WORK-RELATED CARDIOVASCULAR RISK FACTORS AMONG PROFESSIONAL FIREFIGHTERS IN BRITISH COLUMBIA, CANADA: AN INVESTIGATION OF NOISE, CARBON MONOXIDE AND CORTISOL SECRETION

by

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Abstract

Cardiovascular disease is the largest contributor to chronic disease in Canada. The evidence for the risk of cardiovascular disease among firefighters, an occupational group with known exposures to work-related cardiovascular risk factors, is inconsistent. The inconsistencies are thought to be due to influences of the healthy worker effect and lack of exposure data, limiting the ability to develop meaningful internal comparisons.

This dissertation aimed to characterize exposures to work-related cardiovascular risk factors among professional firefighters in British Columbia including carbon monoxide, noise, and stress. Fifty-eight male suppression firefighters from Metro Vancouver were recruited into the exposure study from three large municipal fire departments.

The first study characterized noise and carbon monoxide during firefighting. Firefighters were exposed to elevated noise levels (45% of measurements exceeded occupational limits) that may negatively contribute to their cardiovascular health. Significant determinants of noise were working dayshifts, in non-supervisory jobs, on engine and rescue trucks; responding to increasing number of emergency calls (particularly motor vehicle accidents and building alarms); conducting training; and fire equipment use.

The second and third studies evaluated cortisol to determine the effects of shift work on cortisol secretion and identify determinants of exposure to stress, measured by cortisol secretion. Rotating shifts resulted in significant changes in cortisol secretion; the first day of work and mornings following nightshifts showed the greatest changes in secretion patterns. Our results suggest three days off work are required to return to baseline cortisol secretion following nightshifts. In multivariable models, work-related demographic (duration in current job, job role), psychosocial (coworker social support, subjective stress levels of events, calls involving death) and physical (wearing self-contained breathing apparatus, conducting physical training) factors were identified as determinants in changes in cortisol secretion patterns over the work day when controlling for personal factors.

Collectively these studies contribute to the data gaps in the exposure measurement of work-related cardiovascular risk factors among firefighters. This dissertation provides evidence of

increased exposures to cardiovascular risk factors and points to potential exposure determinants that may be used to develop internal comparisons. However; due to the variability in firefighting, further studies are needed to fully describe exposures.

Preface

As primary author I have led each of these papers however for the purposes of this dissertation I have used 'we' to describe the author instead of 'I'. In this section I will provide details of my contribution and those of my co-authors for each chapter.

The study procedures were approved by the University of British Columbia's Clinical Research Ethics Board (certificate number: H07-01418).

Chapter 3

For this paper I developed the sampling methodology and field sampling forms, conducted the field work, statistical analysis, and wrote the manuscript. All co-authors provided guidance throughout the sampling methodology and analysis and assisted with revision of the manuscript. Christie Hurrell assisted with the development of recruitment brochures. Barbra Karlen and Calvin Ge assisted with some of the field sampling. In addition, Barb Karlen assisted with study recruitment and pilot testing of the monitoring methods. My overall contribution: 95%.

A version of Chapter 3 has been published[1]: Kirkham TL, Koehoorn MW, Davies H, Demers PA. Characterization of Noise and Carbon Monoxide Exposures among Professional Firefighters in British Columbia. *Annals of Occupational Hygiene*. 2011; 55(7): 764-774.

Chapter 4

I conducted the literature review for this paper, collected the field samples and prepared them for analysis, conducted statistical analysis, and prepared the manuscript. Paul Demers assisted with the development of the concept for this paper. Mieke Koehoorn assisted with presentation of the results. All co-authors provided feedback for revision of the manuscript. Additionally, Nicholas Rohleder and Jutta Wolf provided guidance on cortisol sampling methodology. Calvin Ge and Barbra Karlen assisted with sample collection. Barbra Karlen also assisted with pilot testing, recruitment of subjects, and preparation of samples to be shipped for analysis. Cortisol levels in saliva were analyzed at Dr. C. Kirschbaum's

Biopsychology Laboratory at Dresden University of Technology, Germany. My overall contribution: 90%.

A version of Chapter 4 will be submitted to a peer reviewed journal as: Kirkham TL, Demers PA, Davies H, Koehoorn MW. Effects of fast rotating shift work on cortisol secretion among professional firefighters.

Chapter 5

The same saliva samples were used for analysis in Chapter 5 as Chapter 4. I completed the literature review, statistical analysis and prepared the manuscript. Mieke Koehoorn provided guidance with statistical analysis methodology. All co-authors provided feedback for revision of the manuscript. In addition, Georgia Pomaki provided guidance with respect to questionnaire development, particularly with respect to the cortisol diaries and psychosocial constructs within the questionnaires. My overall contribution: 90%.

A version of Chapter 5 will be submitted to a peer review journal as: Kirkham TL, Demers PA, Davies H, Koehoorn MW. Work-related stressors and their effects on salivary cortisol during firefighting work.

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List of Symbols and Abbreviations

%	Percent
®	Registered trademark
ANOVA	Analysis of variance
AUC_g	Area under the curve with respect to ground
AUC_i	Area under the curve with respect to increase
BC	British Columbia
BMI	Body mass indicator
CAR	Cortisol awakening response
CL	Confidence limits
CO	Carbon monoxide
CSA	Canadian Standards Association
CVD	Cardiovascular disease
dB	Decibles
dBA	Decibles in A weighting
dBC	Decibles in C weighting
DoE	Determinants of exposure
GEE	Generalized estimating equation
GM	Geometric mean
GSD	Geometric standard deviation
HazMat	Hazardous material
HPA	Hypothalamic-pituitary-adrenocorticol
hr(s)	Hour(s)
HWE	Health worker effect
HWHE	Healthy worker hire effect
HWSE	Healthy worker survivor effect
IAFF	International Association of Fire Fighters
IRRs	Incident rate ratios
LCL	Lower confidence limit
Leq	Equivalent sound level
Lex	Noise exposure level (shift adjusted)
LOD	Limit of detection
MaxP	Maximum peak noise level
MESA	Medical emergency call
mmHg	Millimeters of mercury
MVA	Motor vehicle accident
n	Number
NHANES	National Health and Nutrition Examination Survey
NIOSH	National Institute of Safety and Health
ORs	Odds ratios
OSHA	Occupational Safety and Health Association
PMRs	Proportionate mortality ratios
PPE	Personal protective equipment
ppm	Parts per million
r	Correlation coefficient

RPE	Rated physical exertion
RRs	Relative risks
SCBA	Self-contained breathing apparatus
sd	Standard deviation
SMRs	Standardized mortality ratios
STEL	Short term exposure limit
TSHE	Time since hire effect
TWA	Time weighted average
UCL	Upper confidence limit
US	United States
Vs.	Versus

Acknowledgements

This dissertation work has been supported and enhanced by many people. First, I am grateful for my co-supervisors: Mieke Koehoorn – who exhibited endless patience and support when needed most, and Paul Demers – who always helps me see the big picture and provides valuable guidance with respect to my future. Thank you also to my committee member Hugh Davies who always provided excellent feedback and advice throughout my journey.

