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FACULTY OF GRADUATE AND
POSTDOCTORAL STUDIES

Daryl Jamie Allard

AUTEUR DE LA THÈSE / AUTHOR OF THESIS

M.A. (Human Kinetics)

GRADE / DEGRÉ

School of Human Kinetics

FACULTÉ, ÉCOLE, DÉPARTEMENT / FACULTY, SCHOOL, DEPARTMENT

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TITRE DE LA THÈSE / TITLE OF THESIS

Glen Kenny

DIRECTEUR (DIRECTRICE) DE LA THÈSE / THESIS SUPERVISOR

CO-DIRECTEUR (CO-DIRECTRICE) DE LA THÈSE / THESIS CO-SUPERVISOR

EXAMINATEURS (EXAMINATRICES) DE LA THÈSE / THESIS EXAMINERS

Denis Prud'homme

Frank Reardon

Gary W. Slater

LE DOYEN DE LA FACULTÉ DES ÉTUDES SUPÉRIEURES ET POSTDOCTORALES /
DEAN OF THE FACULTY OF GRADUATE AND POSTDOCTORAL STUDIES

**VENTILATORY CAPACITY ASSOCIATED WITH FIREFIGHTING AND
DIVING IN THE CANADIAN FORCES**

DARYL JAMIE ALLARD

BPE., Université de Moncton

THESIS

Submitted to the Faculty of Graduate and Postdoctoral Studies

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A sincere thanks to all of you,

Daryl

ABSTRACT

Purpose: The objective of this study was to investigate the effects of occupational exposure during firefighting and oxygen diving on ventilatory capacity while also examining the potential benefit of levels of physical activity and cardiorespiratory fitness on the same ventilatory capacity values. Specifically, study #1 compared firefighter ventilatory capacity values with that of controls and external reference values from non-smoking segments of populations. In addition, the study sought to assess the relationships between levels of physical activity and levels of firefighting exposure with ventilatory capacity. Study #2 was designed to compare ventilatory capacity values of divers with those measured in firefighters and external reference values from non-smoking segments of populations. The study also sought to examine the relationship between levels of physical activity, cardiorespiratory fitness, ventilatory threshold and levels of diving exposure with ventilatory capacity values. **Methods:** *Study #1-* Eighteen Canadian Forces (CF) Firefighters and fifteen controls completed a two part questionnaire to measure levels firefighting exposure as measure by years of firefighting and hours of firefighting and levels of physical activity as measured by frequency and intensity of physical activity. Subjects also underwent ventilatory capacity testing including forced vital capacity (FVC), forced expiratory volume in 1 s ($FEV_{1.0}$), $FEV_{1.0}/FVC$ as well as maximal expiratory flow rates (FEF) at 25-75% and 75% of FVC. *Study #2-* Fifteen CF Divers and sixteen CF Firefighter completed a two part questionnaire to measure levels of diving exposure as measured by years of diving, hours of diving and diving depth and levels of physical activity as measured by frequency and intensity of physical activity. Subjects underwent ventilatory capacity testing including FVC, $FEV_{1.0}$, $FEV_{1.0}/FVC$ as well $FEF_{25-75\%}$ of FVC. CF Divers also completed a direct maximal oxygen uptake and ventilatory threshold evaluation. **Results:** *Study #1-* Firefighters possessed normal ventilatory capacity values when compared to controls and external reference values. Significant correlations were found between intensity of exercise with FVC and $FEV_{1.0}$ and frequency of physical activity with $FEV_{1.0}/FVC$. No relationship was found between years of firefighting or hours of firefighting with ventilatory capacity values. *Study #2-* Divers' possessed higher FVC values when compared to controls and external reference values. Significant correlations were found between intensity of exercise with $FEF_{25-75\%}$ and $FEV_{1.0}/FVC$. Maximum and average diving depth during a single dive was correlated with $FEF_{25-75\%}$ and $FEV_{1.0}/FVC$. No other relationship was found between diving exposure and any other ventilatory capacity values. **Conclusion:** *Study #1-* These results suggest no evidence of lung impairment for CF Firefighters but suggest higher ventilatory capacity values for those who maintain a physically active lifestyle. *Study #2-* These results indicate higher FVC values for CF Divers and suggest higher ventilatory capacity values for those who exercise at higher intensities.

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ABBREVIATIONS

BPM	Beats per Minute
CABA	Compressed Air Breathing Apparatus
CF	Canadian Forces
CFAO	Canadian Forces Administrative Orders
CFPSA	Canadian Forces Personnel Support Agency
FVC	Forced vital capacity (litres)
FEF _{25-75%}	Force expiratory flow (litres/second)
FEV _{1.0}	Forced expiratory volume (litres)
FSW	Feet of Sea Water
mmHg	Millimetres of Mercury
Kg	Kilogram
L	Litre
LWSSBA	Light Weight Surface Supplied Breathing Apparatus
MSW	Meters of Sea Water
SCBA	Self Contained Breathing Apparatus
SCUBA	Self Contained Underwater Breathing Apparatus
VGM	Venous Gas Microembolism
VO _{2 max or peak}	Maximum oxygen consumption (ml·kg ⁻¹ ·min ⁻¹)

DEFINITIONS

FVC	The volume of gas which is exhaled during a forced expiration starting from a position of full inspiration and ending at complete expiration.
FEV _{1.0}	The volume of gas exhaled in a specified time from the start of the forced vital capacity manoeuvre; conventionally, the time is 1 second.
FEF _{25-75%}	Mid-expiratory flow, the mean forced expiratory flow during the middle half of the forced vital capacity (FVC).
FEV _{1.0} /FVC	Ratio of FVC during the first second of forced vital capacity manoeuvre

CHAPTER 1

INTRODUCTION

Introduction

It is widely accepted that diving (McFaydyen et al., 2003) and firefighting (Deakon et al., 1995) are two of the most physically demanding occupations in the Canadian Forces (CF) requiring high levels of physical fitness. Both CF firefighters and CF Divers are required to undertake an annual fitness evaluation and achieve a minimum score above CF minimum norms to better reflect the added physical demands of firefighting and diving. In addition to a high level of physical fitness, ventilatory capacity plays an important role in assuring safe and effective performance. The use of a breathing apparatus has been shown to significantly decrease oxygen uptake at both submaximal and maximal exercise intensities (Louhevaara et al, 1985). Hyperbaria also decreases ventilation and increases oxygen costs of exercise by increasing work of breathing and placing added stress on the pulmonary system (Freud et al., 1992). This increased demand combined with environmental conditions, equipment dead space and the added weight and restrictive nature of the equipment can impact a firefighter or diver's exercise capacity by significantly increasing cardiorespiratory strain.

There is increasing evidence suggesting that occupational groups such as firefighters and divers are at risk of developing acute and chronic pulmonary function abnormalities (Crosbie et al., 1979; Tetzlaff et al. 1998). These abnormalities have been attributed to exposure to toxins of burning materials such as carbon monoxide, benzene and acrolein during firefighting and in the case of divers to hyperbaria and breathing 100% oxygen. This is of particular importance given that a diminution in ventilatory capacity combined with decreases associated with age, smoking, physical inactivity causing airway obstruction has the potential of significantly reducing work

capacity and jeopardizing diver and firefighter safety.

The following study examined the effects of occupational exposure of firefighting and diving on ventilatory capacity. Exposure was measured based on the number of years as a professional firefighter and the total hours of fighting fires. Diving exposure was measured based on the number of years as a professional divers, the total hours of diving as well as mean and maximal diving depth. The study also sought to assess to relationship levels of physical activity as measured by physical activity frequency and intensity and cardiorespiratory fitness with ventilatory capacity. The first study compared firefighter ventilatory capacity values with that of controls and external reference values from non-smoking segments of populations. In addition, the study assessed the relationship between physical activity participation, firefighting exposure ventilatory capacity. The subsequent experiment compared ventilatory capacity values of divers with that of firefighters and external reference values from non-smoking segments of populations. The study also examined the relationship between cardiorespiratory function, ventilatory threshold and diving exposure with ventilatory capacity values.

A) Ventilatory Capacity of Canadian Forces Firefighters: a cross sectional study

CF Firefighters are exposed to stressful environments and potentially harmful toxins from burning material. Toxins resulting from these burning materials can potentially hamper force expiratory volume in one second ($FEV_{1.0}$) measured to be 4.1% per decade in normal populations (Witten et al., 1986). Understanding some of the factors which may potentially increase or decrease firefighter's ventilatory capacity and ability to perform physically demanding tasks is crucial for the survival in adverse environments. The unfortunate death of a CF Submariner on HMCS Chicoutimi in October 2004 due to smoke inhalation highlights the types of stressful

environments and conditions that CF members may be subjected (Murphy et al., 2004). Similarly, CF Firefighters may also be exposed potentially dangerous confined spaces when working aboard Navy Ships (Deakon et al., 1995).

A number of studies have examined the acute (Musk et al., 1979; Sheppard et al., 1986; Brandt-Rauff et al., 1988b; Rothman et al., 1991; Feldman et al., 2004) and chronic (Peters et al., 1974; Musk et al., 1977a, 1977b; Tashkin et al., 1977; Musk et al., 1982; Douglas et al., 1985; Horsfield et al., 1988; Tepper et al., 1991) response of firefighting on ventilatory capacity with varying results. Studies investigating firefighting exposure and ventilatory capacity have usually focused on urban or city firefighters whose exposure rates are much greater than most military or rural firefighters. Few studies to date have investigated ventilatory capacity of military firefighters and even fewer have investigated the relationship with frequency and intensity of physical activity.

The purpose of this study was to measure ventilatory capacity in CF Firefighter and examine its relationship with firefighting exposure and physical activity participation. Specifically, the study was undertaken to examine cross-sectional ventilatory capacity changes (FVC, FEV_{1.0}/FVC, FEF_{25-75%}, and FEF_{75%}) in CF Firefighters and to examine its relationship with years of firefighting, hours of firefighting, physical activity frequency and physical activity intensity.

B) Ventilatory Capacity of Canadian Forces Divers: a cross sectional study

Underwater diving exposes humans to a foreign environment with increased buoyancy, and increased hydrostatic pressure. Studies show that an increase in environmental pressure, along with venous gas microembolism and hyperoxia can have a detrimental effect on ventilatory capacity.

along with venous gas microembolism and hyperoxia can have a detrimental effect on ventilatory capacity.

Cross-sectional and longitudinal studies have repeatedly demonstrated an association between diving and reduced ventilatory capacity. These studies have reported increases in forced vital capacity (FVC) (Crosbie et al., 1977; Crosbie et al., 1979; Davey et al., 1984) and reduction in expiratory airflow rates such as FEV_{1.0} (Crosbie et al., 1977; Crosbie et al., 1979; Skogstad et al., 2000) and forced expiratory flow rate (FEF_{25-75%}) (Van Liew, 1983; Crosbie et al., 1977; Davey et al., 1984; Tetzlaff et al., 1998). Studies investigating diving exposure and ventilatory capacity have typically focused on saturation divers who dive at depths equal to or greater than 100 m with dives that can typically last from 2-3 weeks (Cotes et al., 1994). Few studies to date have investigated ventilatory capacity of divers who dive to depths no greater than 50 m (5 Atmospheres (ATA)) and employ closed-circuit oxygen rebreathing apparatus. Furthermore, even fewer studies have investigated the relationship of ventilatory capacity with frequency of physical activity and levels of cardiorespiratory fitness of divers.

Task related requirements for CF Divers tend to be far more demanding and stressful than tasks associated with most traditional industrial diving trades (e.g. welding, construction). CF Divers are typically the first responders at accident sites and the first to see the wreckage of plain and ship disasters. They are exposed to dangers of razor sharp metals and entrapment amid unpredictable and physically demanding environments. Factors such as lower cardiorespiratory fitness and reduced ventilatory capacity values which may limit performance in these physically demanding conditions are of particular importance in maintaining operational effectiveness. There currently exists a paucity of information regarding the performance characteristics and physiological factors which may limit performance to diving in these conditions. Of particular

importance, is the need to advance our understanding of the relationship of ventilatory capacity with: 1. diving exposure; 2. maximal oxygen uptake; 3. ventilatory threshold and; 4. levels of physical activity.

This study was conducted to examine cross-sectional ventilatory capacity changes in CF Divers and to examine the relationship with diving exposure, maximal oxygen uptake and levels of physical activity. Physical activity variables were measured as maximal oxygen uptake, physical activity frequency and intensity. Diving exposure was measured as years as a certified CF diver, maximum and average diving depth and dive time in the previous 12 months.

1.1 Rationale

A) Work by Serra et al. (1996) with city firefighters demonstrated cross-sectional ventilatory capacity changes when comparing firefighters with a matched group of controls. Changes to FEV_1 have been attributed to narrowing of the larger airways due to exposure to toxins such as acrolein and benzene while increases in FVC have been attributed to training of the respiratory muscles caused by the breathing apparatus. In addition, studies with both normal (Twisk et al., 1998; MacAuley et al., 1998; Cheng et al., 2003) and asthmatic (Malkia et al., 1998) populations have reported positive correlations between physical activity and ventilatory capacity. Thus, it is reasonable to postulate that FVC, FEV_1 and FEV_1/FVC measurements which specifically reflect larger diameter airways, will be different in CF Firefighters when compared to controls and external reference values from non-smoking segments of populations. It is also reasonable to expect that physical activity participation and diving exposure will also be correlated with ventilatory capacity.

B) There is increasing evidence that suggests an increase in environmental pressure caused by diving depth in combination with breathing 100% oxygen can have a detrimental effect on the smaller diameter airways (Van Liew et al., 1983; Crosbie et al., 1977; Davey et al., 1984; Skogstad et al., 2000). Increased breathing resistance caused by breathing dense gas and resulting from the resistance imposed by the breathing apparatus itself has also been associated with higher FVC values (Skogstad, 2000). Greater ventilatory capacity values in physically active population when compared to sedentary population have also been reported in studies involving both normal (Twisk et al., 1998; MacAuley et al., 1998 Cheng et al., 2003) and asthmatic populations (Malkia et al., 1998). Thus, it is reasonable to postulate that FVC, $FEV_{1.0}/FVC$ and $FEF_{25-75\%}$ of CF divers will be different than that of firefighters and external reference values from non-smoking segments of populations and that levels of physical activity and diving exposure will also be correlated with ventilatory capacity.

1.2 Hypotheses

General hypothesis of the thesis

It is hypothesized that ventilatory capacity of firefighting and diving occupational groups will be different than that of controls and external reference values from non-smoking segments of populations values while occupational exposure, levels of physical activity and cardiorespiratory fitness will be correlated with ventilatory capacity values.

Specific hypotheses of the experiments

A) We hypothesized that firefighters would have higher FVC values and lower $FEV_{1.0}$, $FEV_{1.0}/FVC$ values as compared to controls and external reference values from non-smoking segments of populations. Further, we evaluated the hypothesis that firefighter ventilatory capacity

would be positively correlated with physical activity frequency and intensity, and negatively correlate with years of firefighting and hours of exposure to fires in the previous 12 months.

B) It was hypothesized that divers would have higher FVC values and lower FEV_{1,0}/FVC, FEF_{25-75%} values as compared to firefighters and external reference values from non-smoking segments of populations. Further, it was hypothesized that CF Divers' ventilatory capacity would positively correlate with cardiorespiratory capacity (VO₂ max, ml·kg⁻¹·min⁻¹), physical activity frequency and intensity, and negatively correlate with diving exposure as measured by maximum and mean diving depth, hours of diving and years as a professional diver.

1.3 Statement of the Problem

Employers are responsible for the health and safety of their employees. Canadian Forces recognize that firefighters and divers are exposed to risks and situation which typical Canadian employees would not be subjected. Operational requirements can result in exposure to high levels of toxins and diving depths above recommended oxygen breathing guidelines which could potentially result in chronic or permanent debilitating injuries. Today even with increased empirical evidence of ventilatory capacity adaptations, the potential of large and small airway dysfunction caused by occupational exposures have not been considered in the same light of other common musculoskeletal injuries typically encountered in the CF.

There currently exist a lack of information on the effects of firefighting and diving on ventilatory capacity over a military career and the potential benefit of regular physical activity and cardiorespiratory fitness. In the absence of conclusive research one cannot fully address the important issue of maintaining the health and wellbeing of its operational CF Firefighters and Divers during and following a military career.

