject, then 10 ECG lead were connected to the subject.

Steps of the CPET

The exercise testing includes an initial warm-up, progressive uninterrupted exercise with increasing loads and an adequate time interval in each level, and a recovery period[38]

Classified as the following

* 2 minutes were allowed for resting BP measurements record.
* Another 2 minutes of unloading cycle as warming up.
* Exercise test phase begins with increase of work load at rate of 25 watt/min.
* Subject was encouraged to exert his maximum effort and continued the test as much as he could.
* 2 minutes of unloading cycle were allowed as cool down phase.
* 7 minutes were allowed for recovery and recording of VO^2max., Peak HR.
* At the end of test the subject was asked to maintain the revolution of pedaling at 60 ram / minute.
* The test was terminated at any time the subject developed chest pain, cyanosis, pallor, serious arrhythmia, or subject's request to stop as a result of felling of fatigue, wheezing, leg cramps, or dyspnea.

Training procedure for group (A)

Aerobic exercise training was done by bicycles ergometer. The session began with 5 minutes of aerobic exercise in the form of stretching exercise and walking in places (warm-up). Then the subject started the bicycle ergometer training for 40 minutes with an intensity of 65% of maximal heart rate for one month and increased gradually to reach about 80% of maximal heart rate during the second month of the program. Then the workload was gradually reduced over 5 minutes (Cool down) when reaching the exercise limiting end point[7].

This program was performed for three sessions per week for 2 months.

Statistical analysis

The mean values of MVV ,VO_2, Peak HR and blood pressure obtained before and after two months in both groups (A&B) were compared using paired "t" test. Independent "t" test was used for the comparison between the two groups. $P<0.05$ considered statistically significant.

RESULTS

Table (1): The anthropometrical Characteristics of both groups (A&B)

Variables	Group (A)	Group (B)	P value
	Mean ±SD	Mean ±SD	
Age (years)	36.7 ±5.93	39.13 ±7.27	>0.05
Weight (kg)	75.3 ±12.01	77.63 ±11.05	>0.05
Height (cm)	169.9 ±6.51	171.8 ±6.87	>0.05

P> 0.05 : non significant ± SD: standard deviation Kg: kilogram cm: centimeter

As shown from table (1), the mean age in group (A) was 36.7± 5.93 years and that for group (B) was 39.13± 7.27 years. The mean weight was 75.3±12.01kg and 77.63± 11.05 kg respectively, while the mean height was 169.9 ±6.51 cm and 171.8 ±6.87 cm. respectively. These data showed non significant difference between both groups in age, height or weight as P> 0.05.

Table (2): The percentage of chest symptoms in both groups post training

Chest symptoms	Training Group (A)		Control Group (B)		X^2	P value
	No.	%	No.	%		
Cough	12	60	15	75	2.52	>0.05
Sputum	9	46	13	65	3.7	>0.05
Dyspnea	0	0	7	33	12.8	<0.01
Chest pain	0	0	3	14	4.76	<0.05

X^2= Chi-squared test P value <0.05 is significant No.= number
P value >0.05 is non significant %: percentage

As shown in table (2), although there was non statistical significant difference between both groups in the post training results regarding the percentage of subjects complained of cough or sputum (P-value >0.05), but the difference was significant regarding the dyspnea and chest pain (P-value < 0.05).

From the results we can notice that the most frequent and persistent respiratory complains among active firefighters were cough and sputum.

Table (3): The difference between the pre and post values of MVV, VO_2 max., Peak HR and BP in group (A)

Variables	Mean ±SD		Percentage of Relative changes	Significance
	Pre	Post		
MVV L/min	44.67±4.05	55.73±4.43	24.76%	Sig.
VO_2 max. ml/min/Kg	3 0.5 ± 1.2	43.10 ± 1.5	41.31%	Sig.
Peak Heart Rate Beat/min	182±13.62	165.3±18.1	10.16%	Sig.
Systolic BP/mmHg	139.5 ± 5.81	125.5 ± 6.7	-10.04%	Sig.
Diastolic BP/mmHg	90.5 ± 4.5	84.3 ± 5.12	-6.85%	Sig.