I am also very grateful to all the other people who contributed to this work, which could not be done without their help. Thank you to Nicolas Rohleder and Jutta Wolf – for sharing their expertise and suggestions during the method development of my cortisol sampling research and for always being there when I was in desperate need of sampling tubes, and Georgia Pomaki – for her encouragement and support during the development of all my questionnaires.

This work would not have been possible without the help and enthusiasm of the research staff. Thank you to Katherine Rempel for your help in the beginning days. Thank you to Calvin Ge for the sleepless nights and eating competitions you endured to get through this study. A special thank you to Barbra Karlen who was there for me when I needed equipment, someone to sew monitoring equipment into shorts, and who was there to cover for me when I was unable to be there; you were the best study coordinator anyone could ask for.

Many funding agencies have supported this work. Thanks to WorkSafeBC for funding this project. Scholarship support from the Canadian Institute of Health, the Public Health Agency of Canada, WorkSafeBC, and Michael Smith Foundation for Health Research are also greatly appreciated. Special thank you to Centre for Health Services & Policy Research (CHSPR) for providing financial support, and invaluable training opportunities during my PhD degree.

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I am grateful for the continuing support and encouragement from my fellow students in my department and those whom I shared classes with over the duration of this thesis. A huge thank you to my three office mates – who I have developed lifelong friendships with over the last six years (Rakel Kling, Cris Barzan, and Hind Sbihi) – for putting up with my messy desk and being my sounding board. A special thanks also to Melissa Friesen, Niki Garzia, and Maureen Connelly who made this experience enjoyable and who were always available to help.

Lastly, I have to thank my family for their encouragement, love, and emotional support to get through this process.

To the firefighters

Chapter 1: Introduction and Literature Review

1.1 Introduction

Cardiovascular disease (CVD) is the term used to describe all diseases that involve the heart, veins, or arteries and is the number one reported cause of death worldwide, representing approximately 30% of all deaths in 2005[2]. Rates in Canada are slowly declining but are comparable to worldwide rates; in 2004, CVD accounted for 32% of all deaths in Canada where ischemic heart disease accounted for the greatest portion (17% all deaths)[3], compared to the 36% reported in 1999[4].

Several studies have shown an increased risk of cardiovascular disease among some occupational groups, including emergency workers such as firefighters, and as such some workers' compensation systems have recognized cardiovascular disease, particularly line-of-duty cardiac events, as a compensable disease among firefighters. Occupational exposures firefighters encounter that are hypothesized to increase the risk of cardiovascular disease include*:* chemical (carbon monoxide (CO) and particulate) and physical exposures (physical exertion/demands and noise) and stress. However, inconsistencies in the evidence and methodological challenges contribute to an ongoing debate on the occupational risk factors for cardiovascular disease. For example, in the province of British Columbia (BC) the existing presumption for heart disease for workers' compensation benefits was removed based on the lack of evidence supporting claims of the work-relatedness of cardiovascular disease among firefighters in May 2000[5]. This debate over the evidence has led to the need for more studies with improvements in study design, and was the impetus for this PhD dissertation focused on exposure assessment of chemical and physical hazards among firefighters, as part of a larger program of research on cardiovascular disease among emergency workers. Specifically, the purpose of this PhD research was to characterize firefighters' exposures to carbon monoxide, noise, and to determine the effects of firefighting activities on cortisol secretion as a measure of the stress response. This exposure assessment study will provide information regarding exposure levels of work-related cardiovascular risk factors among professional firefighters that may be useful in future studies in developing meaningful exposure groupings and assessment methods.

1.2 Thesis Structure

This dissertation consists of six chapters: this literature review chapter, a chapter summarizing firefighter work, three research chapters that address the research objectives, and a concluding chapter. The primary objectives of each research chapter are described below.

Chapter 1: Introduction and literature review

The first chapter of this thesis presents a summary of the literature that highlights the risk of cardiovascular disease among professional firefighters, modifiable cardiovascular disease risk factors experienced by firefighters addressed in this dissertation, and supporting rationale for the overall research question and approach of this thesis work.

Chapter 2: Description of Firefighter work

This chapter will provide a brief introduction to the organization structure of firefighting and outline the main characteristics of their job and tasks.

Chapter 3: Characterization of carbon monoxide and noise exposures

As discussed in the literature review above, carbon monoxide and noise exposures have both been identified as cardiovascular disease risk factors that firefighters are frequently exposed to during their job; however, little is known about their levels. The objective of this chapter was to characterize firefighters' exposures to noise and CO exposures during their full shift. This information is anticipated to help identify areas where efforts to control for workplace exposures can be implemented to reduce work exposures, thus reducing disease risk.

Chapter 4: Effects of shift work on cortisol secretion

One psychosocial risk factor related to cardiovascular disease is the effects of shift work on the circadian rhythm. The study follows the study subjects over one full work week rotation. The objective of this chapter was to evaluate changes in cortisol secretion over one work week. These results will identify the effect, if any, that fast rotating shift schedule currently used in British Columbia influences their cardiovascular risk.

Chapter 5: Identification of determinants of cortisol secretion

Cortisol secretion and stress in general, is multidimensional. In order to fully understand and compare the relative influence of factors related to physical exertion, thermal stress, and other psychosocial factors, all aspects need to be included in a single study. The objective of this chapter was to identify key work-related determinants affecting cortisol secretion while controlling for personal factors to identify factors which may significantly influence the stress response.

Chapter 6: General discussion

The final chapter of this thesis is a general discussion. This will include a reflection of the research findings, challenges, and future research steps.

1.3 Literature Review

The following literature review section will summarize the existing evidence on the risk of cardiovascular disease among firefighters, followed by a summary of cardiovascular disease risk factors, with a focus on those that are occupational.