1.4 Objectives

- A)** The objective of the study was to examine ventilatory capacity, firefighting exposure and levels of physical activity in CF Firefighters and compare with a group of CF members.
- B)** The objective of the study was to better understand the Canadian Forces diving occupation by examining ventilatory capacity, diving exposure, cardiorespiratory fitness and physical activity participation in CF divers compared with a group of CF Firefighters

1.5 Relevance

- A)** This experiment added military firefighters to firefighting groups previously studied (urban, rural, volunteer, wildland) regarding the effects of firefighting on ventilatory capacity, therefore adding to the existing body of evidence.
- B)** The results of the study provided additional information regarding diver ventilatory capacity and further established a link between diving exposure, cardiorespiratory fitness and levels of physical activity of CF Divers.

1.6 Delimitations

Some delimitations to our study are inherent. Firstly, this was a cross-sectional study to detect chronic changes in CF Firefighters' and Divers' ventilatory capacity. Cross-sectional studies can detect lung impairment when values are below reference populations or controls. Longitudinal studies, on the other hand, are better suited to detect lung impairment when ventilatory capacity demonstrates a deterioration over time greater than typically observed

through ageing (Reed et al., 1999). Another delimitation is that participants are self selected to join their respective trade and are required to undergo an annual fitness evaluation and therefore typically possess an above average fitness level. Therefore, generalization the results to other recreational or professional diving groups would have limited value.

1.7 Limitations

As with most research, limitations exists which could influence or stray results. The following outlines inherent limitations with the chosen methodology which may impact on the studies' validity.

Reference values and control groups

Comparison with improperly selected external reference values from non-smoking segments of populations can be misleading as values can differ between North American and European populations and in some instances between specific geographical regions (Reed et al., 1999). In order to increase the validity of results the selection of external reference values should be accompanied with a control group and resemble population studied with regards to key demographics such as smoking status, age, respiratory symptoms, sex, weight, ethnic group and living environment. The comparison with a control group should be matched for the variables relevant to the occupational group and not merely for age, gender, size and ethnic group for both a control group and external reference values (Reed et al., 1999). A number of steps were taken to assure the control group in both studies were properly selected for comparisons with firefighter and diver treatment groups:

A) Both CF Member controls and CF Firefighters were self selected to join their respective trade, underwent a thorough screening process, were members of the CF, met an annual fitness

evaluation and were all non-smokers.

B) Firefighters (Douglas et al., 1985) as are divers (Skogstad et al. 2000) are often considered to belong to a select population with larger FVC values and provide an ideal matched group to divers (Reed et al., 1999). Nevertheless one must be cautious as firefighters can often be exposed to toxic fumes while fighting fires and perhaps more importantly during overhaul and cleanup which could negatively affect dynamic lung function (Horsfield et al., 1988). Due to increased preventive measures, CF Firefighters are less likely to be exposed to toxic fumes than other professional firefighters. CF Firefighters in Bagotville, Québec were exposed to fires an average of 5.11 hours in the previous twelve months.

Electronic Spirometer

Lung volumes can be determined through closed circuit spirometry, plethysmography, and Gas dilution. Closed circuit spirometry is the preferred method to ventilatory capacity, however it is a costly and time consuming method which isn't conducive to the large number of subject and travel requirements of the study. As a result, an indirect method using an electronic spirometer has been selected to assess pulmonary function of subjects. With regular calibration, the validity and reliability of this method is very good, within 3% when operating within recommended temperature range. Nevertheless there is increased chance of undetected error with the electronic spirometer when compared to close circuit spirometry.

CHAPTER 2

REVIEW OF LITERATURE

2.0 CF Firefighters

The working environment of firefighter requires the integration physical and mental skills to perform physically demanding tasks such as lifting heavy equipment and carrying victims safely and effectively. Firefighters may also be exposed to extreme temperatures, poor air quality and high noise levels (Reischl et al., 1979). The Self Contained Breathing Apparatus protects a firefighter from harmful toxins as long as a seal exists around the nose a mouth. The removal of the masks, often during cleanup, can leave the firefighter vulnerable to high levels of air pollutants (Davis et al., 1987).

In view of the strenuous nature of firefighting and the importance of public and firefighter safety, CF Firefighters must meet an annual physical fitness maintenance evaluation that exceeds the Canadian Forces Minimum Physical Fitness Standard. The annual maintenance evaluation consists of ten simulated firefighting tasks completed in a consecutive manner with rest intervals incorporated between tasks, representing the conduct of tasks at the scene of an actual fire. The average VO_2 max of those meeting the cutoff score is $44 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ (Deakin et al., 1995). CF Firefighters are not required to undergo annual ventilatory capacity testing following their initial medical screening.

There are currently two categories of firefighters employed within the CF and the Department of National Defence (DND). The first are CF Firefighters who are members of the CF and are mostly employed at Air Forces Bases within the CF. The second group, DND Firefighters, are civilian employees who provide firefighter services to the CF. DND Fifefighters are mostly employed on Army and Navy bases across Canada. For the purpose of the thesis, we

have focused on CF Firefighters.

2.1 CF Divers

Underwater diving is widely considered to be one of the most dangerous and demanding occupations in the Canadian Forces (McFadyen, 2003). Divers go through extensive training and preparation, however no course can prepare a diving team for all the eventualities of the underwater world. Extreme water temperature, pollution, poor visibility, fast moving undercurrents and lack of visibility can endanger the life of even the most experienced diver. As with all Canadian Forces members, divers must meet, on an annual basis, a pre-determined physical fitness standard, in addition they must perform regular diving exercises to hone their skills and complete a semi-annual medical examination (Department of National Defence, 1996). Due to varying operational and training requirements, divers must meet physical fitness standards that exceed the Canadian Forces Minimum Physical Fitness Standard. CF Divers are not, however, required to undergo annual ventilatory capacity testing following an entry medical screening. The current diving physical fitness standards are based on a normative data base of CF divers and considered interim until bona fide physical fitness standards have been developed and validated by the Canadian Forces Personnel Support Agency and the University of Victoria. Interim physical fitness maintenance standards for CF Divers are presented in Table 1.

Table 1. Interim Physical Fitness Maintenance Standards for Canadian Forces Male Divers

Fitness Component	AGE GROUPS (years)				
	17-19	20-29	30-39	40-49	50-59
VO ₂ Max (ml kg ⁻¹ min ⁻¹)	52.2	49.2	43.1	38.5	38.5
Handgrip strength (kg/m)	101	105	106	103	96
Push-Ups (continuous)	35	30	25	21	18
Bent Knee Sit-Ups (1min) ¹	44	40	34	29	25

¹ represents the number of bent knee sit-ups completed in 1 minute.

The CF diving community is comprised of a number of different military occupations represented by all 3 CF environments; Land, Air and Maritime. Most trades perform diving as a secondary duty and must remain current with diving exercises on a quarterly basis (Department of National Defence, 1996). Clearance divers which classify diving as a primary duty are the lone exception and thus are exposed to hyperbaric conditions on a more frequent basis. Diving classification and responsibilities are presented in table 2.

Table 2. CF diving classification, job responsibilities, breathing medium and diving limits

Diving Classification	Number of Divers	Breathing Medium	Diving Limit	Task Requirements
Ship Team	200-250	CABA	+ 100 fsw	underwater inspection underwater searches underwater recovery locate and neutralise underwater anti ship explosive devices responding to diving emergencies
Port Inspection	156	CABA or LWSSBA	+ 150 fsw	Reservist underwater hull, seabed and lock searches explosive ordnance reconnaissance
Search and Rescue	132	CABA	+ 100 fsw	sea and air search and rescue victim extrication hiking/mountain climbing surface and CABA swim
Joint Task Force 2 Combat	Classified 142	Classified CABA or LWSSBA	Classified + 100 fsw	Classified destruction of mines and unexploded ordnance underwater construction place underwater obstacles underwater searches underwater explosive charge bridge and ship inspection
Clearance	130	CABA or LWSSBA	*	underwater search and recovery operations maintenance and repair of diving equipment treatment of diving and pressure related injuries emergency response inspect and repair ships' hull

+ with Commanding officers authorization for dives above 50 fsw

++ with authorization of National Defence Headquarter, Commanding Officer Fleet Diving Unit Atlantic, Pacific or Experimental Diving Unit

*maximal authorized depth of equipment

CABA (compressed air breathing apparatus)

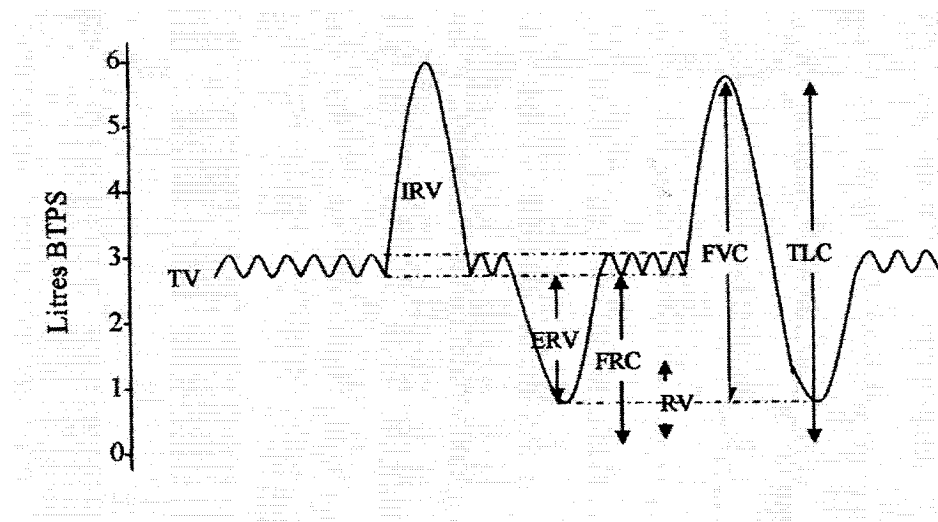
LWSS (Light Weight Surface Supplied Air Panel)

2.2 Ventilatory Capacity

For many years the role of ventilatory capacity testing has been limited to medical screening or following a serious firefighting or diving accident. However, regular ventilatory capacity testing may also be beneficial to measure longitudinal effects of firefighting and diving on both the small and larger airways.

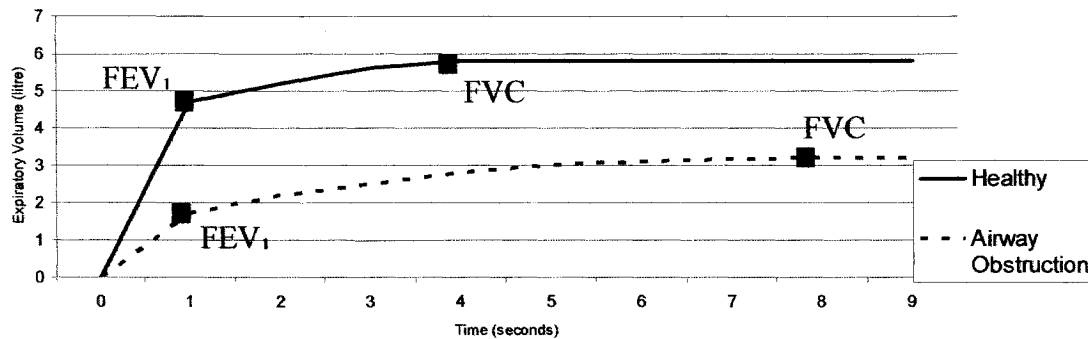
Various ventilatory capacity indices reflect one's ability to increase depth of breathing such as vital capacity (VC), forced vital capacity (FVC), forced expiratory volume ($FEV_{1.0}$) and $FEV_{1.0}/FVC$ and mid-expiratory flow ($FEF_{25-75\%}$). Static lung volumes, as shown in figure 1, are measured by closed circuit spirometry which are based on the completeness of respiratory manoeuvres, so that the velocity of the manoeuvres should be adjusted accordingly. The volume of air moved per breath during the inspiratory or expiratory phase of each breath is termed Tidal Volume (TV). The total volume of air that can be voluntarily moved in one breath, from full inspiration to maximum expiration, or vice versa, is termed the forced vital capacity (FVC),

Figure 1. Static Measures of Lung Volumes.



Dynamic lung volumes are measurements taken during fast breathing movements within the FVC manoeuvre shown in Figure 1 and depend on two factors, the volume of air moved per breath and the speed at which air can be moved. Dynamic lung function values such as FEV_1 , $FEV_{1.0}/FVC$ and $FEF_{25-75\%}$, are especially useful for physically demanding occupations such as firefighting and diving as an early detection tool for potential airway obstruction. Figure 2, depicts dynamic lung function values of healthy patients and patients with airway obstruction.

Figure 2. Idealized forced expiratory spiromograms (volume-time curves) of patients with airflow limitations and healthy subjects breathing air.



FVC, measured in litres, is the volume of gas exhaled during a forced expiration starting from a position of full inspiration and ending at complete expiration. Within the FVC respiratory manoeuvre, FEV₁ (l) is the volume of gas exhaled in one second from the start of the forced vital capacity manoeuvre. FEF_{25-75%} measured in litres/second is determined as the forced expiratory flow during the middle of the forced vital capacity manoeuvre. Lower FEV_{1,0}/FVC and FEF_{25-75%} are sensitive indicators of small airway obstruction while a lower FEV_{1,0} value as depicted in figure 2 is a reflection of larger airway obstruction. Normal FEV_{1,0}/FVC values are close to 85%, while the demarcation point for airway obstruction is considered less than 70% (McArdle et al. 1994). Minimum screening values for FVC and FEV_{1,0} are often recommended as 80% of predicted external reference values from non-smoking segments of populations (Fjer, 1993, Tetzlaff, 1999).

2.3 Ventilatory capacity assessment in the CF

Canadian Forces members must be aerobically fit to meet military operational requirements and ready to perform under a wide range of geographical and environmental conditions while coping with the stresses of sustained operations. Cardiorespiratory fitness

largely depends on actions from the pulmonary and cardiovascular systems. What impact a significant decrement in FVC, FEV_{1.0}, FEV_{1.0}/FVC ratio, and FEF_{25-75%} could have on firefighter or diver performance or safety is debatable as much depends on whether occupational changes, if any, are progressive or reversible and whether they continue from retirement of active diving. The nature of the firefighting and diving environment, specifically breathing resistance cause by breathing apparatus' and/or increase gas density places considerable stress on the pulmonary system further increasing the importance of the pulmonary system (Davey et al. 1984, Thorsen et al. 1993, Bermon et al. 1994). Nevertheless, even with increased knowledge and empirical evidence, the evaluation of dynamic lung function has been primarily limited to clinical application to assess the medical fitness of CF members to enter the firefighting and diving occupations. The CF does not assess lung function as part of an annual medical or fitness assessment and as a result cannot assess the longitudinal impact of firefighting and diving on FVC, FEV_{1.0}, FEV_{1.0}/FVC ratio, and FEF_{25-75%}.

The limited importance placed on ventilatory capacity as a maintenance criteria is likely due to the fact that values are compared with predicted limits and not monitored over a diving career. An initial medical screening wouldn't be able to measure a constant decline in dynamic lung capacity over and above the decline associated with age.

2.4 Factors affecting FVC, FEV_{1.0}, FEV_{1.0}/FVC ratio, and FEF_{25-75%}.

Many factors are known to influence ventilatory capacity such as age, sex, height, weight and ethnicity. These factors should all be considered when comparing ventilatory capacity of specific groups to external reference values. Becklake (1986) demonstrated that sex, age, stature, ethnic group, weight and technical factors accounted for 70% of proportional variability in FVC,

leaving 30% to be explained by smoking, past respiratory disease and other factors such as physical fitness and occupational exposure.

A number of regression equations (Miller et al., 1986; Quanjer et al., 1993; Gulsvik et al., 2001) have been developed for both males and females as well as varying ethnic groups, these pulmonary reference values and established limits of normality may differ slightly from one report to another, likely due to geographical areas. Nevertheless external reference values are not the primary method recommended when quantifying the effects of firefighting or diving exposure on ventilatory capacity. Van Pelt (1994) demonstrated that the use of external reference values can overestimate longitudinal change and suggest using an age, height and weight matched control group. If external reference values overestimate longitudinal change, the comparison of firefighting and diving populations to external reference values may underestimate longitudinal effects of occupational exposure or years of firefighting or diving.

Regardless of the values chosen, some of the difficulties associated with using external reference values could be avoided by adding a control group. The comparison with healthy non-divers should be matched for the variables relevant to the group and not merely for age, gender, size and ethnic group for both a control group and external reference values (Reed et al., 1999). It is imperative that the control group match the population studied with regards to key demographics such as smoking history, age, physical activity frequency, respiratory symptoms, sex, weight, ethnicity and living environment.