L/min: liter/minute. mmHg: millimercury. ml/min/Kg: milliliter/minute/ kilogram
MVV: maximum voluntary ventilation. SD: standard deviation. BP: blood pressure

From table (3) and figure (1) one can notice the significant improvement in MVV after aerobic training from 44.67 ± 4.05 to 55.73 ±4.43 L/min which was statistically significant (P-value <0.05). The VO^2 max also improved showed significant increase from 30. 5-1.2 to 43.10- 1.5) P-value<0.05). There was also statistically significant decrease in both systolic and diastolic blood pressure after training (P-value <0.05). The Peak HR showed also significant decrease after training as it changed from 182.1 ±13.62 to 165.3 ± 18.1beat/min, P<0.05.

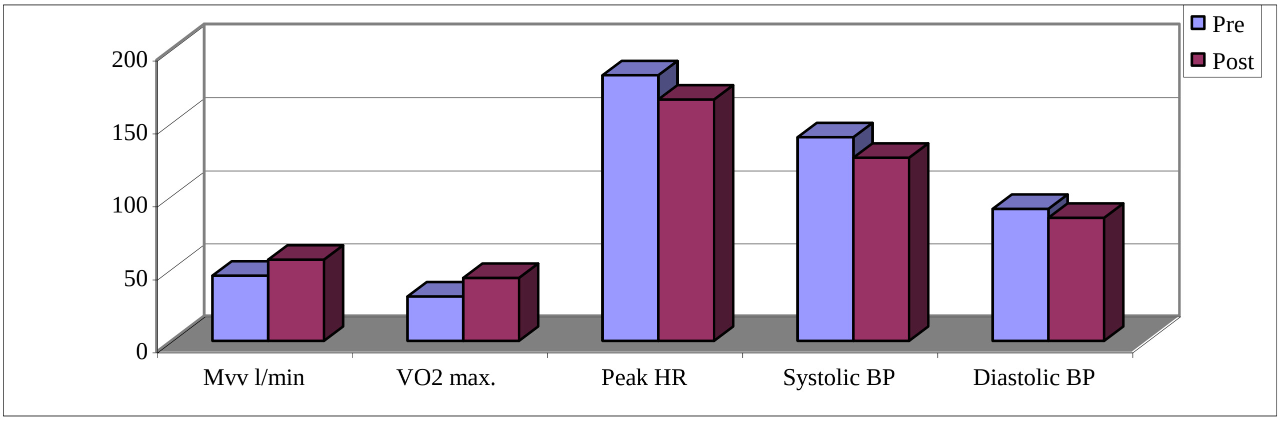

Fig. (1): The difference between the pre & post training values of group (A)

Table (4): The difference between the pre and post values of MVV, VO_2 max., Peak HR and BP group (B).

Variables	Mean ±SD		Percentage of Relative changes	Significance
	Pre	Post		
MVV L/min	42.53±4.50	44.26±4.52	4.07	Non. Sig.
VO_2 max. ml/min/Kg	31.2 ± 1.6	30.20± 3.4	-3.21	Non. Sig.
Peak Heart Rate Beat/min	162.9±17.1	166.5±14.1	2.21	Non sig
Systolic BP /mmHg	136.8±4.9	135.7±5.4	-0.80	Non. Sig.
Diastolic BP/mmHg	87.32±4.2	86.98±4.11	-0.39	Non. Sig.

L/min: liter/minute. mmHg: milimercury. ml/min/Kg: milliliter/minute/ kilogram
MVV: maximum voluntary ventilation. SD: standard deviation.

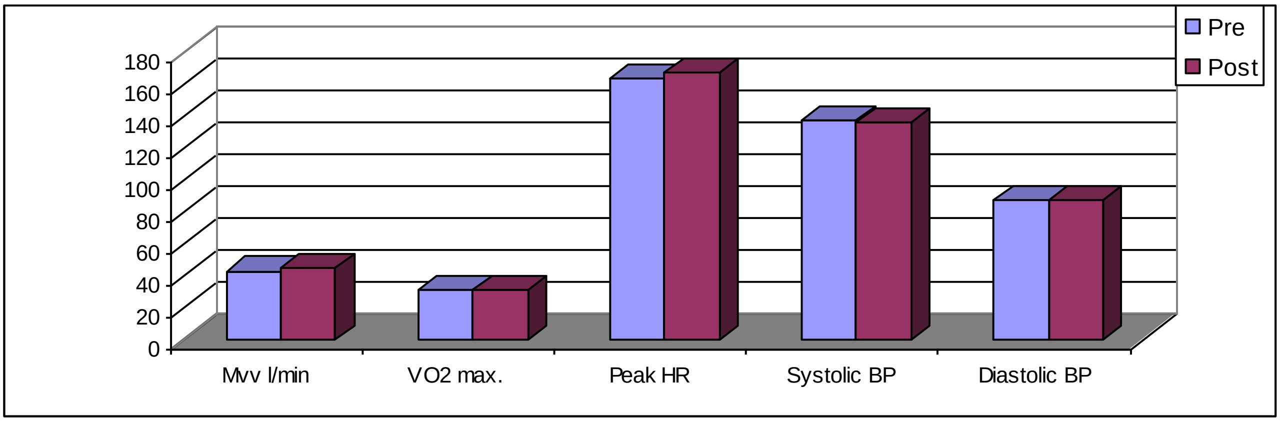

Fig. (2): The Difference between the pre & post Training Values in group (B).