1.3.1 Firefighting and Cardiovascular Disease

1.3.1.1 Mortality Studies

A total of 15 studies reporting Standardized Mortality Ratios (SMRs) [6–20]and 4 proportionate mortality studies[21–24] were identified and reviewed from the literature. Study findings regarding the risk of cardiovascular disease among firefighters were inconsistent, with SMRs ranging from 0.78-1.16 for all circulatory diseases and 0.82-1.15 for ischemic heart disease mortality; associations were slightly stronger for ischemic heart disease mortality compared to all circulatory diseases mortality (Figure 1). Of the ten studies reporting mortality of circulatory diseases four[7,8,12,13] found an increased risk among firefighters, of which only two were statistically significant[8,12]. Whereas six[6,7,12–14,18] of the 11 studies[6,7,9–14,18,18–20] reporting mortality from ischemic heart disease found increased risks associated with being a firefighter; two[7,18] had statistically significant results. Interestingly, Heyer *et al.*[15] and Tornling *et al.*[19] reported a protective effect of firefighting for all circulatory disease mortality, SMR=0.78 (95% CL: 0.68, 0.92) and SMR=0.84 (0.71, 0.98) respectively; however, this effect was not reported for ischemic heart disease mortality. A study of Seattle, Tacoma and Portland firefighters found a decreased risk of ischemic heart disease mortality, SMR=0.82 (0.74, 0.90) [10].

Bates *et al.*[8] found a significant increase in coronary heart disease among 45-54 yr old Toronto firefighters compared with the general population (SMR 1.73; 1.12, 2.66); they also found that the association was stronger among 45-49 year olds compared to 50-54 year olds when stratified by age, SMR=1.80 (1.01, 3.19) and 1.75 (0.9, 3.39) respectively. A study of Toronto firefighters conducted by Aronson *et al.*[6] found non-significant increases SMRs for both ischemic heart disease (SMR = 1.04; 0.92-1.17), and acute myocardial infarction (SMR = 1.07; 0.93-1.23) but no increase for diseases of the circulatory system (SMR = 0.99; 0.89-1.10).

Three proportionate mortality studies reported slightly elevated proportionate mortality ratios (PMRs) for ischemic heart disease ranging from 1.01-1.22 however, only Feuer and Rosenman showed a significant association (PMR=1.22, $p<0.05$)[21,22,24]. Calvert *et al.*[22] reported a significant increased risk of ischemic heart disease for black fire fighters (PMR=1.65; 1.10, 2.49) and a non-significant increase for white firefighters (PMR=1.04; 0.94, 1.14); no association was observed for all black service workers (including police, guards, correction officers, fire fighters). This suggests that firefighters have a greater risk of ischemic heart disease than similar working groups (an important comparator given the challenges of the healthy worker effect), particularly for African Americans. Feuer and Rosenman[24] also reported a non-significant increase in all circulatory diseases (PMR=1.09).

1.3.1.1.1 Latent Effects

Four studies reported circulatory disease mortality rates of firefighters stratified by year of hire[6,7,13,15]. Baris *et al.*[7] and Heyer *et al.*[15] both observed an increasing risk of circulatory disease mortality with earlier date of hire. Aronson *et al.*[6] and Guidotti *et al.*[13] showed no trend with date of hire; however both studies reported the greatest risks of circulatory disease mortality for 20-29 years since hire (SMR 1.18 and 1.26 respectively). In addition, positive trends were also observed for ischemic heart disease for two studies[7,19]; however, Baris *et al.* found a significant increase in SMR for fire fighters hired prior to 1935.

Vena and Fiedler[20] observed an increasing trend in SMRs for arteriosclerotic heart disease with increasing latency, except for the largest age group (50+ years) where a small decrease was observed; Feuer *et al.*[24] observed conflicting results showing decreasing mortality with increasing years since hire. Aronson *et al.*[6], reported a similar trend of mortality of acute myocardial infarction as they did with all circulatory diseases with the greatest response (SMR=1.26) for those hired 20-29 years previously. In addition, Demers *et al*[10]. reported an increasing SMR with increased latency for diseases of the arteries, veins, and pulmonary circulation.

1.3.1.1.2 Duration of Exposure

Similar to latent effects, the results of duration of exposure are also inconsistent; however two studies[15,20] show a clear exposure-response relationship for all circulatory diseases (Figure 2). Three additional studies[6,7,13] report similar changes in SMRs for circulatory diseases by duration of exposure; they observed a pattern with an initial increase in SMR, followed by a decrease in mortality with duration of employment. This pattern may be explained by the healthy worker survivor effect. Similar patterns of increasing and decreasing SMRs were observed for two studies reporting risks of ischemic heart disease[7,19], one study reporting risks of heart disease 30 years following first exposure[9], one study on the risks of acute myocardial infarction[6] and one study on arteriosclerotic heart disease[24]. Similarly with circulatory diseases, Vena and Fiedler[20] show a clear exposure-response for arteriosclerotic heart disease with SMRs ranging from 0.51 to 1.19 from 1 to 40 plus years of exposure.

Further, in a related study conducted by our research group at the School of Population and Public Health on a group of BC firefighters we found an increase in the incidence of acute coronary disease among firefighters with 10-19, 20-29, and 30+ years of employment compared to firefighters with less than ten years of employment, incident rate ratios (IRRs) 1.7(0.9, 3.2), 2.1 (1.1, 4.2), and 1.3(0.6, 2.9) respectively[25]. Relationships with chronic coronary disease and hypertension were not as strong.

1.3.1.1.3 Other Mortality Studies

Hodous, *et al.*[26], compared causes of line of duty deaths of firefighters in the United States (US) from 1998-2001 and found that 191 deaths out of the reported 410 deaths in that time frame were medical related (i.e. non-accidental), and 90% of those (n=171) were myocardial infarctions. The remaining medical deaths were mostly other circulatory disorders including strokes and cardiac arrhythmias. The authors reported that most deaths occurred either at, soon after, or traveling to or from a scene of a call suggesting that a significant proportion of fire fighters' acute myocardial infarctions are due to the stresses (physical and/or psychological) encountered during an emergency call. Washburn *et al.*[27] reports that the leading cause of fatal injury of US firefighters from 1977 to 1995 has been stress induced acute myocardial infarction. They found that 47.7% of firefighter deaths were a result of a heart attack, followed by internal trauma (21.6%), and asphyxiation (15.9%) in 1995.

Leigh and Miller[28] compared occurrences of work-related disease and their associated occupations. They found that heart conditions accounted for 72.5% of all occupational deaths and that firefighters alone accounted for 4.2% of all occupational deaths.

1.3.1.2 Morbidity Studies

A cross sectional study of 77 municipalities in Illinois by Walton *et al.*[29] found that 33% of firefighter workers' compensation claimant injuries from 1992 – 1999 resulted from overexertion and 0.07% of all claims were heart related. Another cross sectional study found that office workers in fire departments reported a higher prevalence of hypertension (7 vs. 5%) and heart complaints (6 vs. 2%) than firefighters on questionnaires[30]. These research findings suggests that firefighters are either healthier or report they are healthier than office workers in the same environment.