2.5 Ventilatory capacity, physical activity and cardiorespiratory fitness

Regular physical activity and cardiorespiratory fitness are considered key factors related to diminishing risks and increasing worker performance during both firefighting (Gledhill et al.,

1992) underwater diving (Doubt, 1996). There exist however a lack of information regarding the relationship between fitness, physical activity and ventilatory capacity with different occupational groups.

Examination of other studies with both normal (Twisk et al., 1998; MacAuley et al., 1998) and asthmatic (Malkia et al., 1998) populations have however reported positive correlations between physical activity habits and ventilatory capacity while other failed to show similar associations (Mahler et al., 1982). An earlier study from Mahler et al. (1982) demonstrated long distance runner values are essentially no different when compared with a control group of comparable body size. More recent studies have, however, associated higher values in physically active populations than sedentary group. Cheng et al. (2003) found higher FVC and FEV₁ values in physically active groups when compared to sedentary counterparts while Twisk et al. (1998) showed that changes in physical activity was associated with higher FVC.

2.6 Firefighting and ventilatory capacity

There currently exist a number of studies examining the acute and chronic effects of firefighting exposure on ventilatory capacity (Tashkin et al., 1977; Musk et al., 1982; Horsfield et al., 1988; Rothman et al., 1991; Serra et al., 1996). The reported effects of firefighting on ventilatory capacity is likely not attributed to the nature of firefighting itself but to the removal of respiratory protection during cleanup or the lack of a proper seal around the nose and mouth (Davis et al., 1987). This was confirmed in the Rothman study (1991) which reported decrease in both FEV_{1.0} and FVC in wildland firefighters who didn't have access to a breathing apparatus for protection. Brandt-Rauf (1988) also showed that firefighters often remove their breathing

apparatus' when smoke becomes tolerable. In 26 fires, when varying levels of benzene and hydrogen chloride were measured, firefighting did not use a breathing apparatus or removed the breathing apparatus during 14 fires. An overview of the various studies measuring acute and chronic effects of firefighting on ventilatory capacity values are presented in Table 3.

Table 3. Effects of Acute and Chronic Firefighting Exposure on Ventilatory Capacity

Reference	Firefighting Population	Type of Study	% change
Rothman et al (1991)	Wildland	Acute Cross-sectional	1.2% decrease in FEV _{1.0} 0.3% decrease in FVC
Rothman et al. (1991)	Wildland	Acute Cross-Sectional	2.9% decrease in FEV _{1.0} 1.9% decrease in FVC
Tashkin et al. (1977)	City	One month following smoke inhalation	No changes in ventilatory capacity values
Musk et al. (1982)	City	Longitudinal 6-years	No changes in ventilatory capacity values
Tepper et al. (1991)	City	Longitudinal 6-10 years	Didn't wear masks = 1.7x greater rate of FEV _{1.0} decline
Horsfield et al. (1988)	Semi rural/semi urban	Longitudinal 4 years	No changes in ventilatory capacity values
Serra et al. (1996)	Forest and open country	Cross-sectional	4.5% reduction in FEV _{1.0} /FVC 3.5% reduction in FEV _{1.0} 0.1% reduction in FEF _{75%} 14.7% reduction in FEF ₅₀ 20.7% reduction in FEF _{25%}

As demonstrated in Table 3 the majority of studies measuring the effects of firefighting on ventilatory capacity involved either wildland/forest firefighters (Serra et al., 1996; Rothman et al., 1991) or city firefighters (Musk et al., 1982; Tashkin et al., 1977; Tepper et al., 1991). In fact, only Horsfield et al. (1988) in a study involving semi rural and semi urban firefighters had any representation of rural firefighters. The author hasn't found any studies, cross-sectional or longitudinal, utilizing a population of military firefighters.

The wide range of results and conclusions as expressed in table 3 may be attributable to the variation in methodologies, the more frequent use of respiratory protection and/or the simple fact that ventilatory capacity testing may still lack the sensitivity to detect subclinical pulmonary function changes.

Differences in methodologies were evident in the Tepper et al. (1991), Tashkin et al. (1977) and Musk et al. (1982) studies. For instance, Tepper et al., (1991) compared the use of respiratory protection between groups over a six and ten year period while the Musk et al. (1982) and Tashkin et al. (1977) only measure longitudinal changes.

The high fraction of smokers observed in some studies (66% for Serra et al. (1996), 50% for Tepper et al. (1991)) could also explain some of the reported lung function reduction. It has been demonstrated that smokers tend to have lower respiratory function than non-smokers (Twisk et al., 1998).

2.7 Diving and ventilatory capacity

Acute effects of underwater diving on ventilatory capacity

In order to fully understand the cumulative effects of hyperbaria, one must understand the immediate or acute response to exposure. It has been suggested with hyperoxia as a breathing medium and during deep saturation dives, that repetitive acute exposures to hyperbaria could cause further permanent or chronic adaptations to the pulmonary system (Thorsen et al., 1994).

The acute effects of underwater diving on ventilatory capacity are not directly due to water immersion itself but likely to the increased pressures and breathing resistance resulting from increased depth. This was confirmed by Brechat et al (1999) who found no differences in respiratory mechanics between a cycle ergometer test in water immersion or on land. Lanphier

and Camporesi (1993) attributed the lung function adaptation to the demanding nature and increased depth caused by increased ambient pressure, raised partial pressure of O₂, increased resistance to movement, added weight and drag of diving equipment, cold stress and a higher breathing resistance. Evidence of acute effects is contradictory at best as wet and dry dives simulating various depths and duration have provided inconsistent results. The wide range of results and conclusions highlighted in table 4 may be attributable to the variation in methodologies and/or the simple fact that pulmonary testing may still lack the sensitivity to detect subclinical pulmonary function changes.

Table 4. Effects of Acute Exposures of Underwater Diving on Ventilatory Capacity.

Reference	Dive Type	Equivalent Diving Depth	% change
Catron et al. (1986)	Air	87 MSW	No changes in dynamic lung function
Thorsen et al (1990a)	Saturation	360 MSW	No changes in dynamic lung function
Clark et al. (1991)	Air	99 MSW	5.9% reduction in FEV _{1.0} 11.9% reduction in FEF _{25-75%}
Thorsen et al (1993b)	Saturation	25 MSW	9% reduction in FEF _{25-75%}
Thorsen et al. (1994)	Saturation	450 MSW	3.7% reduction in FEF _{25-75%}
Susuki (1994)	Saturation	450 MSW	No changes in FVC
Skogstad et al (1996)	Air	10-15 MSW	reduction in FEV _{1.0} reduction in FEF _{25-75%} reduction in FVC
Tetzlaff et al. (1999)	Air	50 MSW	No changes in dynamic lung function

Studies by Catron et al. (1986) and Tetzlaff et al. (1999) found no difference between wet and dry chamber dives between 87 and 50 meters of sea water respectively, suggesting that the increased breathing resistance does not contribute to changes in pulmonary function, FVC, FEV_{1.0} & FEF_{25-75%} within 24 hours after dives. In contrast, Thorsen (1994) with deep saturation

dives using hyperoxia as a breathing medium demonstrated significant decreases in $FEF_{25-75\%}$ but no changes in FVC and $FEV_{1.0}$ suggesting that hyperoxia, venous gas microembolism (VGM) and hyperbaria may be responsible for acute pulmonary function changes to $FEF_{25-75\%}$ after a single saturation dive.

Studies using compressed air divers reported similar $FEF_{25-75\%}$ decreases, albeit with a relatively low n value but in addition also found significant reductions in $FEV_{1.0}$ (Clark et al. 1991, Skogstad et al 1996) and in one instance with FVC (Skogstad et al 1996). The comparison between Skogstad et al. (1996) and Thorsen et al. (1994) is interesting considering Thorsen's subjects were exposed to greater depths for a prolonged exposure of 3-27 days. Those subjects did not demonstrate reduction in $FEV_{1.0}$ and FVC. In contrast, Skogstad's study subjects who were exposed to short air bounce dives demonstrated a reduction in FVC, $FEV_{1.0}$ and $FEF_{25-75\%}$. As the divers in Skogstad's research were breathing air and performing relatively shallow dives neither hyperoxia nor venous gas microembolism (VGM) would have contributed to the changes encountered with respect to pulmonary function. As a result a definite argument can be made for hyperbaria playing a predominate role over hyperoxia and venous gas microembolism (VGM) in causing these acute changes in dynamic lung function.

A possibly explanation for the conflicting results of diving on FVC between the studies from Thorsens et al. (1994) and Skogstad et al. (1996) maybe attributable to the nature of diving exposure. Deep saturation diving is multifactorial in nature and may cause conflicting influences on FVC. The increase in gas density and breathing resistance cause a training effect on respiratory muscles possible leading to and increase FVC while the increase depth and venous gas microembolism (VGM) and oxygen toxicity may result in decreasing FVC thus negating any effect. This could have been the case with Thorsen's study (1994) but subjects in the Skogstad

study (1996) would only have been exposed to an increase in gas density and breathing resistance which ultimately resulted in an increase of forced vital capacity (FVC).

In most studies where effects of short air or saturation dives on pulmonary function were reported changes were reversible and seemed to normalize within four to six weeks (Bouhuys et al., 1979, Cotes et al. 1986). Nevertheless, the possible health implication of acute diving exposures remains an important factor in understanding longer term effects of diving on ventilatory capacity.

Underwater Saturation Diving and long term effects on ventilatory capacity

For the most part the studies on the chronic respiratory effects of routine or shallow air bounce dives are relatively scarce. Saturation diving is considered experimental and borderline, as a result most researchers choose to focus their energy on saturation diving. The term saturation signifies that a diver can stay at greater depth long enough for the gas dissolved in tissues to be equilibrated with the partial pressure of gas in the environment. Divers can therefore remain at depth for days and thus reducing the number of times a divers is exposed to potentially dangerous decompression. Saturation divers are thus exposed to greater depths for much longer periods of times when compared to their air diver counterparts. A summary of the effects of long term saturation dives on dynamic lung function are reviewed in table 5.

Table 5. Effects of Long Term Exposures of Saturation Diving on Ventilatory Capacity

Reference	Years of diving or diving depth	% change
Thorsen (1990b)	Comparison with control group and reference values	7.2% reduction in FEV _{1.0} 5% reduction in FEV _{1.0} /FVC 28% reduction in FEF _{25-75%}
Thorsen et al (1993a)	1-4 yrs 460MSW dive	210 ml reduction in FEV _{1.0} 323 ml reduction in FEF _{25-75%}
Susuki (1994)	450 MSW	No changes in FVC
Thorsen et al. (1994)	450 MSW	3.7% reduction in FEF _{25-75%}

MSW: Metres of Sea Water

Thorsen et al. (1990b) demonstrated lower values for FEV_{1.0}, FEV_{1.0}/FVC ratio and FEF_{25-75%}, associated with saturation diving exposure when compared to a matched control group and external reference values from non-smoking segments of populations suggesting a cumulative long term effect of diving on pulmonary function. Significant FVC differences were also reported between divers, controls and three out of the four external reference values (Thorsen et al. 1990b). Lower forced vital capacity values for divers in comparison to external reference values are somewhat interesting considering divers are often considered part of a select group with larger than predicted lung volumes (Crosbie et al. 1979, Davey et al. 1984, Watt 1985). A possible flaw in the Thorsen study (1990b) is that age, height and smoking status were the only variables considered when comparing anthropometric data with the control group and external reference values. Other factors such as body mass and ethnic group are also important determinants of lung size (Quanjer et al. 1993). Nevertheless similar results were reported during a one and four year longitudinal study with both saturation and reference divers (Thorsen, et al. 1993a) indicating the development of airflow limitation in relation to diving.

Long term effects of Underwater Air Diving on dynamic lung function

Davey and al. (1984) was the first longitudinal study to associate lung function adaptation with non saturation divers and years of underwater diving. The study showed that changes in

FVC was positively correlated with increased maximal depth while FEV_{1.0}/FVC was negatively associate with diving depth. No correlation was associated with FEV_{1.0} and diving exposure. Subsequent studies on the effects of long term air dives on dynamic lung function are reviewed in table 6.

Table 6. Effects of Long Term Exposures of Underwater Diving on Ventilatory Function

Reference	Years of diving experience and/or diving depth	% change
Davey et al (1984)	5 yrs	Increase in FVC Reduction in FEV _{1.0} /FVC
Clark et al. (1991)	99 MSW	5.9% reduction in FEV _{1.0} 11.9% reduction in FEF _{25-75%}
Bermon et al. (1994)	8-9yrs of diving	Higher FVC Higher FEV _{1.0} No longitudinal change
Tetzlaff et al. (1999)	50 MSW	No changes in dynamic lung function
Skogstad et al (2000)	3yrs of diving at 10- 50 MSW	1.8% reduction in FEV _{1.0} 6.5 % reduction in FEF _{25-75%}

MSW: Metres of Sea Water

In many instances researchers associated diving exposure with maximal depth based on the subjects' estimates of personal diving exposure. While this is plausible it leaves room for some doubt as to the measurement accuracy of diving exposure. Without reference log books much of the quintessential information necessary in quantification of diving exposure such as time and gas pressure are not available.

Bermon et al. (1994) reported similar results with a firemen-diver population over eight and nine years of diving suggesting possible chronic effects of diving on small airways. Cross-sectional analysis of a firemen-diver population demonstrated larger FVC, FEV_{1.0} and lower residual volume when compared to external reference values from non-smoking segments of

populations. Longitudinal analysis also showed a smaller FVC reduction than FEV_{1.0} reduction leading to a FEV_{1.0}/FVC decrease with time. Davey et al. (1984) showed no association between small airflow reduction and diving history, possibly due to the small n value of 20. Another basic issue is that the population selected had firefighting duties above and beyond regular diving responsibilities, as a result it remains unclear what extent specific firefighting pollutants, fumes and toxic substances would have added to the lung function deterioration.

In a later study by Skogstad et al. (2000) characterising diving exposure and pulmonary function in professional divers for the first three years of a diving career demonstrated, as many others (Clifford et al. 1984, Corsbie et al. 1979; Davey et al. 1984), an initial larger than predicted lung capacity for divers. Skogstad et al.(2000) demonstrated a slight increase in FVC over the first three years of diving along with a significant decrease in FEV_{1.0} and FEF_{25-75%} but again no association with diving exposure.

The patterns of change are not dissimilar between acute and chronic effects of diving on ventilatory capacity which leads one to suggest that the effects of single dives may be cumulative leading to a long term loss of ventilatory capacity. Nevertheless, it is clear from the review that further research on routine shallow dives below 100 m and better quantification of diving exposure along with further cross-sectional and longitudinal data on commercial, military and other diving populations are still required before findings can be considered conclusive.

CHAPTER 3

METHODOLOGY

3.0 Subjects

A) The study participants consisted of healthy non-smoking Caucasian male CF Firefighters (Table 7). Twenty-eight firefighters from Canadian Forces Base (CFB) Bagotville, (Québec) were invited to participate. Of these, four declined and six were subsequently excluded due to their smoking habits, leaving a total of eighteen firefighters (treatment group) for the study. For safety precautions all participants were required to have completed an approved Canadian Forces physical fitness evaluation within the fiscal year of the main data collection.

CF Firefighters were compared with a control group of fifteen healthy non-smoking Caucasian males from the Canadian Forces Support Unit Ottawa (CFSU Ottawa) with no previous firefighting experience. Ex-smokers were classified as non-smokers if they had remained smoke free for at least 12 months prior to the study. Both treatment and control participants were provided with background information (refer to appendix 3 and 4) and gave informed consent (refer to appendix 6 and 7) prior to enrolling in the study. The protocol and informed consent received institutional approval from the University of Ottawa Research Ethics Board (refer to appendix 1) and DND (refer to appendix 2)

The assessment of ventilatory capacity and administration of questionnaires (refer to appendix 9 and 10) were performed between April 2004 and January 2005 for treatment and controls respectively. Ventilatory capacity results were compared with controls and external reference values from non-smoking segments of populations using regression equations (Miller et al.,1986; Quanjer et al., 1993) to estimate values for firefighters.

Table 7. Study Overview Experiment 1.