As notice from table (4) &figure (2), in the control group, the MVV, VO_2 max, Peak HR and also both systolic and diastolic blood pressure although all showed changed after the 2 months, but it was statistically non significant as P-value > 0.05.

Table (5): The difference between values of MVV, VO_2 max, Peak HR and BP in both groups (A&B) after 2 months.

	Mean ±SD		P-value	Significance
	Group (A)	Group (B)		
MVV L/min	55.73±4.43	44.26±4.52	< 0.05	Sig.
VO_2 max.ml/min/Kg	43.10 ± 1.5	30.20± 3.4	< 0.05	Sig.
Peak Heart Rate Beat/min	182±13.62	166.5±14.1	< 0.05	Sig.
Systolic BP /mmHg	125.5 ± 6.7	135.7 ± 5.4	< 0.05	Sig.
Diastolic BP/mmHg	84.3 ± 5.12	86.98±4.11	< 0.05	Sig.

L/min: liter/minute. mmHg: millimercury. ml/min/Kg: milliliter/minute/ kilogram
MVV: maximum voluntary ventilation . SD: standard deviation. BP: blood pressure

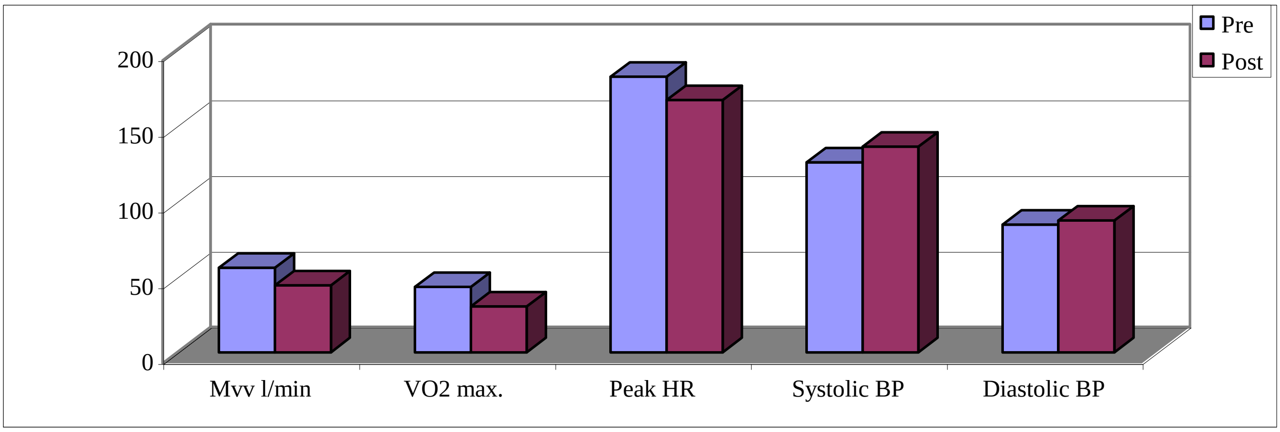

Fig. (3): The Difference between the post Training Values in both groups.

On comparing the results in both groups after the total duration of the study, 2 months, as presented in table (5) & fig(3) one can notice the significant difference between all variables in both groups, with the favor for the training group (A), P-vale< 0.05.

DISCUSSION

The present work was conducted to study the influence of aerobic training upon the improvement of the physical fitness among firefighters in Cairo. The maximum oxygen consumption, maximum voluntary ventilation, resting blood pressure, and peak heart rate were chosen as an acceptable predictors for the firefighters' physical fitness[7].

Exercises require the coordinated function of the heart, lungs, peripheral and pulmonary circulations to match the increased cellular respiration required to live and work[38].