Glueck, *et al.*[31] found a lower incidence rate of coronary heart disease morbidity in firefighters than a working group of males (1.35/1000 vs. 2.07/1000 man years: $p<0.1$) during a prospective cohort of Cincinnati firefighters. One disadvantage of this study is that the mean follow-up was only 6.4 years on average. Licciardone *et al.*[32] however found no increase risk to firefighters of developing CVD morbidity (Relative Risk (RR) = 1.0; 0.7, 1.4) compared to employed men enrolled in the National Health and Nutrition Examination Survey (NHANES).

In conclusion, the evidence regarding cardiovascular risk and firefighting is inconsistent although some well-designed studies suggest an increased risk of cardiovascular disease is associated with the firefighting occupation. The inconsistencies may be due to challenges with identifying an appropriate reference population given the healthy worker effect among a physically fit cohort, differences in outcome measures of cardiovascular disease for both mortality and morbidity, differences in adjustment for modifiable and non-modifiable risk factors across studies, and challenges associated with measuring and quantifying exposures on the job. The next section will highlight some of these challenges.

1.3.2 Challenges of Conducting Research on Firefighters

1.3.2.1 Healthy Worker Effect

Most research evaluating the risk of cardiovascular disease among fire fighters has used the general population as a control group. Although this approach is frequently used in occupational epidemiological studies, it can bias the study results. This bias occurs when workers exhibit lower standardized mortality ratios than the general population, termed the healthy worker effect (HWE)[33–38]. The HWE describes a phenomenon that workers are typically healthier than members of the general population of the same age and sex; this is because the general population includes people whose health status may prevent them from seeking and/or gaining employment. There are three components to the HWE including the healthy worker hire effect (HWHE), the healthy worker survivor effect (HWSE), and the time since hire effect (TSHE)[34,36–44].

The HWHE occurs during the initial selection process of employment where healthy people are more likely to seek and gain employment than those who are less healthy[36,38–40]. This could occur due to the fact that those with a chronic disease may be (1) less willing to seek employment due to their illness, or (2) more likely to be rejected by employers on the basis of their disease status. The HWSE is an extension of the selection process that occurs during continual employment; over time unhealthy workers are more likely to quit their jobs due to their illness whereas healthy individuals continue employment thereby causing an increase in the health among those who remain employed, termed survivors[34,36,40]. TSHE is characterized as a temporal decline in the health status of workers since the initial selection into the workforce, which causes an increase in mortality over time[37,39,40,42,44]. Unlike the HWHE and the HWSE that tend to result in lower than expected mortality rates due to the health status of those who seek and retain employment, the TSHE tends to overestimate mortality rates among higher cumulative exposure groups as lower cumulative exposure groups inherently include more recent hires or younger employees as lower risk of disease.

The impact of the HWE is highly variable and it is difficult to determine the net effect of its presence in any given study. A number of modifying factors that that may contribute to the differences observed between studies. The common modifying factors of the HWE include gender[33,36,40,45,46], occupational class[33,36,45–47], race[33,35,38,45], temporal variation (age at hire[17,33,34,46,48,49], duration of employment[6,7,15,20,24,34,41,44,45,50], and time since entering follow-up[19,20,33,36,48]) and cause of death[35,36,40,46]. Several control measures have been proposed to help limit or control for the effects of the HWE in studies including: (1) the use of internal comparison groups;(2) restricting the cohorts to survivors of a fixed number of years of follow-up; (3) exposure lagging to exclude recent exposure incurred by those who remained employed; (4) adjusting for employment status as a confounder; and (5) using G-test statistical methods treating the HWSE simultaneously as an intermediate and confounding variable[35–37,39,40,42,51–54].

Given the variance in expression of the HWE among studies, no general adjustment is possible and each study requires independent evaluation for the presence of the HWE as it may have significant impacts on study finding interpretations and hence policy implications.

The HWE may be significantly influencing the study results regarding the relationship between cardiovascular disease and firefighting. Firefighters are especially vulnerable to this bias as the physical requirements for entry into the firefighting profession are very stringent, indicating that they are some of the fittest people in the population at the time of hire.

1.3.2.2 Appropriate Reference Populations

Of the 15 mortality studies reviewed only two used comparison groups other than the general population to attempt to address the HWE. Demers *et al.*[10] compared firefighters to the general male population of the study cities and also to a cohort of police officers. Although the reported SMRs were lower than 1.0, they did observe an increase in firefighters' SMR's when compared to police officers (heart disease SMR: 0.86; 0.74-1.00 and ischemic heart disease SMR: 0.88; 0.74, 1.04) than when compared to the general male population (heart disease SMR: 0.79; 0.72, 0.87 and ischemic heart disease SMR: 0.82; 0.74, 0.90). These results help support claims that the healthy worker effect may be influencing mortality results of firefighters' risk of developing cardiovascular disease. Hansen *et al.*[14] also found an increase in mortality from ischemic heart disease, although not significant (SMR = 1.15; 0.74, 1.71) when compared to civil servants and salaried employees in physically demanding jobs (ex. military and police officers, prison workers, male nurses, and railway workers). It is suggested identification of an appropriate occupational comparison group in the design phase of the research could help control for the HWE among firefighters[55]; the difficulty is finding an occupation with similar fitness requirements at entry.

1.3.2.3 Internal Comparison Groupings

Few studies have reported mortality using internal comparisons, which is partly due to a lack of available exposure data on this occupational group. Several researchers studying firefighters have reported mortality using crude number of runs as an indicator of exposure. A study of Philadelphia firefighters evaluated risk of circulatory and ischemic heart disease among low exposed ($\leq$ 3,919 of cumulative runs) and high exposed (>3,191 cumulative runs) firefighters based on historical company/hall run averages[7]. They found a statistically significant protective effect of increased exposure (i.e. cumulative runs) for both circulatory and ischemic heart disease; however when restricting number of runs to the first five years of employment as a firefighter (≤729 runs vs. >729 runs) they observed an increased risk for both circulatory diseases and ischemic heart disease, rate ratios 1.08 (0.91, 1.27) and 1.17 (0.96, 1.42) respectively suggesting that exposures early in the career may be more important. Tornling *et al.*[19] also compared risk of ischemic heart disease and exposure levels (<800, 800-1000, >1000 runs); they reported no association with exposure level measured by number of runs. In both studies the estimated number of runs may be resulting in a high level of exposure misclassification, potentially attenuating the true relationships. In addition, there is no available information to verify if number of runs is a good measure of exposure to cardiovascular risk factors.