Study Group	Measurement period	Number of participants	Measurements performed	Background information collected
Firefighters	May 2004	18	-Height, Weight -FVC, FEV _{1.0} , FEV ₁ /FVC, FEF _{25-75%} , FEF _{75%}	-firefighting exposure and physical activity questionnaire
CF Members	November 2004 to January 2005	15	-Height, Weight -FVC, FEV _{1.0} , FEV ₁ /FVC, FEF _{25-75%}	-firefighting exposure and physical activity questionnaire

B) The study participants consisted of 15 Caucasian non-smoking male CF Divers stationed in Ottawa, Ontario and 16 Caucasian male CF Firefighters employed at 3 Wing Bagotville, Québec (Table 8). The CF Divers (treatment group) were compared with a group of non-smoking Caucasian males firefighters with no previous diving experience. For safety precautions all participants were required to have completed an approved Canadian Forces physical fitness evaluation within the fiscal year of the main data collection. Ex-smokers were classified as non-smokers if they had remained smoke free for at least 12 months prior to the study. Participants were provided with background information (refer to appendix 3 and 5) and gave informed consent (refer to appendix 6 and 8) prior to enrolling in the study. The protocol and informed consent received institutional approval from the University of Ottawa Research Ethics Board (refer to appendix 1) and DND (refer to appendix 2).

The assessment of ventilatory capacity, maximal oxygen uptake and administration of the questionnaires were performed in April 2004 and January 2005 for firefighters and divers respectively. Ventilatory capacity results of divers were compared with firefighters and external reference values from non-smoking segments of the general population based on age and height,

using regression equations (Miller et al., 1986; Quanjer et al., 1993) to estimate values for divers.

Table 8. Project Overview Experiment 2.

Study Group	Measurement period	Number of participants	Measurements performed	Background information collected
CF Divers	January 2005	15	-Height, Weight -FVC, FEV _{1.0} , FEV ₁ /FVC, FEF _{25-75%} -Maximal cardiorespiratory evaluation -Ventilatory threshold	- Physical activity and diving questionnaire
CF Firefighters	May 2004	16	-Height, Weight -FVC, FEV _{1.0} , FEV ₁ /FVC, FEF _{25-75%}	- Physical activity and diving questionnaire

3.1 Protocols

Consistent with industry standard, each subject reviewed the informed consent form and complete the CF Health Appraisal Questionnaire before test and measurements. The CF Health Appraisal Questionnaire includes a Physical Activity Readiness Questionnaire (PAR Q) as well as resting blood pressure and resting heart rate measurements. All participants met American College of Sports Medicine (ACSM, 2001) pre-test screening guidelines; heart rate equal or below 100 beats/min, blood pressure equal or below 144/94 mmHg.

Ventilatory capacity

In addition to height and weight measurements, CF Firefighters, CF Divers and CF Members completed ventilatory capacity tests via basic spirometry. Ventilatory Capacity was determined using an ALPHA portable spirometer from Vitalograph Inc. (Lenexa, Kansas, USA) and administered in the same location by the same trained assessor using procedures set forth by

the American Thoracic Society (1987). The spirometer was calibrated by means of a three litre syringe prior to the morning and afternoon sessions. Participants were seated for the tests and wearing a nose-plug and asked to performed three flow maneuvers starting from a full inspiration and ending at a complete expiration. The highest of three flow-volume maneuvers for FVC, FEV₁, FEV_{1.0}/FVC, FEF_{25-75%} not differing by more than five percent of each other were retained for analysis. FVC was measured as the volume of gas exhaled during a forced expiration starting from a position of full inspiration and ending at complete expiration while FEV₁ was measured as the volume of gas exhaled in one second from the start of the forced vital capacity manoeuvre. FEF_{25-75%} was determined as the forced expiratory flow during the middle of the forced vital capacity manoeuvre.

Cardiorespiratory fitness and ventilatory threshold

Cardiorespiratory fitness was measured in divers as VO₂ max (ml kg⁻¹ min⁻¹) to assess its relationship with ventilatory capacity. The test was performed using a MOXUS-T Modular Oxygen Uptake System from AEI Technologies (Pittsburgh, Pennsylvania, USA). A modified Astrand protocol was utilized (Pollock et al., 1976). Subjects were permitted to warm-up on the treadmill for a period of 5 minutes at a self-selected speed between 8.0 and 12 kilometers per hour. For the initial 3 minutes of the test, a 0% grade was used. Every minute thereafter, the grade was increased 1% until volitional fatigue was reached. A polar S810i Heart Rate Monitor was used to monitor and record heart rate at 5 second intervals throughout the test. The test was administered by the same trained assessor and calibration were performed twice daily, in the morning prior to the testing session and in the afternoon at the mid-point of the testing sessions.

Ventilatory threshold (ml kg⁻¹ min⁻¹) was estimated during the max test based on the disproportional increase in minute ventilation when compared to oxygen uptake (Loat et al.,

1993).

Questionnaire

CF Firefighters, CF Divers and CF members completed a two part questionnaire that was reviewed with an administrator. Questionnaires were reviewed and approved by the CF Directorate of Human Resources Research and Evaluation and are included in Appendix 9 and 10. The two main components of the questionnaires were diving/firefighting exposure and levels of physical activity. Diving exposure was described on the basis of the number of years as a certified CF diver, days diving (training and work), hours diving in the previous 12 months as well as the average and maximum time spent on a single dive. Firefighting exposure was described on the basis number of years as a certified CF Firefighter, days firefighting (training and work), hours firefighting in the previous 12 months as well as the average and maximum time spent fighting fires. Physical activity was characterized as activity that is sufficiently prolonged (at least 20 min) and intense to cause sweating and a rapid heart beat. Physical activity exercise variables were base on: intensity during physical activity (light, moderate, intense) and frequency of physical activity per week (rarely or never, once or twice, three or four, five or more).

CHAPTER 4

ARTICLE 1

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Contact: Daryl Allard
Email: daryl.allard@sympatico.ca
Guarantor: Dr. Glen P. Kenny

Ventilatory Capacity of Canadian Forces Firefighters: a cross sectional study

Daryl J. Allard, BPE.^{1,2}; Glen P. Kenny 1, Ph.D.¹

1. School of Human Kinetics
125 University
Montpetit Hall
University of Ottawa
Ottawa, Ontario
K1N 6W5
Canada

2. Canadian Forces Personnel Support
Agency
Startup
101 Colonel By Drive
Ottawa ON
K1A 0K2
Canada

Running Title: Ventilatory Capacity and Firefighting

Address of Correspondence to:

Glen. P. Kenny, PhD.
University of Ottawa
Faculty of Health Sciences
School of Human Kinetics
Laboratory of Human Bioenergetics
and Environmental Physiology
125 University Ave.
Ottawa Ontario
K1N 6W5
(613) 562-5800 ext. 4282
(613) 562-5149 (Fax)
gkenny@uottawa.ca

Ventilatory Capacity, Firefighting,
Military, Physical Fitness, Spirometry

Abstract

This study was conducted to compare ventilatory capacity in Canadian Forces Firefighters with those of non firefighting Canadian Forces personnel. Further we examine changes in ventilatory capacity in relation to firefighting exposure and levels of physical activity.

Eighteen Canadian Forces Firefighters and 15 controls completed a two part questionnaire to measure firefighting exposure and levels of physical activity. Subjects also underwent ventilatory capacity testing including forced vital capacity (FVC), forced expiratory volume in 1 s (FEV_1), FEV_1/FVC as well as maximal expiratory flow rates (FEF) at 25-75% and 75% of FVC.

The results showed that firefighters possessed normal ventilatory capacity values when compared to controls and external reference values from non-smoking segments of populations. Positive correlations were found between intensity of exercise with FVC and FEV_1 while frequency of physical activity was correlated with FEV_1/FVC . No relationship was found between years of firefighting or hours of firefighting in the previous 12 months with ventilatory capacity values.

These results indicate no evidence of lung impairment for Canadian Forces Firefighters when compared to non-firefighting Canadian Forces personnel but suggest higher ventilatory capacity values for those who maintain a physically active lifestyle.

Introduction

Firefighting in both civilian (1,2) and military (3) settings is one of the most physically demanding occupations requiring high levels of physical fitness (4). In addition to a high level of physical fitness, ventilatory capacity plays an important role in assuring safe and effective performance. Studies demonstrate that use of a self contained breathing apparatus can significantly increase the work of breathing (5,6). This increased demand combined with the weight and restrictive nature of the equipment has been shown to decrease work capacity as measured by a 15-20% decrease in maximal oxygen uptake (7,8). Based on these findings Bascom et al. (9) subsequently recommended that occupational groups such as firefighters meet a minimal standard for ventilatory capacity equal to 80% of FVC (Force Vital Capacity) and 70% of FEV_{1.0}/FVC (Force Expiratory Volume/ Force Vital Capacity). These values were defined based on comparative values obtained from non-smoking general population group.

Canadian Forces Firefighters are typically exposed to stressful and adverse environments and potentially harmful toxins from burning material. For example, toxins such as acrolein and benzene from these burning materials has been shown to impact lung function and therefore exacerbate the age related decrease in ventilatory capacity as measured as a decrease of 4.1% for FEV_{1.0} per decade in a normal population group (10). This effect combined with a potential decrease in ventilatory capacity attributed to a decrease in the levels of physical fitness and/or physical activity may result in a significant performance decrement and increased risk of short and long term health injury. For example, there have been a large number of studies examining the acute (11,12,13,14,15) and chronic (16,17,18,19,20,21,22,23) response of firefighting on ventilatory capacity. A number of studies show that firefighters are at a greater risk of developing ventilatory capacity abnormalities (11,12,13,14,15,16,17,18,19) such as airway restriction and

small airway dysfunction, albeit some studies suggest that there is little to no effect on ventilatory capacity (20,21,22,23).

Any potential decrease in ventilatory capacity whether attributed to: 1) occupational exposure, 2) age, 3) decreases in levels of physical activity, or 4) decreases in physical fitness may significantly reduce the Canadian Forces Firefighters ability to complete strenuous tasks under adverse stressful conditions.

The recent death of a Canadian Forces Submariner on the HMCS Chicoutimi in October 2004, which was shown by a Canadian Forces board of inquiry to be related to smoke inhalation highlights the adverse environments that Canadian Forces personnel are exposed to. Advancing our understanding of those factors which may potentially increase or negatively impact ventilatory capacity and their ability to perform physically demanding tasks is important. To date there is a paucity of information regarding the relationship between firefighter's ventilatory capacity with firefighting exposure and physical activity.

The following study was conducted to examine ventilatory capacity as assessed by FVC, FEV_1/FVC , FEF_{25-75} , FEF_{75} in Canadian Forces Firefighters to measure its relationship with years of firefighting, hours of firefighting in the previous 12 months and levels of physical activity. We hypothesized that firefighters would have higher FVC values and lower FEV_1 and FEV_1/FVC values as compared to 1) non-firefighting Canadian Forces personnel, and 2) predicted external reference values from the general population. Further, we evaluated the hypothesis that firefighter ventilatory capacity would be positively correlated with physical activity frequency and physical activity intensity and negatively correlate with years of firefighting and total exposure to fires in the previous 12 months.

Methods

Subjects

The study participants consisted of healthy non-smoking male Canadian Forces Firefighters (Table 1). Twenty-eight firefighters from Canadian Forces Base (CFB) Bagotville, Québec were invited to participate. Of these, four declined and six were subsequently excluded due to their smoking habits, leaving a total of eighteen participants (treatment group) for the study. The firefighters were compared with a control group of fifteen healthy non-smoking males from the Canadian Forces Support Unit Ottawa (CFSU O) with no previous firefighting experience. Ex-smokers were classified as non-smokers if they had remained smoke free for at least 12 months prior to the study. Both treatment and control participants were provided with background information and gave informed consent prior to enrolling in this study. The protocol and informed consent received institutional approval from the University of Ottawa Research Ethics Board.

The assessment of ventilatory capacity and administration of questionnaires were performed between April 2004 and January 2005 for treatment and controls respectively. Ventilatory capacity results were compared with non-firefighting Canadian Forces personnel and external reference values from non-smoking segments of populations using regression equations to estimate values for firefighters (24,25).

INSERT TABLE 1 HERE

Ventilatory Capacity

Ventilatory capacity was determined using an ALPHA portable spirometer from Vitalograph Inc. (Lenexa, Kansas, USA) and administered in the same location by the same

trained assessor using procedures set forth by the American Thoracic Society (26). The spirometer was calibrated by means of a three litre syringe prior to the morning and afternoon sessions. Participants were seated for the tests and wearing a nose-plug and asked to performed three flow maneuvers starting from a maximal inspiration followed by a maximal expiration. The highest of the three flow-volume measures for FVC, FEV_1 , $FEV_{1.0}/FVC$, $FEF_{25-75\%}$ and $FEF_{25\%}$ not differing by more than five percent of each other were retained for analysis. FVC was measured as the volume of gas exhaled during a forced expiration starting from a position of full inspiration and ending at complete expiration while FEV_1 was measured as the volume of gas exhaled in one second from the start of the forced vital capacity manoeuvre. Maximal expiratory flow rates (FEF) at 25-75% and 25% of FVC was determined as the forced expiratory flow during the middle and first quarter of the forced vital capacity manoeuvre.

Questionnaire

Both firefighters and controls completed a standardized two part questionnaire that was reviewed with an administrator. The two main components of the questionnaire dealt with levels of firefighting exposure and levels of physical activity. Firefighting exposure was defined on the basis of the number of years as a certified Canadian Forces Firefighter, hours firefighting (training and work) in the previous 12 months as well as the average and maximum time spent fighting fires. Physical activity was characterized as an activity that is sufficiently prolonged and intense so as to cause sweating and a sustained rapid heart rate for a minimum of 20 minutes. Levels of physical activity were defined based on the intensity of the physical activity (i.e. light, moderate, intense) and the frequency of physical activity over a week period (i.e. rarely or never, once or twice, three or four, five or more).

Statistical Analyses

The data analyses were performed using SPSS version 12.0 for Windows. One way analysis of variance (ANOVA) was performed to measure differences in age, height, weight and physical activity frequency between the firefighters and controls. Summary of ventilatory capacity variables of firefighters were calculated as means of total and compared via independent sample t-test with controls and paired sample two-tailed t-tests with external reference values. Reference values were derived from Quanjer et al. (25) and Miller (24) studies respectively. Bivariate Pearson correlations were subsequently performed to quantify the relationship between ventilatory capacity, firefighting exposure as well as physical activity and exercise variables. A p value less than 0.05 was considered significant.

Results

No differences were measured between firefighter and controls with respect to age, height, weight and frequency of physical activity. Significant differences were demonstrated in FEV₁/FVC between values recorded for firefighters as compared to predicted reference values from Quanjer et al. (12) (p=0.001). No other differences were found in lung volumes (FVC, FEV₁, FEV₁/FVC) or expiratory flows (FEF_{25-75%}) between firefighters and values from both controls and predicted external reference values from Miller (11) (Table 2).

Significant correlations were found between intensity of exercise and both FVC (p=0.025) and FEV₁ (p=0.022) while FEV₁/FVC ratio and FEF₂₅₋₇₅ were positively correlated with frequency of physical activity over a typical seven day period (p=0.017) (Table 3).

Significant correlations between years of firefighting and FVC and FEV₁ were found. However, partial correlations analysis shows that these measures were dependent on age rather

than years of firefighting.

INSERT TABLE 3 HERE

Discussion

The principal finding of this study is that Canadian Forces Firefighters possess normal ventilatory capacity values when compared to controls and external reference values from non-smoking segments of populations. There was no relationship between years of firefighting and hours fighting fires in the previous 12 months with any of the ventilatory capacity values. However, a positive relationship was shown between intensity of exercise and both FVC and FEV₁, while FEV₁/FVC ratio and FEF₂₅₋₇₅ were positively correlated with frequency of physical activity over a typical seven day period.

Numerous studies have reported decreases in ventilatory capacity in firefighters, albeit in civilian firefighters from large cities and urban areas (16,17,18,19). This may be expected due to the relative greater level of exposure typically associated with metropolitan and urban firefighters. For example, cross-sectional and longitudinal studies examining city, urban and wildland firefighters have shown lower FVC (14) and FEV₁ values (18, 14, 26). Further, Rothman et al. (14) showed reduction in FEF at 25, 50 and 75% of FVC among wildland firefighters. However to the best of our knowledge there have been no studies examining ventilatory capacity in military firefighting personnel.