The capacity to perform high-intensity exercise over an extended period of time is influenced by several factors. The availability of oxygen and energy substrate, as well as the efficiency of muscle energy production mechanisms, the potential of the respiratory and cardiovascular systems to adapt to regular exercise training are fundamental to maintain a given exercise intensity level. These give good explanation to the present results regarding the improvement in all measuring variables[27,43].

Forty active firefighters were participated in this study, their ages ranged from 30- 42 years. The subjects were assigned into two groups the trained one enrolled into an aerobic program for two months, while the control one followed their habitual daily activities without any physical interventions.

Analysis of the results revealed improvement in the selected physical fitness parameters of the firefighters in the training group, as measured by improvement of the MVV, VO_2 max, blood pressure, and peak heart rate after two months of aerobic training.

The maximum voluntary ventilation was improved in the training group. This was mainly, depends upon the ability of the respiratory muscles to contract and relaxes rapidly and deeply with increased exercise intensity level to supply the needed amount of oxygen. That improvement could be related to the respiratory muscles strength and endurance capability which increased in the training group by 24.76%, while in the control group only by 4.07%.

This finding is consistent with the previous results, which found that active firefighters experienced a rate of decline in pulmonary function 2.5 times greater than those who had retired or resigned[29].

The reduced pulmonary function and associated respiratory symptoms may be explained in many ways[24]. Several air pollutant components of wood smoke such as SO_2, NO_2, and particulates increase the respiratory symptoms and affect lung function even in low concentrations[27]. Also, short term increase of airway responsiveness has been reported in firefighters[33].

This explanation was previously supported by many authors[21,39]. They investigated the association between smoke inhalation and change in physical fitness and/or ventilatory function. They found that exposure to the combustion products could lead to pulmonary function defects.

The presence of respiratory symptoms among the firefighters, which may be maintained even after training, was coincide with previous results, which reported that the acute ventilatory responses to inhalation of wood smoke consisted of two phases: either a slowing of respiration or an augmented breath triggered within one or two breathes after the smoke was inhaled and then a delayed tachypnea[30]. The slowing of respiration and the augmented breath may originate from the stimulation of the lung Vagal C fiber nerve endings and rapidly adapting receptors, respectively. Whereas the delayed tachypnea may result in part from the activation of the arterial chemoreceptor. This again explained the reduction in the pre-training MVV and the considerable improvement by aerobic training as a result of increased in respiratory muscle function[11,13,18].

The second important finding was the improvement in VO_2 max after training by 41.31% in the training group (A), which not obtained in the control group (B), only 3.21%. Analysis of the results of the present study showed that active firefighters had significantly low VO_2max. This was improved significantly after the training program, although the control untrained group maintained their low VO_2 max values.

The present results were supported by previous studies. The tissue hypoxia is considered as the most important effect of carbon monoxide produced by the fires and the smoke that are the most common source of carbon monoxide poisoning and consequently low VO_2 max[31]. Others concluded that aerobic capacity was 20% lower before training than that seemed sufficient for safe performance of fire suppression duties. Training resulted in a large increase in aerobic capacity, by 28%, so that the trainees ended the program with an aerobic capacity considered appropriate for fighting fires[29].

Inactive firefighters have a 90% greater risk of myocardial infarction than those who are aerobically fit. Because of the critical job demands of firefighting and the negative consequences of inadequate fitness and aerobic capacity, periodic aerobic capacity testing with individualized exercise prescriptions and work—community support may be advisable for all active-duty firefighters[40,41].

Result of this study is contradicted with others[21] who found that pulmonary function (FVC, FEV_1,MVV) and diffusing capacity for CO were normal in 68% as well as a normal VO_2 max among 59% of their tested firefighters. Also early results[16] showed that long- term occupational exposure was not associated with pulmonary function abnormalities. They believed that the lack of functional impairment observed in their study was because few firefighters had evidence of moderate or severe pulmonary involvement, none displayed airway hyperactivity, and none showed gas exchange abnormalities significant enough to cause exercise desaturation. Thus, the lack of moderate to severe pulmonary dysfunction, coupled with possible self-selection for less strenuous job assignments, accounted for the general absence of work-related performance problems and the use protective face mask[26,4].