Other research has shown that the odds of coronary mortality among firefighters is highly associated with firefighting task, with the greatest odds of mortality occurring during fire suppression, alarm response, and physical training[56]. These findings shed some light on the fact that there specific job tasks/exposures that may be important with regards to cardiac health and identify some potential groupings for internal comparisons. Even with this addition to the understanding of risk, little actual exposure data on cardiovascular risk factors (e.g. CO, noise and stress) have been collected. This comes partly due to the challenges associated with measuring and quantifying exposures among mobile workers in a hostile work environment. Further studies are needed in order to identify which jobs/tasks result in higher exposures to these risk factors to appropriate classifies exposure groups.

1.3.2.4 Exposure Assessment

Few exposure studies among firefighters are publically available which contributes to the inability to fully evaluate the risk of cardiovascular disease among firefighters using internal comparisons. The reasons for the lack of exposure data is not known; however we can speculate that logistical difficulties encountered during firefighting plays an important role in impeding sampling attempts.

Firefighters work in potentially hostile environments that can significantly interfere with hygiene sampling equipment functionality. For example, the environment may include extreme temperatures, humidity, fire, particulate matter, or banging and/or jarring which can lead to sensor malfunction, equipment overload, or breakage. In addition to the feasibility of finding equipment capable of withstanding the potential environmental conditions, the sampling equipment must also be wearable in a way that it will not interfere or impede firefighters' movement or safety.

Although there are significant influencing factors contributing to the ability to obtain exposure measures, sampling is still possible with creative approaches and advanced hygiene sampling equipment design. As mentioned previously, some analysis of disease risk among firefighters has been attempted using internal comparisons. However, without sufficient sampling of determinants of exposure, it is difficult to classify individuals into exposure groupings. Further, without initial sampling there is little or no information on the potential determinants of exposure that are present during firefighting activities.

1.3.3 Cardiovascular Disease Risk Factors

There are both non-modifiable and modifiable risk factors associated with CVD (Table 1.1). Non-modifiable risk factors, which cannot be changed or controlled for, include age, gender, and familial history/genetic factors. Modifiable risk factors, those that can be changed or controlled, include those associated with diet, physical activity, and environmental exposures including work-related exposures.

1.3.3.1 Modifiable Work-related Risk Factors

1.3.3.1.1 Carbon Monoxide

CO is an odorless gas, which is a common byproduct of incomplete combustion (ex. vehicle exhaust, fire smoke). It is a chemical asphyxiant that displaces oxygen from heme forming carboxyhemoglobin, reducing the oxygen carrying capacity of blood leading to stress[57]. In addition to its ability to displace oxygen from heme, the addition of CO to heme changes the partial pressure of oxygen reducing its ability to dissociate/remove its self from the heme molecule, thus further impairing delivery of oxygen to the tissues[57]. CO has also been known to bind to myoglobin (the protein responsible for transporting oxygen to skeletal and cardiac muscle), which can lead to myocardial muscle dysfunction[57].

Epidemiologic evidence suggests that workers exposed to carbon monoxide may have an increased risk of cardiovascular disease[58–61]. Yang *et al.*[61] found a 1.19% (0.99, 1.39%) and a 2.83% (2.07, 3.60%) increase in hospital admissions for cardiovascular and ischemic heart disease for a 1 ppm increase in 1-hr maximum ambient CO concentrations (average=3.09 ppm). Similarly, Schwartz[58] found a 2.79% (0.51, 5.41%) increase in cardiovascular disease hospital admissions for an inter-quartile range increase in ambient CO exposure.

A prospective mortality study by the National Institute for Occupational Safety and Health (NIOSH) found that motor vehicle examiners, who were exposed to low levels of CO (TWA 10-24 ppm), found a slight increase in mortality for all cardiovascular disease and diseases of the arteries, SMR=1.05 and 2.18 respectively[59]; the association for cardiovascular disease increased (SMR=1.34) when analysis was restricted to the first ten years of employment. A classic study of bridge and tunnel workers[60] illustrates an exposure response relationship where tunnel workers exhibited higher SMRs than bridge workers for all heart disease (SMR=0.84; 0.71, 0.99 vs. SMR=1.24; 1.01, 1.51 respectively) and arteriosclerotic heart disease (SMR=0.85; 0.71, 1.02 vs. SMR=1.35; 1.09, 1.68 respectively). Koskela *et al.*[62] also observed an elevated risk of cardiovascular diseases. They found an increased risk of ischemic heart disease mortality among a group of Finnish foundry workers from 1973-1993 (SMR= 2.15; 1.00, 4.63) with regular exposure to CO.

A population based case referent study of acute myocardial infarction and occupational exposure to CO found an increased relative risk of acute myocardial infarction for intermediate (RR=1.42; 1.05, 1.92) and high (2.11; 1.23, 3.60) exposures to combustion products compared to those in the low exposure group63.

1.3.3.1.2 Stress

The Stress Response

Stress is a complex multidimensional exposure that comes from both internal (factors that influence your ability to deal with stress including your overall physical and mental health) and external (environmental factors such as mechanical/physical influences, chemical/biological influences, work demands, relationships with others, and dangerous situations or threats of harm) factors, which can be both positive and negative. The stress response becomes negative when the body is no longer able to deal with the frequency, duration or magnitude of the stressor.

The response to acute stressors invokes a series of hormonal changes in the body that were first explained by Cannon in the early 1900's that occurs to prepare the body to react to the stressor. Immediately following exposure to a stressor the autonomic nervous system is triggered, releasing a set of hormones (epinephrine/adrenaline and norepinephrine/noradrenaline); this process is commonly termed the "fight or flight" response[64–66]. The sympathetic nervous system is activated by increasing blood pressure and heart rate to prepare for the stressor/danger. This is then followed by activation of the hypothalamic-pituitary-adrenocorticol axis (HPA) and the release of cortisol. These actions provide a burst of energy and a decreased sensitivity to pain, heightened memory function, temporarily increase in immunity and helps maintain homeostasis, allowing the body to better cope with the stress. To maintain regular physiological function, the body then acts to turn off these activation systems in a negative feedback loop once the danger has passed. However, repeated or prolonged exposure to stressors can lead to an over activation of the HPA response leading to permanent changes in the normal biological response.

Stress and Cardiovascular Disease

Studies have reported that the effects of chronic and acute stressors may be different. Chronic stress is thought to accelerate the formation of atherosclerotic plaques, whereas acute stress may trigger a cardiac event in persons with underlying atherosclerosis [67–69].

Observational studies have indicated that workers with high demands and low control (i.e. high strain) have been shown to have an increased risk of cardiovascular disease morbidity and mortality compared to workers with low demands and high control (i.e. low strain)[68,70,70,71]. A prospective cohort study of metal industry employees in Finland with high job strain were over two times (risk ratio=2.2) to experience cardiovascular mortality than those with low job strain; the risks of cardiovascular mortality were slightly higher among those with a high effort-reward imbalance (risk ratio = 2.4) compared to those with a low effort-reward imbalance[71]. Observational studies have also indicated that psychosocial factors such as depression, anxiety, social isolation, lack of social support also influence the risk of cardiovascular disease; increased risks as high as 5 times[72].