Our results show that there is a significant difference in FEV₁/FVC as measured on Canadian Forces Firefighters study participants as compared to the Quanjer et al. external reference values for the general population (25). However when the FEV₁/FVC values were

compared to those reported by Miller (24), which is also a representation of the general population, no differences were found. This discrepancy is likely due to the fact that there exists a significant difference between external reference values from Quanjer et al. (25) and those values reported by the Miller study (24) possibly caused by differences in geographical regions which has been shown to influence ventilatory capacity values (33). No other comparisons between Canadian Forces Firefighters, controls and external reference values were measured. This observation is consistent with previous studies examining ventilatory capacity in firefighting in that no decrease in FVC, FEV₁, FEV₁/FVC or FEF flow rates at 25-75% of FVC were reported (20,21,22,23). Moreover, these studies did not show a relationship between levels of exposure and ventilatory capacity.

The reported differences between studies may be due to differences in smoking habits, differences in use and type of breathing apparatus and propensity levels of firefighting exposure. Although, few studies present data on levels of physical activity, this may also be a factor. The greater number of smokers included in some studies, for example 66% of the subjects in Serra et al. (26) and 50 % of the subjects in Tepper et al. (18) studies were smokers and could partly explain some of the reported lung function reduction. It has been demonstrated that smokers tend to have a lower ventilatory function than non-smokers (29). In our study, only non-smokers or ex-smokers, who had remained smoke free for at least 12 months, were able to participate. Thus, smoking status was not likely to have influenced Canadian Forces Firefighter's ventilatory capacity values.

Frequency of exposure and removal of the breathing apparatus may also account for some of the differences. Brandt-Rauf (1988) showed that firefighters often remove their breathing apparatus' when smoke becomes tolerable. In 26 fires, when varying levels of benzene and

hydrogene chloride were measured, firefighting did not use a breathing apparatus or removed the breathing apparatus during 14 fires. Our firefighters had an average of 5.1 hours of exposure to fires in the previous 12 months while Canadian Forces policy requires the use of respirators during training, firefighting and clean up. In previous studies involving city (21) and wildland (14) firefighters, exposure to fire ranged from over 170 fires for a single department in one year (21) to over 98 hours of firefighting in a 4-week period (14). In the case of wildland firefighters limited respiratory protection was used (14).

We observed a significant relationship between levels physical as measured by physical activity frequency and intensity with ventilatory capacity. To date there is a lack of information regarding the relationship between physical activity and ventilatory capacity of firefighters in general as well as with other occupational groups. However, our demonstration of a positive correlation between intensity of exercise and FVC and FEV₁ as well as a significant relationship between frequency of physical activity and FEV₁/FVC are consistent to previous studies of normal (28,29,30) and asthmatic (31) groups. The nature of this relationship, in one instance has been attributed to changes in the lung β -adrenergic nervous system, caused by an increase in cardiorespiratory fitness (10) while others, albeit with an older obese population, have attributed the changes to a decrease in weight rather than cardiorespiratory exercise (32). In contrast to the Womack et al. study (32), our results did not show a relationship between body mass index or body weight with any of the ventilatory capacity values. However, the type of analysis chosen for this study did not permit us to detect a cause effect relationship.

The majority of studies examining the relationship between ventilatory capacity and physical activity have focused solely on FVC, FEV₁ and FEV₁/FVC (28,29,30). To the best of our knowledge no previous studies have reported a relationship between physical activity and

exercise as it relates to FEF_{75%} and FEF_{25-75%}. However, expiratory flow rates are of particular importance to firefighting as exposure has been associated with decreases in FEF_{75%} and FEF_{25-75%} and possible obstruction of the small airways (29). Our study showed a positive relationship between levels of physical activity and both FEF_{75%} and FEF_{25-75%} values. These results suggest that a physically active lifestyle is an important factor in maintaining healthy ventilatory capacity, specifically small airway function.

Some limitations to our study are inherent. Firstly, this was a cross-sectional study to detect chronic changes in firefighter ventilatory capacity. Cross-sectional studies can detect lung impairment when values are below reference populations or controls. Longitudinal studies, on the other hand, are better suited to detect lung impairment when ventilatory capacity demonstrates an increased deterioration over time than natural deterioration typically observed through ageing (33). Another limitation is that participants are self selected to join the firefighting trade and generally have a higher than average level of physical fitness that is greater than their non-firefighter counterparts. Therefore, generalization to other groups, especially clinical populations, would have limited value.

Summary

Firefighting is a physically demanding occupation whereby the individual is regularly exposed to pollutants and by-products of fire that can have a detrimental effect on ventilatory capacity values (16, 17, 18). We showed that this effect may be attenuated through maintenance of a physically active lifestyle. Further investigation should be placed on validating the relationship of ventilatory capacity with physical activity, cardiorespiratory fitness and exposure to potentially toxic environments.

Acknowledgements

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List of Tables

Table 1. Mean age, height, weight, firefighting experience and activity frequency of Canadian Forces Firefighters and Controls.

Table 2. Firefighter ventilatory capacity values compared with controls and external reference values adjusted for age, height and smoking status.

Table 3. Bivariate pearson correlations between Physical activity intensity and frequency with selected ventilatory capacity variables.

Table 1.

	N	Age (yr)	Height (cm)	Weight (kg)	FF Experience (yrs)	Activity (session/wk)
Firefighters	18	37 (9.7) ⁽¹⁾	176.1 (4.6)	90.0 (13.3)	14.7(11.3)	3.9 (0.7)
Controls	15	33 (3.7)	176.0 (6.6)	82.1 (9.3)	0.00	4.1 (0.5)

Note: (1) SD: Standard Deviation; FF: Firefighting; session/wk: session per week

Table 2.

	FVC (litres)	FEV₁ (litres)	FEV₁/FVC	FEF_{25-75%} (litres/sec)
Firefighters	4.97 (0.73) ⁽¹⁾	4.1 (0.65)	82.5 (4.75)	4.11 (1.09)
Controls	5.50 (0.93)	4.27 (0.59)	79.1 (9.02)	3.95 (1.32)
Quanjer et al.	4.83	3.99	**86.91 (p=0.001)	4.5
Miller	5.08	4.18	81.48	---

Note: (1) SD: standard deviation; FVC: forced vital capacity; FEV₁: forced expiratory volume in one second; FEF_{25-75%}: maximal expiratory flow at 25-75% of FVC; * indicates a level of significance at p (0.05); ** indicates significance at p(0.01); Quanjer et al., (1993); Miller (1986).

Table 3.

	FVC	FEV₁	FEV₁/FVC	FEF_{25-75%}	FEF_{75%}
Intensity of exercise	0.53* (p=0.025)	0.53* (p=0.022)	0.02	0.34	0.38
Frequency of physical activity (7days)	0.06	0.32	*0.56 (p=0.017)	0.46	*0.59 (p=0.011)

FVC: forced vital capacity; FEV₁: forced expiratory volume in one second; FEF_{25-75,75%}: maximal expiratory flow at 25-75% and 75% of vital capacity; * indicates a level of significance at p (0.05); ** indicates significance at p(0.01);

CHAPTER 5

ARTICLE 2

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Contact: Daryl Allard
Email: daryl.allard@sympatico.ca
Guarantor: Dr. Glen P. Kenny

Ventilatory Capacity of Canadian Forces Divers: a cross sectional study

Daryl J. Allard, BPE. ^{1,2}; Glen P. Kenny 1, Ph.D. ¹

1. School of Human Kinetics
125 University
Montpetit Hall
University of Ottawa
Ottawa, Ontario
K1N 6W5
Canada

2. Canadian Forces Personnel Support
Agency
Startup
101 Colonel By Drive
Ottawa ON
K1A 0K2
Canada

Running Title: Diving and ventilatory capacity

Address of Correspondence to:

Glen. P. Kenny, PhD.
University of Ottawa
Faculty of Health Sciences
School of Human Kinetics
Laboratory of Human Bioenergetics
and Environmental Physiology
125 University Ave.
Ottawa Ontario
K1N 6W5
(613) 562-5800 ext. 4282
(613) 562-5149 (Fax)
gkenny@uottawa.ca

Ventilatory Capacity, Diving,
Military, Physical Fitness, Spirometry

Abstract

This study was conducted to evaluate cross-sectional ventilatory capacity changes in Canadian Forces (CF) Divers and to examine its relationship with diving exposure, maximal oxygen uptake and levels of physical activity.

Fifteen CF Divers and sixteen CF Firefighter completed a two part questionnaire to measure diving exposure and levels of physical activity. Subjects underwent ventilatory capacity testing including forced vital capacity (FVC), forced expiratory volume in 1 s (FEV_1), FEV_1/FVC as well as maximal expiratory flow rates (FEF) at 25-75% of FVC. CF Divers also completed a direct maximal oxygen uptake and ventilatory threshold evaluation.

The results illustrate that CF divers possess higher FVC values when compared to firefighters and external reference values. Positive Correlations were found between intensity of exercise with FEF_{25-75} and FEV_1/FVC . Maximum and average diving depth during a single dive was correlated with FEF_{25-75} and FEV_1/FVC . No other relationship was found between diving exposure and any other ventilatory capacity values.

These results indicate higher FVC values for CF Divers and suggest higher ventilatory capacity values for those who exercise at higher intensities.

Introduction

Underwater diving exposes human to a foreign hyperbaric environment that has been shown to increase the work of breathing (1,2), reduce minute ventilation at various levels of physical activity (3,4) and increase the oxygen costs of exercise (5). The added work of breathing combined with a decrease in ventilatory capacity due to long term hyperbaric exposure may increase the risk of breathlessness at exercise and significantly reduce the diver's ability to complete physically demanding tasks efficiently and safely.

Cross-sectional and longitudinal studies have described an association between diving and reduced ventilatory capacity. These studies have reported increases in forced vital capacity (FVC) (6,7,8) and reductions in expiratory airflow rates such as forced expiratory volume in one second ($FEV_{1.0}$) (6,7,9) and maximal mid-expiratory flow rate ($FEF_{25-75\%}$) (4,6,8,10). Studies investigating diving exposure and ventilatory capacity have usually focused on saturation divers who dive at depths of 100 meters of sea water and deeper with dives that can typically last from 2-3 weeks (11). Few studies to date have investigated ventilatory capacity of divers who dive in shallow water, up to 50 meters, and employ a compressed air breathing apparatus and even fewer have investigated the relationship with levels of physical activity of those who use 100% oxygen as a breathing gas.

Task related requirements for CF Divers tend to be far more demanding and stressful than tasks associated with most traditional industrial diving trades (e.g. welding, construction). CF Divers are typically the first responders at accident sites and the first to see the wreckage of plain and ship disasters. They are exposed to dangers of razor sharp metals and entrapment amid unpredictable and physically demanding environments. Factors such as cardiorespiratory fitness and ventilatory capacity values which may limit or increase performance to diving in these

physically demanding conditions is of particular importance. There currently exists a paucity of information regarding the performance characteristics and physiological factors which may limit performance to diving in these conditions. Of particular importance, is the need to advance our understanding of the relationship of ventilatory capacity with diving exposure, maximal oxygen uptake, ventilatory threshold and levels of physical activity.

The following study was conducted to investigate the relationship of ventilatory capacity of divers (FVC, FEV₁/FVC, FEF_{25-75%}) with physical activity and diving exposure variables. Physical activity variables were measured as maximal oxygen uptake, physical activity frequency and intensity of physical activity. Diving exposure was measured as years as a certified CF diver, maximum and average diving depth, and dive time in the previous 12 months. Measurements were compared with a group of CF Firefighters and external reference values from non-smoking segments of populations (12,13). We tested the hypothesis that divers would have higher FVC values and lower FEV₁, FEV₁/FVC, FEF_{25-75%} values as compared to age and size matched controls and external reference values from normal populations. Further, we evaluated the hypothesis that CF Divers' ventilatory capacity would be positively correlated with cardiorespiratory capacity (VO₂ max ml kg⁻¹min⁻¹), physical activity frequency and intensity, and negatively correlate with diving exposure as measured by maximum and mean diving depth and years as a professional diver.

Methods

Subjects

The study participants consisted of 15 Caucasian non-smoking male CF Divers stationed in Ottawa and 16 Caucasian male CF Firefighters employed at 3 Wing Bagotville, Québec (Table 1). The CF Divers (treatment group) were compared with a control group of non-smoking Caucasian males firefighters with no previous diving experience. The diving group was aged from 26 to 42 years with an average of 8.5 years of diving experience. Firefighters were aged from 20 to 55, with an average of 13 years firefighting experience. Ex-smokers were classified as non-smokers if they had remained smoke free for at least 12 months prior to the study. Participants were provided with background information and gave informed consent prior to enrolling in this study. The protocol and informed consent received institutional approval from the University of Ottawa Research Ethics Board.

The assessment of ventilatory capacity, maximal oxygen uptake and administration of the questionnaires were performed in April 2004 and January 2005 for firefighter controls and divers respectively. Ventilatory capacity results were compared with controls and external reference values from non-smoking segments of the general population based on age and size, using regression equations to estimate values for divers (12,13).

INSERT TABLE 1 HERE

Ventilatory Capacity

Ventilatory capacity was determined using an ALPHA portable spirometer from Vitalograph Inc. (Lenexa, Kansas, USA) and administered in the same location by the same

trained assessor using procedures set forth by the American Thoracic Society (14). The spirometer was calibrated by means of a three litre syringe prior to the morning and afternoon sessions. Participants were seated for the tests and wearing a nose-plug and asked to performed three flow maneuvers starting from a full inspirations and ending at a complete expiration. The highest of three flow-volume maneuvers for FVC, FEV₁, FEV_{1.0} /FVC, FEF_{25-75%} not differing by more than five percent of each other were retained for analysis. FVC was measured as the volume of gas exhaled during a forced expiration starting from a position of full inspiration and ending at complete expiration while FEV₁ was measured as the volume of gas exhaled in one second from the start of the forced vital capacity manoeuvre. FEF_{25-75%} was determined as the forced expiratory flow during the middle of the forced vital capacity manoeuvre.

Cardiorespiratory Capacity and Ventilatory threshold

Cardiorespiratory capacity was assessed in divers as VO₂ Max (ml·kg⁻¹·min⁻¹). The VO₂ max test was performed using a MOXUS-T Modular Oxygen Uptake System from AEI Technologies (Pittsburgh, Pennsylvania, USA). A modified Astrand protocol was utilized (15). Subjects were permitted to warm-up on the treadmill for a period of 5 minutes at a self-selected speed between 8.0 and 12 kilometers per hour. For the initial 3 minutes of the test, a 0% grade was used. Every minute thereafter, the grade was increased 1% until volitional fatigue was reached. A polar S810i Heart Rate Monitor was used to monitor and record heart rate at 5 second intervals throughout the test. The test was administered by the same trained assessor and calibrations were performed twice daily, in the morning prior to the testing session and in the afternoon at the mid-point of the testing sessions.

Ventilatory threshold (ml·kg⁻¹·min⁻¹) was estimated during the VO₂ max test based on the

disproportional increase in minute ventilation when compared to oxygen uptake (16).

Questionnaire

Both divers and firefighter controls completed a standardized two part questionnaire that was reviewed with an administrator. The two components of the questionnaire were diving exposure and physical activity levels. Diving exposure was described on the basis of the number of years as a certified CF diver, days diving (training and work), hours diving in the previous 12 months as well as the average and maximum time spent on a single dive. Physical activity was characterized as activity that is sufficiently prolonged (at least 20 min) and intense to cause sweating and a rapid heart beat. Physical activity exercise variables were based on: intensity during physical activity (light, moderate, intense) and frequency of physical activity per week (rarely or never, once or twice, three or four, five or more).

Statistical Analyses

The data analyses were performed using SPSS version 12.0 for Windows. One way analysis of variance (ANOVA) was performed to measure differences in age, height, weight and physical activity frequency between the CF Divers and controls. Summary of FVC, FEV₁, FEV₁/FVC, FEF_{25-75%} of CF Divers were calculated as means of total and compared via independent sample two-tailed t-tests with controls and paired sample t-test with external reference values derived from the European Coal and Steel Community (ECCS) (13) and Miller (12) studies respectively.

Bivariate Pearson correlations were subsequently performed to quantify the relationship between above mentioned ventilatory capacity values with physical activity and diving

exposure variables from the questionnaire with the addition of VO_2 max and ventilatory threshold. A p value less than 0.05 was considered significant.

Results

No differences were measured between firefighter and controls with respect to age, height, weight and frequency of physical activity (Table 1).

Comparisons between diver ventilatory function with values from both firefighters and predicted reference equations (12,13) revealed that CF Divers had significantly higher FVC values when compared to firefighters ($p=0.033$) and Miller (12) ($p=0.021$) (Table 2). Significant differences were also demonstrated with FEV_1/FVC values recorded for CF Divers and predicted values from ECCS (13) ($p=0.001$). No other differences between FEV_1 , FEV_1/FVC , $\text{FEF}_{25-75\%}$ of CF Divers and controls were observed and values remained within normal ranges when compared to the external reference values from non-smoking segments of populations (12,13) (Table 2).