Concerning the BP & Peak HR which showed significant changes in the training group (A), this may be explained as following, During exercise, coronary blood flow must increase to meet the higher metabolic demands of myocardium. During strenuous exertion, sympathetic discharge is maximal and parasympathetic stimulation is withdrawn resulting in vasoconstriction in most circulatory body systems, except for that exercising muscle and in the cerebral and coronary circulations. As exercise progresses the skeletal muscle blood flow is increased, oxygen extraction increases as much as 3-folds, total calculated peripheral resistance decreases and the systolic blood pressure and mean arterial pressure and pulse pressure are usually increase. Diastolic blood pressure may remain unchanged or decrease to a minimal degree. The pulmonary vascular bed can accommodate as much as a 6- fold increase in cardiac output without a significant increase in pulmonary artery pressure. In normal subjects, this is not a limiting determinant of peak exercise capacity[4,16].

Also during strenuous exertion in the upright position, cardiac output can increase as much as a 4- 6 fold above basal levels depending on genetic endowment and level of training. In the post-exercise phase, the homodynamic return to baseline or less within minutes of termination. Vagal reactivation is an important cardiac deceleration mechanism after exercise which was responsible for the reduction in Peak HR. It is accelerated in well-trained athletes but may be blunted in reconditioned and/or "medically ill" patient[9].

A limitation of this study, as in most respiratory surveillance programs[25], was that, the actual magnitude of smoke exposure couldn't be directly or quantitatively determined. Occupational smoke exposure in firefighters would be expected to have two potential sources: (1) improperly fitted or poorly functioning self contained breathing apparatus (SCBA); and (2) inconsistent use of respiratory protection during fighting activities. Information about SCBA function during active firefighting is limited. Although positive-pressure SCBA provide a high degree of protection, our data clearly indicate that such personal protective equipment was less often in support, standby and overhaul/ clean-up phases of firefighting.

Conclusion and recommendation

In general, firefighters work at maximal levels of exertion. Fitness for such duty requires adequate aerobic capacity maximum oxygen consumption [VO_2 max]. Aerobic fitness can both improve a worker's ability to perform and offer resistance to cardiopulmonary conditions.

It is hoped that the results of this study will encourage those who oversee workers who are responsible for the public's safety to mandate assessment of physical fitness of new hires, with mandatory participation in exercise training for those new hires that are found to possess less than appropriate aerobic capacity.

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الملخص العربى

تأثير التدريبات الهوائيةعلى الكفائة البدنية لرجال المطافيء فى مدينة القاهرة

أجريت هذه الدراسة لمعرفة تأثير التدريبات الهوائيةعلى اللياقة البدنية لدى عمال المطافئ العاملين فى القاهرة . **الهدف من الدراسة :** هو تقييم وتسجيل فحوصات اللياقة الفيزيائية لدى عمال المطافئ المشاركين فى إطفاء حرائق المنازل وذلك من خلال قياس القيمة القصوى لاستهلاك الأكسجين ومعدل ضربات القلب القصوى قياس ضغط الدم . وقد شارك في هذه الدراسة اربعون عامل مطافئ من عدة محطات إطفاء موجودة فى القاهرة . وتراوحت أعمارهم من ثلاثين إلى خمس وخمسون سنة . وقد تم فحص الأشخاص إكلينيكيا للتأكد من خلوهم من أمراض القلب والرئة والسمنة وحروق الجلد وقد تم استبعاد الأشخاص اللذين شاركوا فى الحرائق الكيميائية أو اللذين سبق لهم دخول المستشفى نتيجة لشدة التعرض للدخان . وقد تم توزيع الأشخاص إلى مجموعتين : مجموعة(أ) مارست برنامج تدريبى هوائى و مجموعة ضابطة (ب) لم تمارس اى تدخل رياضي . وقد أجرى لكل منهم اختبار وظائف الرئة، قياس ضغط الدم قبل إجراء الاختبار. ثم بعد ذلك قام كل منهم بإجراء اختبار التمرين القلب رئوى وذلك لقياس القيمة القصوى لاستهلاك الأكسجين ومعدل ضربات القلب القصوى . وقد أظهرت النتائج وجود اختلافات ذات دلالة إحصائية بين المجموعتين حيث أن قيمة استهلاك الأكسجين القصوى ، معدل ضربات القلب القصوى ، اختبار وظائف الرئة،و قياس ضغط الدم لدى عمال المطافئ فى صالح المجموعة (أ) . ويستخلص من هذه الدراسة أن عمال المطافئ يعانون من اختلالات قلب رئوية بشكل واضح (انخفاض فى القيمة القصوى لاستهلاك الأكسجين ومعدل ضربات القلب القصوى) ناتج عن استنشاق دخان الحرائق. و ان اتباع برنامج تأهيلى يؤدى الى تحسن ملحوظ فى الكفائة البدنية لهم .