It has been hypothesized that disruption of sleep cycles can affect the natural body cycle (i.e. circadian rhythm), and lead to adverse health effects such as cardiovascular disease[73–76]. Several epidemiological studies have examined the association between disruption of the circadian rhythm and cardiovascular disease. They have found that shift workers had a higher risk of hypertension, altered lipoprotein profile, ischemic heart disease, all circulatory disease and myocardial infarction[77–82]. The effects of working longer hours (i.e. >40 hours/week) has also been associated with a twofold increase risk of myocardial infarction[83,84]. Research evaluating the effects of long work hours (24 hour shifts) among medical residents found a significant increase in daytime time blood pressure compared to day workers only and concluded it may contribute to cardiovascular risk[85].

I have reviewed the potential benefits of physical activity with respect to cardiovascular disease however; intense or irregular physical exertion causes an increase in heart rate and EKG activity which can lead to sudden death among those with underlying cardiovascular disease[86]. A study of sudden/unexpected deaths among young competitive athletes (13 to 30 years of age) found that 76% (22/28) of the sudden deaths were attributable to structural cardiovascular abnormalities[87]. Firefighters' work includes sedentary periods interspersed with rapid, intense physical activity known to significantly increase heart rate[88–90]. In the case of firefighters, this risk is also influenced by the use of personal protective equipment and hot environments, limiting their ability to regulate their body temperature[91].

Research has shown that there is biological plausibility for the risks of CVD and exposure to carbon monoxide, noise and stress. Based on this evidence it is clear that firefighters may be at an increased risk of CVD as they may encounter all of these risk factors in their everyday work environment.

1.3.3.1.3 Noise

Noise is a ubiquitous exposure observed in both the work and community environments. The auditory effects of noise have been well established[92–94] however questions still remain regarding the non-auditory effects of noise exposure. Noise is thought to contribute to the development of cardiovascular disease in a manner described by the general stress theory. The general stress theory hypothesizes that noise acts as a "stressor" and causes a stress response, as outlined above, through activation of the autonomic nervous and endocrine systems. Activation of these systems leads to physiological responses including temporary increases in heart rate, vasoconstriction, and blood pressure[95–98]; where chronic activation can lead to the development of permanent effects including hypertension and ischemic heart disease[99–101].

Steenland *et al.*[102] studied the US working population and found that a combination of exposure to noise, reduced job control, shift work, and environmental tobacco smoke resulted in approximately 4,500 – 12,900 occupational deaths from coronary heart disease in 1997 based on attributed fractions. Fogari *et al.*[96] found that workers exposed to noise (>85 dBA) had a 6 and 3 mmHg increase in systolic and diastolic blood pressure respectively when compared to unexposed workers (<80 dBA). They also reported an elevated heart rate among exposed workers compared to unexposed workers during (1) exposure, (2) non-working hours, and (3) non-working days (+ 3.7, 2.8, and 2.8 beats per minute respectively).

A study of airline pilots found that pilots with high noise exposure (L_{eq} 93 dBA) had elevated heart rates and systolic blood pressure, and had a higher prevalence (39% VS 9%) of basal hypertension than pilots with low noise exposure (L_{eq} 79 dBA)[103]. In addition they found that the prevalence of hypertension increased within each exposure group with increasing duration of exposure, measured by flight hours. Lusk *et al.*[97] found a similar association between noise exposure and elevated blood pressure and heart rate using ambulatory monitoring of auto assembly workers; they postulate that mechanism for changes in blood pressure and heart rate are different. Specifically they suggest that peak noise exposure (i.e. impulse noise) may be more import for the observed increases in heart rate whereas the overall noise exposure (i.e. average noise levels, L_{eq}) are responsible for increases in blood pressure.

A study of hypertension among sawmill workers showed that hypertension was positively associated with high noise exposure (>85 dBA). They observed an increased relative risk of hypertension (RR=1.32) among high exposed workers compared to low exposed workers when evaluating cumulative exposure[104]. A study by Inoue *et al.*[105] found conflicting results; they found that workers in noisy workplaces had lower prevalence of hypertension than workers in non-noisy workplaces (16.9% vs. 34.7% respectively), suggesting a protective effect with increased noise exposure.

Multiple studies have reported an association of increased risk of myocardial infarction with noise exposure[106–110 98-100]. Selander *et al.*[109] observed a small non-significant increase in risk of myocardial infarction with long-term exposure to noise greater than 50 dBA and air pollution (OR=1.12; 0.95, 1.33) in a community study. This relationship was strengthened (OR=1.38; 1.11, 1.71) when restricting analysis to those without hearing loss and occupational exposure. Babisch *et al.*[106] found similar results among residents in Berlin. They found a non-significant increased odds of having being exposed to noise among men who had an acute myocardial infarction who have been exposed for greater than 10 years by place of residence (OR 1.8; 1.0, 1.32), no association was observed for women. In a retrospective cohort study of sawmill workers Davies *et al.*[107] observed an elevated risk of myocardial infarction that was strongest for workers who did not wear hearing protection. They also reported a dose response for duration of exposure in years worked from <3, 3-9, 10-19, and >19 years (RR 1, 3.9, and 4.0 respectively; p=0.003) using a threshold of 85 dBA. Another occupational exposure study using the NHANES data by Gan *et al.*[108] observed a two to three fold increase in the prevalence of myocardial infarction, coronary heart disease, and hypertension among people who were currently employed compared to those who were not employed for those less than 50 years of age. No effect was observed among those 50 plus years of age.

Similar finding were reported among studies evaluating the risk of ischemic heart disease from noise expsosure[111,100,112]. A prospective cohort of industrially employed men reported that workers with continuous noise exposure combined with exposure to impulse noise were at an increased risk of ischemic heart disease, which increased with follow-up from 5 years to 13 years, relative risk 1.28 and 1.58 respectively[112]. In addition, a 2002 meta-analysis of the effects of noise exposure, and blood pressure and ischemic heart disease reported that there was a positive association between occupational noise exposure and air traffic noise exposure with hypertension (RR = 1.14; 1.01, 1.29; and RR = 1.26; 1.14, 1.39 respectively) [103]. They concluded that road traffic noise exposure increases the risk of acute myocardial infarction and ischemic heart disease by cross sectional design however, the evidence was still inconclusive.