INSERT TABLE 2 HERE

Subject had a mean VO_2 max of $52.2 \text{ ml kg}^{-1} \cdot \text{min}^{-1}$ (range 45-55 $\text{ml kg}^{-1} \cdot \text{min}^{-1}$) and an average ventilatory threshold of $34.75 \text{ ml kg}^{-1} \cdot \text{min}^{-1}$ (range 27.7- 40.8). Questionnaire results revealed significant correlations between intensity of exercise and both FEV_1/FVC ($p= 0.036$) and $\text{FEF}_{25-75\%}$ ($p=0.014$) (table 3). None of the other physical activity parameters (VO_2 max, frequency of physical activity) were correlated with any of the measured ventilatory capacity values.

The mean dive time for CF Divers in the past 12 months was 15 hours, mean maximum depth was 43 feet and average depth was 25 feet. Average dive time during a single dive was 77 minutes and significantly correlated with both FEV₁/FVC (p=0.011) and FEF_{25-75%} (p=0.006). Similarly, significant correlations were found between maximum dive time during a dive and FEV₁/FVC (p=0.03) and FEF_{25-75%} (p=0.014). Additionally, a significant correlation between years of diving and FEV₁ was measured. However, partial correlations analysis illustrate that the correlations between years of diving and FEV₁ were dependent on age rather than years of diving (Table 3).

INSERT TABLE 3 HERE

Discussion

The principal finding of this study was the significantly larger FVC in CF Divers compared to firefighter and external reference values from non-smoking segments of populations from Miller (12). Analyses of divers also revealed a positive correlation between average and maximum diving time and expiratory flow rates, namely FEV₁/FVC and FEF_{25-75%}. Additionally exercise intensity was positively correlated with FEV₁/FVC & FEF_{25-75%}.

Previous cross-sectional studies have reported increases in forced vital capacity (FVC) (6,7,8,9,17), reduction in both expiratory airflow such as forced expiratory volume in one second (FEV_{1.0}) (6,7,9,17) and maximal mid-expiratory flow rate (FEF_{25-75%}) (6,7,8,9,17). To the best of our knowledge, our study is the first to examine the effects of diving on ventilatory capacity with military oxygen divers.

We measured larger FVC values in CF Divers when compared to both controls and

external reference values (12). These results are consistent with previous studies involving compressed air divers which showed large lung volumes in divers when compared to predicted values (17) and controls (8) but vary from other cross-sectional studies with recreational (18) and oxygen divers (10). It is plausible that differences could be attributed to comparisons with improperly selected external reference values in which changes in ventilatory capacity can take place without being detected. For example both Tetzlaff (10) and Lemaire (18) reported differences in smoking status and age between divers and controls. Forty four percent of controls and 29% of divers were smokers for the Tetzlaff study (10) while 34 % of controls and 21% of divers were smokers for the Lemaire study (18). In addition there was a 4 year difference in age between the controls and treatment groups in both studies which may have accounted for some of their findings.

In this study, firefighters were selected based on similar age, gender, size and ethnic group characteristics when compared with the CF Diver population. In addition, firefighters', as divers, were self selected to join their respective trade, underwent a thorough screening process, were members of the CF, met an annual fitness evaluation and were all non-smokers. Thus the influence of smoking status, fitness or health conditions on ventilatory capacity would be limited.

Previous studies have shown that measured increases in FVC in divers when compared to control groups could be attributed to a number of factors. These factors include regular ventilatory training during sports (8), high density breathing gas (7) or simply the healthy worker effect in which divers had higher FVC values at the onset of their diving career (9). Firefighter controls exhibited similar physical activity participation patterns when compared to divers, are also self-selected to join their occupation and yet did not possess higher FVC values than reference values. Thus, the observed increased FVC values in divers is more likely related to the

density of the breathing gas (7) rather than physical activity levels (8) or the healthy worker effect (9).

Our results show that there is a significant difference between CF Divers FEV₁/FVC and ECCS external reference values for the general population(13). However when diver FEV₁/FVC values are compared to the Miller study (12), also for the general population, no differences were found. This discrepancy is likely due to the fact that there exists a significant difference between ECCS reference values (13) and external reference values from Miller (12). No other comparisons between CF Divers and both controls and external reference values revealed significant differences in FEV₁, FEV₁/FVC or FEF₂₅₋₇₅. This observations is consistent with previous air study findings (9, 19).

Analyses revealed a positive correlation between maximum and average diving depth with FEF₂₅₋₇₅ and FEV₁/FVC. These results suggest that even though cross-sectional analysis did not detect a change in FEF₂₅₋₇₅ and FEV₁/FVC with controls and external reference values there may still be a relationship between diving depth and FEF₂₅₋₇₅ and FEV₁/FVC. Similarly, Crosbie (6,7) reported a decrease with in FEF₂₅₋₇₅ and FEV₁/FVC and Davey (8) reported a reduction in FEF₂₅₋₇₅ with diving depth.

Based on the analysis of our questionnaire, exercise intensity appears to be related with FEF₂₅₋₇₅ and FEV₁/FVC. There exist a lack of information regarding the relationship between fitness and physical activity with ventilatory capacity of military divers and other occupational groups. However, examination of other studies with both normal (20,21) and asthmatic (22) populations have also reported positive correlations between physical activity habits and FEV₁/FVC.

Some limitations to our study are inherent. Firstly, this was a cross-sectional study to

detect chronic changes in CF Divers' ventilatory capacity. Cross-sectional studies can detect lung impairment when values are below reference populations or controls. Longitudinal studies, on the other hand, are better suited to detect lung impairment when ventilatory capacity demonstrates an increased deterioration over time than natural deterioration typically observed through ageing (23). Another limitation is that participants are self selected to join the diving trade and were extremely fit with an average VO_2 max of over $50 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$. Therefore, generalization the results to other recreational or professional diving groups would be difficult and not recommended.

Summary

The nature of diving itself exposes divers to hyperbaric gases that over time suggest an effect on ventilatory capacity. We showed that this effect on expiratory flow rates, namely FVC, FEF_{25-75} and FEV_1/FVC , may be minimized through high intensity training. Further investigation involving larger diver populations with varying levels of physical fitness is warranted. Particular attention should be placed on further validating the relationship of ventilatory capacity with physical activity, cardiorespiratory fitness and diving exposure.

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List of Tables

Table 1. Age, height, weight, diving experience and physical activity participations of Canadian Forces Divers (n = 15) and controls (n = 16).

Table 2. Ventilatory capacity compared with controls and external reference values adjusted for age, height and smoking status.

Table 3. Bivariate Pearson correlation values between ventilatory capacity, physical activity, fitness and exercise variables.

Table 1.

	n	Age (yr)	Height (cm)	Weight (kg)	Diving Experience (yrs)	Activity (x/wk)
Divers	15	35 (3.71) ⁽¹⁾	177.9 (7.21)	88.7 (8.18)	8.5(5.1)	4.4 (0.71)
Controls	16	38 (3.71)	176.3 (6.66)	88.5 (9.35)	0.00	4.0 (0.51)

Note: (1) SD: Standard Deviation; FF: Firefighting; session/wk: session per week

Table 2.

	FVC (litres)	FEV₁ (litres)	FEV₁/FVC (%)	FEF_{25-75%} (litres/sec)
Divers	5.67 (0.95) ⁽¹⁾	4.32 (0.35)	78.47 (9.19)	3.88 (1.27)
Controls	*4.96 (0.78)	4.12 (0.70)	83.00 (4.78)	4.20 (1.13)
ECCS	5.33 (0.59)	4.37 (0.43)	**86.91 (0.14)	*4.66 (0.19)
Miller	*5.08 (0.42)	4.21 (0.32)	78.96 (9.30)	---

Note: (1) SD: standard deviation; FVC: forced vital capacity; FEV₁: forced expiratory volume in one second; FEF_{25-75%}: maximal expiratory flow at 25-75% of FVC; * indicates a level of significance at p (0.05); ** indicates significance at p(0.01); Quanjer et al., (1993); Miller (1986).

Table 3.

	FVC	FEV₁	FEV₁/FVC	FEF_{25-75%}
Intensity of exercise	0.29	0.34	*0.55	*0.62
Frequency of Physical activity (7days)	0.50	0.07	0.49	0.19
Maximal Oxygen uptake (ml kg ⁻¹ min ⁻¹)	0.53	0.22	0.38	0.19
Ventilatory Threshold (ml kg ⁻¹ min ⁻¹)	0.28	-0.22	-0.22	-0.36
Average time during dive (min)	-0.31	0.41	**0.64	*0.66
Max time during dive (min)	-0.20	0.39	*0.56	**0.64
Diving experience (yrs)	0.22	*0.56	0.20	0.32

FVC: forced vital capacity; FEV₁: forced expiratory volume in one second; FEF_{25-75,75%}: maximal expiratory flow at 25-75% and 75% of vital capacity; * indicates a level of significance at p (0.05); ** indicates significance at p(0.01);

CHAPTER 6

DISCUSSION

6.0 Discussion

Cardiorespiratory fitness is largely dependent upon the performance of the pulmonary and cardiovascular systems. The pulmonary system, however, is not usually the limiting factor in performance and as a result a decrement in FVC, FEV_{1.0}, FEV_{1.0}/FVC ratio, and FEF_{25-75%} is not likely to impact cardiorespiratory capacity. However changes to gas density caused by hyperbaria during diving or the restrictive nature of firefighting equipment places an added demand on the pulmonary system (Van Liew, 1983). This is an important factor to consider as any diminution of ventilatory capacity combined with decreases associated with age, smoking, physical inactivity or equipment could possibly reduce exercise capacity and impact diver and firefighter safety. The overall aim of this study was to provide further insight regarding the effects of occupational exposure, such as firefighting and diving, on ventilatory capacity while examining the potential benefit of physical activity and cardiorespiratory fitness.

The first article examined ventilatory capacity (FVC, FEV₁/FVC, FEF₂₅₋₇₅, FEF₇₅) in CF Firefighters and examined its relationship with firefighting exposure and physical activity. CF Firefighter ventilatory capacity measurements were compared with a control group of 15 CF members and external reference values from non-smoking segments of populations. The results suggest that either the limited CF firefighter exposure did not cause changes in pulmonary function values or that the use of CF firefighter's respiratory protection system was sufficiently adequate to protect them against the effects of exposure to smoke and various toxins. We had hypothesized that firefighters would have higher FVC values and lower FEV_{1.0}, FEV_{1.0}/FVC

values when compared to controls and external reference values from non-smoking segments of populations. However, based on our observations we reject this hypothesis. Results did, however, show that frequency of physical activity per week and intensity of physical activity were positively correlated with CF Firefighter ventilatory capacity values suggesting that regular physical activity participation could be a factor in minimizing the effects of exposure to toxins of burning materials and thus accepting our second hypothesis.

Similar to the first study, the second study sought to quantify the relationship the relationship of ventilatory capacity of divers (FVC, FEV_1/FVC , $FEF_{25-75\%}$) with physical activity and diving exposure variables but with the addition of maximal oxygen uptake and ventilatory threshold variables. The results suggest that CF divers possess higher FVC values but that other ventilatory capacity values are normal when compared to controls and external reference values from non-smoking segments of populations accepting in part our first hypothesis. Results also showed correlations between intensity of exercise with $FEF_{25-75\%}$ and FEV_1/FVC . Maximum and average diving depth during a single dive was correlated with $FEF_{25-75\%}$ and FEV_1/FVC accepting our second hypothesis. These results suggest that even though cross-sectional analysis did not detect a change in $FEF_{25-75\%}$ and FEV_1/FVC with controls and external reference values that there may still be a relationship between diving depth and $FEF_{25-75\%}$ and FEV_1/FVC and that this relationship may be minimize through high intensity exercise.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.0 Conclusion

An overall conclusion of this work is that the effects of firefighting and diving exposure on ventilatory capacity may be minimized to some extent by maintaining a physically active lifestyle. Specifically, we showed that the only ventilatory capacity differences in CF Divers and CF Firefighters when compared with controls and external reference values was with CF Divers who demonstrated higher FVC results. Additionally we showed a positive association between physical activity constructs and ventilatory capacity.

While the focus of the research was the comparison of CF Firefighter and Diver ventilatory capacity values with similar populations and predicted values from normal populations, further research should attempt to re-examine this relationship with a larger sample size and in addition conduct a longitudinal examination of ventilatory capacity over the course of a firefighters or divers career.

There also exist a paucity of information regarding the relationship between physical activity and ventilatory capacity of occupational groups. Further investigation involving firefighters, divers and other occupational groups at risk of developing ventilatory capacity abnormalities is clearly warranted. Particular attention should be placed on further validating the relationship of ventilatory capacity with physical activity, cardiorespiratory fitness and occupational exposures.

CHAPTER 8

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APPENDIX 1

University of Ottawa Ethics Approval

HEALTH SCIENCES AND SCIENCE RESEARCH ETHICS BOARD

CERTIFICATE OF ETHICAL APPROVAL

This is to certify that the University of Ottawa Health Sciences and Sciences Research Ethics Board has examined the application for ethical approval for the research project **Dynamic lung function and cardio-respiratory fitness associated with clearance diving in the Canadian Forces (File H 06-03-02)** submitted by Daryl Allard and supervised by Glen Kenny. The Board found that this research project met appropriate ethical standards as outlined in the Tri-Council Policy Statement and in the Procedures of the University of Ottawa Research Ethics Boards, and accordingly gave it a Category 1a (approval). This certification is valid for one year from the date indicated below.

Andrée Bertrand
Protocol Officer for Ethics in Research,
For the Chairperson of the Health
Sciences and Science REB
Daniel Lagarec

August 6th, 2003
Date

August 6th, 2003

Mr. Daryl Allard
2828, Richmond Rd, Unit 26
Ottawa (Ontario)

Object: Dynamic lung function and cardio-respiratory fitness associated with clearance diving in the Canadian Forces (File H 06-03-02)

Dear Mr. Allard,

You will find enclosed the Health Sciences and Science Research Ethics Board Certification for your research project.

Please note that it is the responsibility of the researchers to:

- a) Send a copy of this approval to the Research Services, if necessary;
- b) Notify the ethics office of any changes in the research project;
- c) Fill out an annual status report to be sent to the Protocol officer for ethics in research. Such report can be found on the ethics web site at: http://www.uottawa.ca/services/research/rge/rebs/download/rapport_annuel_projets_angl_ais.doc

If you have any question, you can contact me at extension 5387.

Sincerely yours,

Andrée Bertrand
Protocol Officer for Ethics in Research
For Daniel Lagarec
Chair of the Health Sciences and Science REB

C.c: Professor Glen Kenny, School of Human Kinetics

APPENDIX 2.

Department of National Defence Approval

Director Human Resources Research and Evaluation
National Defence Headquarters
101 Colonel By Drive
Ottawa ON K1A 0K2

DHRRE RESEARCH REVIEW BOARD DECISION

Serial Number: 301/03

Title: Dynamic Lung Function and Cardio-respiratory Fitness Associated
with Diving in the Canadian Forces

Researcher: Daryl Allard

Organization: CFPSA

Review and Discussion:

1. The general idea of any research on individuals is to provide a product respecting the rules of the scientific approach and following the deontological code of behavioural sciences. Your research proposal satisfies these two requirements and is therefore approved.

2. Your project is assigned survey coordination number: 301/03. **The following text shall be displayed on the front page of your survey(s):**

DHRRE authorizes the administration of this survey within DND/CF in accordance with CANFORGEN 145/02 ADMHRMIL 079 UNCLASS 131028Z DEC 02. Authorization number: 301/03.

DRERH autorise l'administration de ce sondage dans le MDN/FC en accord vec CANFORGEN 145/02 ADMHRMIL 079 UNCLASS 131028Z DEC 02. Numéro d'autorisation : 301/03.

3. You are reminded that any changes to the approved protocol or any untoward incidents or injuries arising as a result of any subject's participation in the study shall be brought to the attention of the Committee Chairperson in writing immediately.

4. This approval is valid for the period of 18 months from the date of this meeting. Subject involvement must be complete by this date; otherwise, the protocol will require further review.

5. To ensure that the survey co-ordination function primarily serves practical rather than research interests, DHRRE requires an electronic copy of any research reports arising out of this request/project.

6. **The following disclaimer shall be presented as the first page of the research report.**

“The opinions expressed in this document are those of the author and are not necessarily those of the Department of National Defence or the Canadian Forces”

7. You are required to contact the Level 1 authorities, Maj L. Bradley and Capt N. Perron, prior to the administration of your survey in order to coordinate appropriate timings and locations. Failure to do so will result in revocation of this authorization.

8. Please accept our acknowledgements for your contribution to research within the Canadian Forces and the Department of National Defence.

(original signed by)

C.D. Lamerson, Ph.D.
Colonel
Director Human Resources Research and Evaluation
(613) 992-0244

(Forwarded 29 March 2004)

APPENDIX 3.

Background and Information Firefighter



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Faculté des sciences de la santé
École des sciences de l'activité physique

Faculty of Health Sciences
School of Human Kinetics

BACKGROUND INFORMATION FOR THE PARTICIPANT (Firefighter)

Dynamic Lung Function and Cardio-respiratory fitness associated with Clearance diving in the Canadian Forces

Investigators:

**Daryl Allard – Graduate student
Dr. Glen Kenny – Supervisor
University of Ottawa, School of Human Kinetics, Ottawa, ON**

This study is being funded by the Department of National Defence, the Canadian Forces Personnel Support Agency and conducted by the School of Human Kinetics under the supervision of Dr. Glen Kenny. Dr. Kenny can be reached at (613) 562-5800 extension: 4282.

The purpose of this study (Dynamic Lung Function and Cardio-respiratory fitness associated with Clearance diving in the Canadian Forces) is to better understand the Canadian Forces diving occupation, its possible influence on dynamic function and the benefit, if any, of cardio respiratory fitness. The research project will examine the effects of diving on dynamic lung function, specifically FVC, FEV_{1.0}, FEV_{1.0}/FVC ratio, and FEF_{25-75%} as well as its relationship with cardio-respiratory fitness¹(see definitions below).

As a participant for this study you must be physically active by virtue of having met an approved CF fitness evaluation in the previous 12 months.

If you do meet the criteria and desire to continue taking part in the project you will then be asked to complete a short questionnaire.

Your consent for the University of Ottawa and the Canadian Forces Personnel Support Agency to access your EXPRES test and dynamic lung function results¹ from 1990 to date will be solicited and followed by the completion of a short Canadian Forces Diving diving and exercise questionnaire

¹ Note: Definitions for abbreviations:

FVC – Forced Vital Capacity – The total volume of air expired after a maximal inhalation, during which time the subject is attempting to exhale as rapidly and forcefully as possible.

FEV_{1.0} – Forced Expiratory Volume in One Second – The amount of air exhaled in the first one second of a forced vital capacity maneuver.

FEF_{25-75%} - Forced Expiratory Flow – The flow rate during the middle 50% of the forced vital capacity maneuver, or from 25% to 75% of the exhaled volume.

125 rue Université C.P. 450, Succ. A
Ottawa (Ontario) K1N 6N5 Canada

125 University St., P.O. Box 450, Stn A
Ottawa, Ontario K1N 6N5 Canada

(613) 562-5800 • Téléc/Fax: (613) 562-5149



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Your anonymity is ensured throughout all aspects of this research. All data will be assigned alphanumeric codes known only to the principal investigator and will be presented in pooled form as numerical means so the identity of the subjects will not be revealed in any form. Data will be maintained in digital form in a secure laboratory, where access to the data will be restricted to the investigator and the research supervisor however since the research is conducted by the CF, data pertaining to the study it is accessible under the Access to Information and Privacy Acts. Prior to releasing requested information, the Directorate of Access to Information and Privacy (DAIP) screens the data to ensure that individual identities are not disclosed. You are encouraged to request and discuss the results at any time. All raw data will be destroyed within 3 years of the completion of the study.

For the duration of the study you may refuse to participate and/or withdraw your consent at any time, for any reason, without consequence or prejudice to you.

If you have any further questions regarding the nature of this study please feel free to contact me Daryl Allard, 613-992-4628 or my supervisor Dr. Glen Kenny at 613-562-5800 extension: 4282, or the Research Ethics Board for the University of Ottawa at ethics@uottawa.ca.

125 rue Université C.P. 450, Succ. A
Ottawa (Ontario) K1N 6N5 Canada

125 University St., P.O. Box 450, Stn A
Ottawa, Ontario K1N 6N5 Canada

(613) 562-5800 • Téléc/Fax: (613) 562-5149



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For the duration of the study you may refuse to participate and/or withdraw your consent at any time, for any reason, without consequence or prejudice to you.

If you have any further questions regarding the nature of this study please feel free to contact me Daryl Allard, 613-992-4628 or my supervisor Dr. Glen Kenny at 613-562-5800 extension: 4282, or the Research Ethics Board for the University of Ottawa at ethics@uottawa.ca.

125 rue Université C.P. 450, Succ. A
Ottawa (Ontario) K1N 6N5 Canada

125 University St., P.O. Box 450, Stn A
Ottawa, Ontario K1N 6N5 Canada

(613) 562-5800 • Téléc/Fax: (613) 562-5149

APPENDIX 4.

Background and Information CF Member



Université d'Ottawa • University of Ottawa

Faculté des sciences de la santé
École des sciences de l'activité physique

Faculty of Health Sciences
School of Human Kinetics

BACKGROUND INFORMATION FOR THE PARTICIPANT (CF Member)

Dynamic Lung Function and Cardio-respiratory fitness associated with Clearance diving in the Canadian Forces

Investigators:

**Daryl Allard – Graduate student
Dr. Glen Kenny –Supervisor
University of Ottawa, School of Human Kinetics, Ottawa, ON**

This study is being funded by the Department of National Defence, the Canadian Forces Personnel Support Agency and conducted by the School of Human Kinetics under the supervision of Dr. Glen Kenny. Dr. Kenny can be reached at (613) 562-5800 extension: 4282.

The purpose of this study (Dynamic Lung Function and Cardio-respiratory fitness associated with Clearance diving in the Canadian Forces) is to better understand the Canadian Forces diving occupation, its possible influence on dynamic function and the benefit, if any, of cardio respiratory fitness. The research project will examine the effects of diving on dynamic lung function, specifically FVC, FEV_{1.0}, FEV_{1.0}/FVC ratio, and FEF_{25-75%} as well as its relationship with cardio-respiratory fitness¹(see definitions below).

As a participant for this study you must be physically active by virtue of having met an approved CF fitness evaluation in the previous 12 months. In order to increase validity of results, you must be a non-smoker (having been smoke free for at least a year). For safety precautions volunteers with any major health problems or on medication will be excluded from participating in the study.

If you do meet the criteria and desire to continue taking part in the project you will then be asked to complete a short questionnaire.

An experimental session will be scheduled following the completion of the Canadian Forces Diving, Firefighting and Exercise Questionnaire where the lead investigator and qualified Canadian

¹ Note: Definitions for abbreviations:

FVC – Forced Vital Capacity – The total volume of air expired after a maximal inhalation, during which time the subject is attempting to exhale as rapidly and forcefully as possible.

FEV_{1.0} – Forced Expiratory Volume in One Second – The amount of air exhaled in the first one second of a forced vital capacity maneuver.

FEF_{25-75%} - Forced Expiratory Flow – The flow rate during the middle 50% of the forced vital capacity maneuver, or from 25% to 75% of the exhaled volume.

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Forces Fitness Appraisers will administer the lung function test. Your dynamic lung function will be tested via electronic spirometry. Measurements will be taken during forced inspiration and expiration when maximal effort is applied through the respiratory manoeuvre. While performing the tests you will be required to wear a nose plug and breathe through a mouthpiece. At any time during this test you may stop.

In order to achieve standardize and ease measurements, the following instructions must be followed:

- a) Foods: Do not eat for at least 2 hours prior to testing
- b) Beverages: Do not drink any caffeine beverage for 2 hours prior to testing, or alcoholic beverages for 6 hours prior to testing
- c) Exercise: Refrain for exercise 6 hours prior to testing

The following measurements will be taken during the experimental trial:

Dynamic Lung Function – An electronic spirometer will be used to assess dynamic lung function, FVC, FEV_{1.0}, FEV_{1.0}/FVC ratio, and FEF_{25-75%}. You will be required to wear a nose plug and breathe through a valve connected to the electronic spirometer.

You should be aware that there are some minor physical risks associated with any form of testing. Such risks are minimized through the screening procedure since only participants with no health conditions can take part in the study. As well, there will be registered appraisers, certified in CPR and first aid, present during field-testing. All tests will be conducted under standard exercise conditions for human exercise experiments as laid out by the Canadian Society for Exercise Physiology and the American College of Sports Medicine. Every effort will be made to ensure that these tests are conducted so as to minimize any discomfort.

Your anonymity is ensured throughout all aspects of this research. All data will be assigned alphanumeric codes known only to the principal investigator and will be presented in pooled form as numerical means so the identity of the subjects will not be revealed in any form. Data will be maintained in digital form in a secure laboratory, where access to the data will be restricted to the investigator and the research supervisor however since the research is conducted by the CF, data pertaining to the study it is accessible under the Access to Information and Privacy Acts. Prior to releasing requested information, the Directorate of Access to Information and Privacy (DAIP) screens the data to ensure that individual identities are not disclosed. You are encouraged to request and discuss the results at any time. All raw data will be destroyed within 3 years of the completion of the study.

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Ottawa (Ontario) K1N 6N5 Canada

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Ottawa, Ontario K1N 6N5 Canada

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APPENDIX 5.

Background and Information Diver



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École des sciences de l'activité physique

Faculty of Health Sciences
School of Human Kinetics

BACKGROUND INFORMATION FOR THE PARTICIPANT (DIVER)

Dynamic Lung Function and Cardio-respiratory fitness associated with Clearance diving in the Canadian Forces

Investigators:

**Daryl Allard – Graduate student
Dr. Glen Kenny –Supervisor
University of Ottawa, School of Human Kinetics, Ottawa, ON**

This study is being funded by the Department of National Defence, the Canadian Forces Personnel Support Agency and conducted by the School of Human Kinetics under the supervision of Dr. Glen Kenny. Dr. Kenny can be reached at (613) 562-5800 extension: 4282.

The purpose of this study (Dynamic Lung Function and Cardio-respiratory fitness associated with diving in the Canadian Forces) is to better understand the Canadian Forces diving occupation, its possible influence on dynamic function and the benefit, if any, of cardio respiratory fitness. The research project will examine the effects of diving on dynamic lung function, specifically FVC, FEV_{1.0}, FEV_{1.0}/FVC ratio, and FEF_{25-75%} as well as its relationship with cardio-respiratory fitness¹ (see definitions below).

As a participant for this study you must be physically active by virtue of having met an approved CF fitness evaluation in the previous 12 months. For safety precautions volunteers with any major health problems or on medication will be excluded from participating in the study.

As a participant, you will be asked to volunteer in 1 session of approximately 30 minutes. Prior to the session you will have the chance to ask questions and voice concerns you may have. You will also be asked to fill out 1) the informed consent (Appendix 2), which will attest that you understand what is required and that you possess the appropriate participation criteria.

If you do not meet the criteria you will be given an explanation why certain participant

¹ Note: Definitions for abbreviations:

FVC – Forced Vital Capacity – The total volume of air expired after a maximal inhalation, during which time the subject is attempting to exhale as rapidly and forcefully as possible.

FEV_{1.0} – Forced Expiratory Volume in One Second – The amount of air exhaled in the first one second of a forced vital capacity maneuver.

FEF_{25-75%} - Forced Expiratory Flow – The flow rate during the middle 50% of the forced vital capacity maneuver, or from 25% to 75% of the exhaled volume.

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characteristics are needed for the study. If you do meet the criteria and desire to continue taking part in the project you will then be asked to complete the diving and exercise questionnaire.

In order to achieve standardize and ease measurements, the following instructions must be followed:

- a) Dress requirements: a t-shirt, shorts or sweat pants, and running shoes.
- b) Foods: Do not eat for at least 2 hours prior to testing
- c) Beverages: Do not drink any caffeine beverage for 2 hours prior to testing, or alcoholic beverages for 6 hours prior to testing
- d) Exercise: Refrain for exercise 6 hours prior to testing

The following measurements will be taken during the experimental trial:

Dynamic Lung Function – An electronic spirometer will be used to assess dynamic lung function, FVC, FEV_{1.0}, FEV_{1.0}/FVC ratio, and FEF_{25-75%}. You will be required to wear a nose plug and breathe through a valve connected to the electronic spirometer.

Your anonymity is ensured throughout all aspects of this research. All data will be assigned alphanumeric codes known only to the principal investigator and will be presented in pooled form as numerical means so the identity of the subjects will not be revealed in any form. Data will be maintained in digital form in a secure laboratory, where access to the data will be restricted to the investigator and the research supervisor. You are encouraged to request and discuss the results at any time. All raw data will be destroyed subsequent to final publication of the study.

For the duration of the study you may refuse to participate and/or withdraw your consent at any time, for any reason, without consequence or prejudice to you.

If you have any further questions regarding the nature of this study please feel free to contact me Daryl Allard, 613-759-0865 or my supervisor Dr. Glen Kenny at 613-562-5800 extension: 4282, or the Research Ethics Board for the University of Ottawa at ethics@uottawa.ca.

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INFORMED CONSENT OF THE PARTICIPANT (Firefighter)

University of Ottawa – School of Human Kinetics Laboratory

Investigators:

Daryl Allard – Graduate student

Dr. Glen Kenny – lead investigator & supervisor
University of Ottawa, School of Human Kinetics

This study is being funded by the Department of National Defence, the Canadian Forces Personnel Support Agency and conducted by the School of Human Kinetics under the supervision of Dr. Glen Kenny. Dr. Kenny can be reached at (613) 562-5800 extension: 4282.

Having read the background information provided to me, I understand that the purpose of this study (Dynamic Lung Function and Cardio-respiratory fitness associated with Clearance diving in the Canadian Forces) is to better understand the Canadian Forces diving occupation, its possible influence on dynamic function and the benefit, if any, of cardio respiratory fitness. The research project will examine the effects of diving on dynamic lung function, specifically FVC, FEV_{1.0}, FEV_{1.0}/FVC ratio, and FEF_{25-75%} as well as its relationship with cardio-respiratory fitness¹.

I have read and understood the information presented in the information letter and I understand all the risks involved with each evaluation and the instrumentation that will be used with the tests. I understand that if I need further explanation I can consult the principle investigator before participating.

I authorize the University of Ottawa and the Canadian Forces Personnel Support Agency, to administer and conduct a battery of field test. This battery of field test is designed to evaluate

¹ Note: Definitions for abbreviations:

FVC – Forced Vital Capacity – The total volume of air expired after a maximal inhalation, during which time the subject is attempting to exhale as rapidly and forcefully as possible.

FEV_{1.0} – Forced Expiratory Volume in One Second – The amount of air exhaled in the first one second of a forced vital capacity maneuver.

FEF_{25-75%} - Forced Expiratory Flow – The flow rate during the middle 50% of the forced vital capacity maneuver, or from 25% to 75% of the exhaled volume.

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APPENDIX 6.

Informed Consent Firefighter



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dynamic lung function. This battery of field tests include FVC, FEV_{1.0}, FEV_{1.0}/FVC ratio, and FEF_{25-75%} via electronic spirometry¹.

For safety purposes during performance of the tests, if I experience intolerable discomfort, pain in the chest, shortness of breath, nausea, or dizziness, I will immediately inform the testers and terminate the task without prejudice. Instructions in regards to the conduct of each test will be given to the start of each test component.

Every effort will be made to conduct all the tests in such a manner as to minimize discomfort and risk. I acknowledge that the testing procedures have been fully explained to me and that I can withdraw my participation at any time without any explanation. I also acknowledge that I have completed an approved Canadian Forces fitness evaluation within the last 12 months.

I understand that my anonymity will be maintained at all times through the assignment of specific codes. Access will be restricted to the investigators and the data will be presented in pooled form. In any written reports or publications I will not be identified. Since the research is conducted by the CF, data pertaining to the study is accessible under the Access to Information and Privacy Acts. I understand that prior to releasing requested information, the Directorate of Access to Information and Privacy (DAIP) screens the data to ensure that individual identities are not disclosed. The only benefit to me in participating is gaining the knowledge of my dynamic lung function and learning about the research process. The investigator may however learn more about effects of underwater diving on dynamic lung function and its relationship with cardio-respiratory fitness.