1.3.3.2 Other Modifiable Risk Factors

Numerous modifiable risk factors for cardiovascular disease have been identified. These can roughly be broken into disease/health status factors and drug use factors.

1.3.3.2.1 Disease and Health Status Factors

Disease and health status factors shown to increase the risk of cardiovascular disease include diabetes, obesity, abnormal lipoprotein profiles, elevated heart rate and blood pressure, and physical inactivity. Research has shown an increased risk of cardiovascular disease among diabetics[113–116], and indicates that other cardiovascular disease risk factors are higher among diabetics than those without diabetes[115]. A sedentary lifestyle and lack of physical activity at work or during leisure time has been associated with an increased risk of cardiovascular disease. A meta-analysis of physical inactivity and coronary heart disease reported a summary relative risk of 1.9 (1.6, 2.2) for people who work in sedentary occupations compared to those in active jobs[117].

Being overweight or obese also increases the risk of cardiovascular. Male study participants from the Framingham Heart study who were overweight and obese had elevated relative risks of cardiovascular disease compared to those of average weight, relative risk 1.21 (1.05, 1.40) and 1.46 (1.20, 1.77) respectively[118]. However, a review of 24/700 identified prospective observational studies concluded the risk of cardiovascular disease is lower among active obese individuals than sedentary individuals of normal weight highlighting the importance of activity in prevention of cardiovascular disease[119]. It has been well established that high levels of low density lipoproteins ("bad cholesterol") can lead to blockage of the arteries and is associated with increased cardiovascular disease risk[120–122].

Elevated blood pressure (i.e. hypertension) above 140/90 mmHg can lead to cardiovascular disease as over time the pressure exerted on the blood vessel walls may lead to scarring which can promote the development of fatty plaque along the walls which can lead to artery blockage. Individuals with high blood pressure are approximately two to three times more likely to develop cardiovascular disase[123]; however, systolic blood pressure has been shown to be a stronger predictor of cardiovascular disease risk than diastolic blood pressure[124]. Similar findings for elevated heart rate have been reported; Kannel *et al.* [125] found that all mortality and cardiovascular mortality increased with increasing elevated heart rate.

1.3.3.2.2 Smoking, Alcohol, and Caffeine

Exposure or use of some drugs including smoking, alcohol and caffeine has all been associated with increased risk of cardiovascular disease. The mechanism in which smoking is thought to contribute to cardiovascular disease is through processes of inflammation, platelet aggregation, and/or endothelial dysfunction promoting atherosclerotic disease. Research has shown that smokers had clinically elevated C-reactive protein (OR=1.98; 1.57, 2.51), fibrinogen (2.15; 10.6, 2.80), and homocysteine (2.10; 1.2, 2.74) compared to never smoking cigarettes[126]. Studies evaluating the risk of second hand smoke have also seen an increased risk of cardiovascular disease[127,128]. A study by Law[129] reported a clear dose response relationship between the risk of ischemic heart disease and exposure to passive smoke, light smoking (1 cigarette per day), and heavy smoking (20 cigarettes per day); relative risks were 1.30 (1.22, 1.38), 1.39 (1.18, 1.64), and 1.78 (1.31, 2.44) respectively.

Alcohol consumption has a more complicated profile of risk. Most studies show an inverse "U" dose response curve where moderate drinking is beneficial. A recent meta-analysis on experimental studies of alcohol intake and measured cardiovascular risk factors concluded that alcohol intake was protective; they estimate a 24.7% decrease in coronary heart disease with a daily intake of 30 grams of alcohol[130]. Results on the benefits or risks of caffeine consumption and cardiovascular disease are inconclusive[131–133]; however most research studies have reported no association[133].

1.3.3.3 Non-modifiable Risk Factors

Several non-modifiable risk factors for cardiovascular disease are well established including age, sex, and family history of disease. Research has shown that increasing age is the most important risk factor for cardiovascular disease. The difference in risk of developing cardiovascular disease based on sex is more complex and the risks are dependent on age. Generally speaking, men are approximately two times more likely to develop cardiovascular disease than women, especially at a younger age[134,135]. A family history of cardiovascular disease also increases the risk of developing the disease, particularly among young men[136,137]. In addition to genetics, this is also thought to be related to family culture (i.e. lifestyle factors) that can influence modifiable risk factors such as eating and exercise habits.

1.4 Study Rationale

The fundamental goal of this dissertation is to characterize firefighters' exposures to occupational risk factors for cardiovascular disease, specifically noise, carbon monoxide, and stress (measured by cortisol secretion) to help improve future studies evaluating the risk of cardiovascular disease among professional firefighters. Appropriate exposure assessments of workplace hazards can improve our ability to identify and use appropriate comparison groups (e.g. low exposed firefighters) to evaluate disease risk. Further, identification of modifiable occupational determinants of exposure/response can help identify areas of concentration for the development of exposure reduction programs. This exposure assessment study was carried out among firefighters in the province of BC, a jurisdiction where compensation for cardiovascular disease has been a contentious issue.

The specific objectives of this dissertation were to:

1. Characterize firefighters' exposures to noise and CO during typical work shifts.
2. Determine if firefighters' noise and carbon monoxide exposures are within occupational exposure limit.
3. Evaluate the effects of fast rotating shift work on firefighters' circadian rhythm as measured by cortisol secretion over one full work cycle.
4. Determine work demographic, psychological, and physical factors that influence cortisol secretion on dayshifts as a measure of stress.

To address these questions a field study of firefighters in BC was conducted, measuring carbon monoxide, noise, and salivary cortisol. Participants were selected from 15 different fire halls in three large municipalities. Sampling was conducted over nine months to take into account some effects of seasonality.