I attest that I have never been made aware of any health conditions and that I am not taking medications for any health conditions that could put me at risk in this experiment. I attest that I have had a medical evaluation in the past year and am unaware of possible health conditions.

I have talked with Daryl Allard (and/or his supervisor Dr. Glen Kenny) about this study and my questions have been answered. If I have any other questions I may call him at (613) 992-4628 or contact the Research Ethics Board for the University of Ottawa at ethics@uottawa.ca.

I have been given a copy of this consent form and of the background information sheet. My participation in this research is voluntary. I am free to withdraw from the project at any time, before or during an experiment, refuse to participate and refuse to answer questions without prejudice or discrimination of any form. All raw data collected at termination of the study will be destroyed within 6 months.

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Faculty of Health Sciences
School of Human Kinetics

Volunteering subject _____

Date _____

Signature of Researcher _____

Date _____

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APPENDIX 7.

Informed Consent CF Member



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School of Human Kinetics

INFORMED CONSENT OF THE PARTICIPANT (control group)

University of Ottawa – School of Human Kinetics Laboratory

Investigators:

Daryl Allard – Graduate student

Dr. Glen Kenny – lead investigator & supervisor
University of Ottawa, School of Human Kinetics

This study is being funded by the Department of National Defence, the Canadian Forces Personnel Support Agency and conducted by the School of Human Kinetics under the supervision of Dr. Glen Kenny. Dr. Kenny can be reached at (613) 562-5800 extension: 4282.

Having read the background information provided to me, I understand that the purpose of this study (Dynamic Lung Function and Cardio-respiratory fitness associated with diving in the Canadian Forces) is to better understand the Canadian Forces diving occupation, its possible influence on dynamic function and the benefit, if any, of cardio respiratory fitness. The research project will examine the effects of diving on dynamic lung function, specifically FVC, FEV_{1.0}, FEV_{1.0}/FVC ratio, and FEF_{25-75%} as well as its relationship with cardio-respiratory fitness¹.

I have read and understood the information presented in the information letter and I understand all the risks involved with each evaluation and the instrumentation that will be used with the tests. I understand that if I need further explanation I can consult the principle investigator before participating.

I authorize the University of Ottawa and the Canadian Forces Personnel Support Agency, to administer and conduct a battery of laboratory tests. The battery of tests are designed to evaluate

¹ Note: Definitions for abbreviations:

FVC – Forced Vital Capacity – The total volume of air expired after a maximal inhalation, during which time the subject is attempting to exhale as rapidly and forcefully as possible.

FEV_{1.0} – Forced Expiratory Volume in One Second – The amount of air exhaled in the first one second of a forced vital capacity maneuver.

FEF_{25-75%} - Forced Expiratory Flow – The flow rate during the middle 50% of the forced vital capacity maneuver, or from 25% to 75% of the exhaled volume.

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dynamic lung function. This battery of tests include FVC, FEV_{1.0}, FEV_{1.0}/FVC ratio, and FEF_{25-75%} measured via electronic spirometry¹.

For safety purposes during performance of the tests, if I experience intolerable discomfort, pain in the chest, shortness of breath, nausea, or dizziness, I will immediately inform the testers and terminate the task without prejudice. Instructions in regards to the conduct of each test will be given to the start of each test component.

Every effort will be made to conduct all the tests in such a manner as to minimize discomfort and risk. I acknowledge that the testing procedures have been fully explained to me and that I can withdraw my participation at any time without any explanation. I also acknowledge that I have completed an approved Canadian Forces fitness evaluation within the last 12 months.

I understand that my anonymity will be maintained at all times through the assignment of specific codes. Access will be restricted to the investigators and the data will be presented in pooled form. In any written reports or publications I will not be identified. The only benefit to me in participating is gaining the knowledge of my dynamic lung function and cardio-respiratory fitness while learning about the research process. The investigator may however learn more about effects of underwater diving on dynamic lung function and its relationship with cardio-respiratory fitness.

I attest that I have never been made aware of any health conditions and that I am not taking medications for any health conditions that could put me at risk in this experiment. I attest that I have had a medical evaluation in the past year and am unaware of possible health conditions.

I have talked with Daryl Allard (and/or his supervisor Dr. Glen Kenny) about this study and my questions have been answered. If I have any other questions I may call him at (613) 992-4628 or contact the Research Ethics Board for the University of Ottawa at ethics@uottawa.ca.

I have been given a copy of this consent form and of the background information sheet. My participation in this research is voluntary. I am free to withdraw from the project at any time, before or during an experiment, refuse to participate and refuse to answer questions without prejudice or discrimination of any form. All raw data collected at termination of the study will be destroyed within 6 months.

Volunteering subject _____

Date _____

Signature of Researcher _____

Date _____

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APPENDIX 8.

Informed Consent Diver



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École des sciences de l'activité physique

Faculty of Health Sciences
School of Human Kinetics

INFORMED CONSENT OF THE PARTICIPANT (Diver)

University of Ottawa – School of Human Kinetics Laboratory

Investigators:

Daryl Allard – Graduate student

Dr. Glen Kenny – lead investigator & supervisor
University of Ottawa, School of Human Kinetics

This study is being funded by the Department of National Defence, the Canadian Forces Personnel Support Agency and conducted by the School of Human Kinetics under the supervision of Dr. Glen Kenny. Dr. Kenny can be reached at (613) 562-5800 extension: 4282.

Having read the background information provided to me, I understand that the purpose of this study (Dynamic Lung Function and Cardio-respiratory fitness associated with Clearance diving in the Canadian Forces) is to better understand the Canadian Forces diving occupation, its possible influence on dynamic function and the benefit, if any, of cardio respiratory fitness. The research project will examine the effects of diving on dynamic lung function, specifically FVC, FEV_{1.0}, FEV_{1.0}/FVC ratio, and FEF_{25-75%} as well as its relationship with cardio-respiratory fitness¹.

I have read and understood the information presented in the information letter and I understand all the risks involved with each evaluation and the instrumentation that will be used with the tests. I understand that if I need further explanation I can consult the principle investigator before participating.

I authorize the University of Ottawa and the Canadian Forces Personnel Support Agency, to administer and conduct a battery of field and laboratory tests. The battery of tests are designed to

¹ Note: Definitions for abbreviations:

FVC – Forced Vital Capacity – The total volume of air expired after a maximal inhalation, during which time the subject is attempting to exhale as rapidly and forcefully as possible.

FEV_{1.0} – Forced Expiratory Volume in One Second – The amount of air exhaled in the first one second of a forced vital capacity maneuver.

FEF_{25-75%} - Forced Expiratory Flow – The flow rate during the middle 50% of the forced vital capacity maneuver, or from 25% to 75% of the exhaled volume.

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evaluate dynamic lung function and cardiorespiratory fitness. This battery of tests include FVC, FEV_{1.0}, FEV_{1.0}/FVC ratio, and FEF_{25-75%} measured via electronic spirometry¹ and VO₂ max measured via a modular oxygen system.

For safety purposes during performance of the tests, if I experience intolerable discomfort, pain in the chest, shortness of breath, nausea, or dizziness, I will immediately inform the testers and terminate the task without prejudice. Instructions in regards to the conduct of each test will be given to the start of each test component.

Every effort will be made to conduct all the tests in such a manner as to minimize discomfort and risk. I acknowledge that the testing procedures have been fully explained to me and that I can withdraw my participation at any time without any explanation. I also acknowledge that I have completed an approved Canadian Forces fitness evaluation within the last 12 months.

I understand that my anonymity will be maintained at all times through the assignment of specific codes. Access will be restricted to the investigators and the data will be presented in pooled form. In any written reports or publications I will not be identified. The only benefit to me in participating is gaining the knowledge of my dynamic lung function and cardio-respiratory fitness while learning about the research process. The investigator may however learn more about effects of underwater diving on dynamic lung function and its relationship with cardio-respiratory fitness.

I attest that I have never been made aware of any health conditions and that I am not taking medications for any health conditions that could put me at risk in this experiment. I attest that I have had a medical evaluation in the past year and am unaware of possible health conditions.

I have talked with Daryl Allard (and/or his supervisor Dr. Glen Kenny) about this study and my questions have been answered. If I have any other questions I may call him at (613) 992-4628 or contact the Research Ethics Board for the University of Ottawa at ethics@uottawa.ca.

I have been given a copy of this consent form and of the background information sheet. My participation in this research is voluntary. I am free to withdraw from the project at any time, before or during an experiment, refuse to participate and refuse to answer questions without prejudice or discrimination of any form. All raw data collected at termination of the study will be destroyed within 6 months.

Volunteering subject _____

Date _____

Signature of Researcher _____

Date _____

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APPENDIX 9.

Questionnaire Firefighter and CF Member



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DIVING, FIREFIGHTING AND EXERCISE QUESTIONNAIRE

1. BACKGROUND AND HEALTH INFORMATION

Name _____ Location/Unit _____
(optional)

Date of Birth ____ - ____ - ____ Height _____ Weight _____
yyyy mmm dd

Are you a member of a visible minority group? Yes No (see insert for details)

Have you met an approved CF Physical Fitness Evaluation in the last 12 months?

Yes No

Do you or did you ever suffer from medical or health problems? Yes No

If yes, please specify:

Are you on any medications? Yes No

If yes, please specify:

Have you smoked in the last 12 months? Yes No



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2. FIREFIGHTING EXPERIENCE

Years of Experience as a Firefighter: Volunteer _____ CF: _____ Other _____

Total time you spent fighting fires in 2003: Work Time _____ Training _____

In the last calendar year (2003), please list the following:

	Length time	
	Average	Max
Work fighting fires time	_____	_____
Training firefighting time	_____	_____

3. DIVING EXPERIENCE

Are you a sport or commercial diver? Yes No (if no, go to section 4)

Years of Experience as a Diver: Sport _____ CF: _____

Have you been a:			Number years of Experience	Year Qualified
	Yes	No		
Port Inspection Diver	Yes	No	_____	_____
Ship's Diver	Yes	No	_____	_____
Combat Diver	Yes	No	_____	_____
Clearance Diver	Yes	No	_____	_____

Overall total dive time in water: _____

Total dive time in water for 2003 _____

In the last calendar year (2003), please list the following:

	Length time		Depth	
	Average	Max	Average	Max
Work dive time	_____	_____	_____	_____
Training dive time	_____	_____	_____	_____
Wet vs chamber time	Wet time _____		Chamber time _____	
Total dive time in the last calendar year (2003)	_____			

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4. EXERCISE AND PHYSICAL ACTIVITY

Based on the last 2-3 months, please answer the following questions:

Over a typical seven-day period (one week), how many times do you engage in physical activity that is sufficiently prolonged (at least 20 minutes) and intense to cause sweating and a rapid heart beat?

At least three times

Normally once or twice

Rarely or never

When you engage in physical activity, do you generally have the impression that you:

Make an intense effort

Make a moderate effort

Make a light effort

In a general fashion, would you say that your current physical fitness condition is:

Very good

Good

Average

Poor



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Make a list of the activities that you regularly engage in. Indicate the typical length, the frequency (# of times per week), the intensity (light, moderate, hard) and general environmental conditions (indoor/outdoor, cold, hot, warm, humid, dry, etc...) for these activities:

Activity (sport)	Length	Frequency	Intensity	Conditions

Indicate the percentage of physical training spent on:

Aerobic Activities _____% Weights _____% Other _____%
(specify)

5. DYNAMIC LUNG FUNCTION VALUES (to be filled out by appraiser)

FVC a. _____ b. _____ c. _____

FEV₁ a. _____ b. _____ c. _____

FEF₂₅₋₇₅ a. _____ b. _____ c. _____



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Insert 1

BACKGROUND AND HEALTH INFORMATION

Visible Minorities

A member of a visible minority group in Canada is someone (other than an Aboriginal person) who is non-white in colour or race, regardless of place of birth or citizenship.

Examples of visible minority groups include:

Black (e.g. African, West Indian)

East Asian (e.g. Chinese, Japanese, Korean)

Southeast Asian (e.g. Malaysian, Cambodian, Filipino, Thai, Vietnamese)

South Asian/East Indian (e.g. Indians from India; Pakistani, Bangladeshi, Sri Lankan, East Indians from Guyana, Trinidad, East Africa)

West Asian/Arab (e.g. Egyptian, Armenian, Iranian, Lebanese, Turkish)

Non-white Latin American (including indigenous persons from Central and South America)

Persons of Mixed Heritage (with one parent in one of the visible minority groups listed above)

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APPENDIX 10.

Questionnaire Diver



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Faculty of Health Sciences
School of Human Kinetics

CF DIVING EXPOSURE AND EXERCISE QUESTIONNAIRE

1. BACKGROUND AND HEALTH INFORMATION

1.1. Sex: Male

Female

1.2. Are you a member of a visible minority group? Yes (see insert for details)

No

1.3. Have you met an approved CF Physical Fitness Evaluation in the last 12 months?

Yes

No

1.4. Are you on any medications? Yes

No

If yes, please specify:

1.5. Have you smoked in the last 12 months? Yes

No

If yes, how many cigarettes on average do you smoke per day _____

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2. DIVING EXPERIENCE

2.1. Years of Experience as a Diver: Sport _____
Professional/CF: _____

2.2. Have you been a:			Years of Experience
Port Inspection Diver	Yes	No	_____
Ship's Diver	Yes	No	_____
Combat Diver	Yes	No	_____
Clearance Diver	Yes	No	_____

2.3. Total dive time in the previous 12 months (days) _____

2.4. Wet vs chamber time Wet time (days) _____
Chamber time (days) _____

2.5. In the last 12 months, please list the following:

	Length (per dive)		Depth (per dive)	
	Average	Max	Average	Max
Work dive time (hours)	_____	_____	_____	_____
Training dive time (hours)	_____	_____	_____	_____

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3. EXERCISE AND PHYSICAL ACTIVITY

Based on the last 2-3 months, please answer the following questions:

3.1. Over a typical seven-day period (one week), how many times do you engage in physical activity that is sufficiently prolonged (at least 20 minutes) and intense to cause sweating and a rapid heart beat?

- At least 5 times
- Three or 4 times
- Normally once or twice
- Rarely or never

3.2. When you engage in physical activity, do you generally have the impression that you:

- Make an intense effort
- Make a moderate effort
- Make a light effort

3.3. In a general fashion, would you say that your current physical fitness condition is:

- Very good
- Good
- Average
- Poor

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3.4. Make a list of the activities that you regularly engage in (see insert 2 for list of physical activities). Indicate the typical duration (minutes), the frequency (# of times per week), the intensity (light, moderate, hard) and general environmental conditions (indoor/outdoor, cold, hot, warm, humid, dry, etc...) for these activities:

Activity (sport)	Duration (minutes)	Frequency (# per week)	Intensity (light/moderate/hard)	Conditions (indoor/outdoor, hot/cold/warm, humid/dry etc)

Indicate the percentage of physical training spent on:

Aerobic Activities _____ % Weights _____ % Other _____ %
(specify)

Thank you for completing the questionnaire

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4. DYNAMIC LUNG FUNCTION VALUES (to be filled out by appraiser)

Date of Birth / / Height (cm) Weight (kg)
 yyyy mm dd

FVC a. b. c.

FEV₁ a. b. c.

FEF₂₅₋₇₅ a. b. c.

FEV% a. b. c.

FEF a. b. c.



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Insert 1

BACKGROUND AND HEALTH INFORMATION

Visible Minorities

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Examples of visible minority groups include:

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Southeast Asian (e.g. Malaysian, Cambodian, Filipino, Thai, Vietnamese)

South Asian/East Indian (e.g. Indians from India; Pakistani, Bangladeshi, Sri Lankan, East Indians from Guyana, Trinidad, East Africa)

West Asian/Arab (e.g. Egyptian, Armenian, Iranian, Lebanese, Turkish)

Non-white Latin American (including indigenous persons from Central and South America)

Persons of Mixed Heritage (with one parent in one of the visible minority groups listed above)

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Insert 2

ACTIVITY INVENTORY

Aerobics/exercise to music	Orienteering
Archery	Racquetball
Badminton	Ringette
Basketball	Roller Skating
Bicycling	Rowing
Calisthenics	Running/Jogging
Canoeing/Kayaking	Skiing (X-Country)
Circuit Training	Skiing (Downhill)
Climbing	Snowshoeing
Dancing	Soccer
Fencing	Squash
Floor Hockey	Swimming
Football	Soccer
Handball	Stair Climbing
Hiking	T'ai chi
Hockey	Tennis
Ice Skating	Volleyball
Inline Skating	Weight training
Martial Arts	Yoga

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