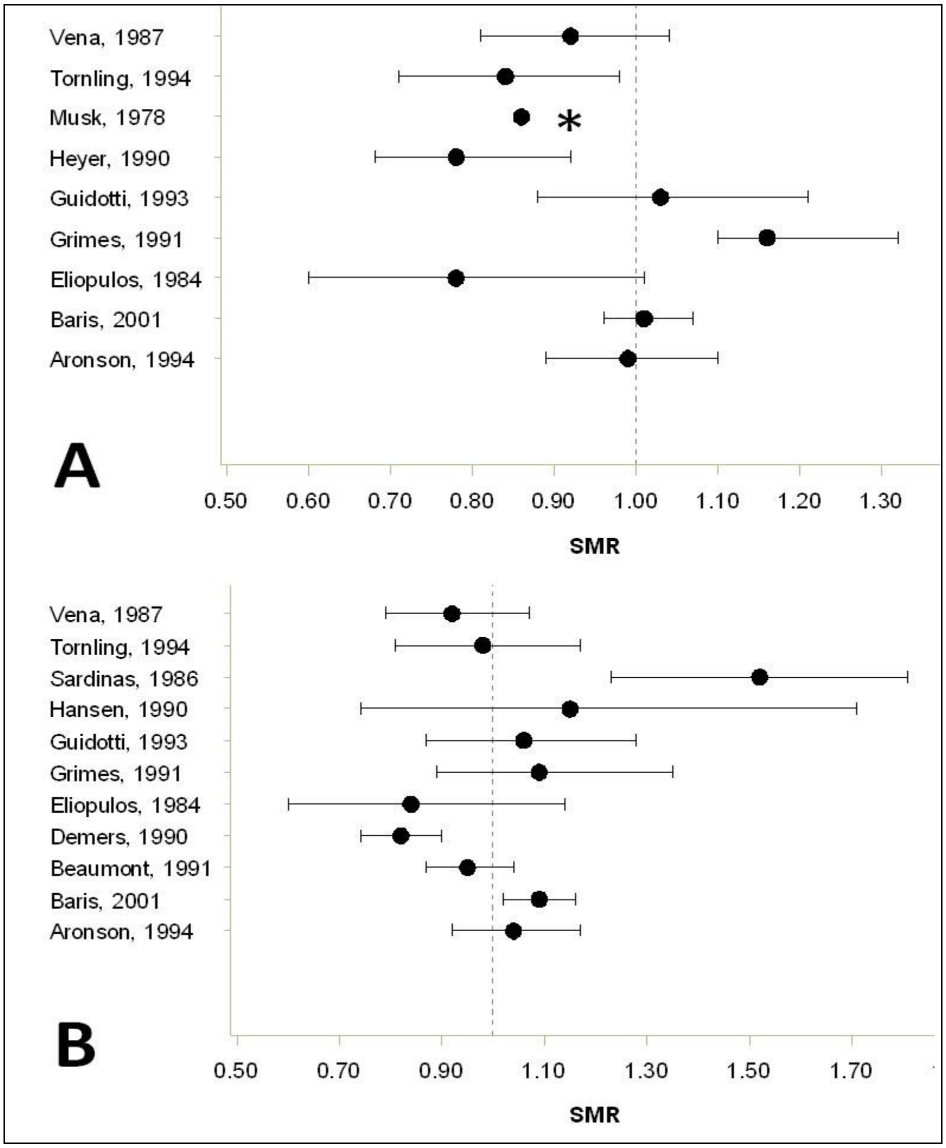


Figure 1-1. SMRs for reviewed mortality studies of (A) all circulatory diseases, and (B) ischemic heart disease. Dots represent SMR, whiskers represents 95% CI, and dashed vertical line represents no effect (i.e. SMR=1). *Musk, 1978 did not report confidence limits.

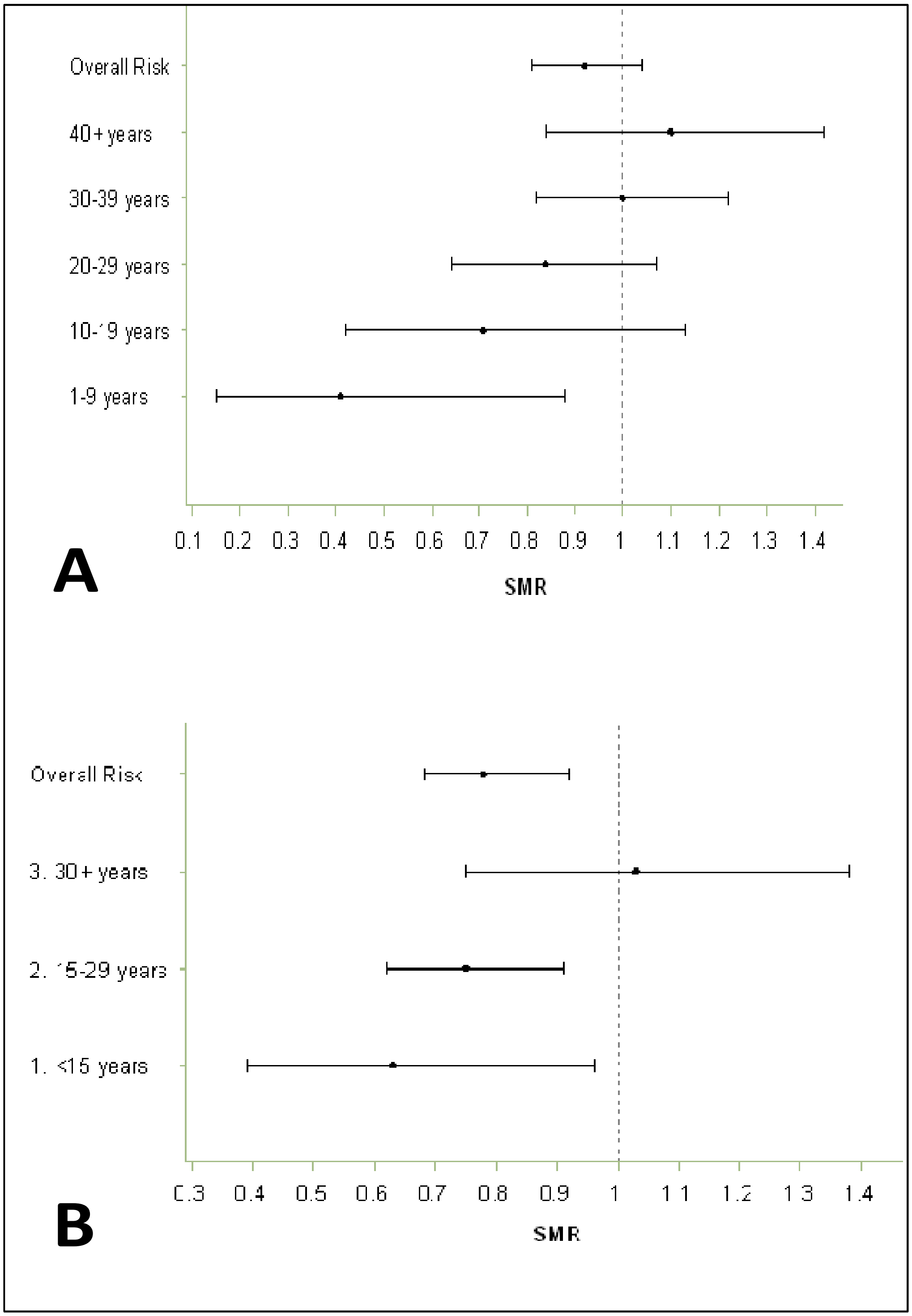


Figure 1-2. All circulatory diseases mortality stratified by duration of employment by study (A) Vena and Fiedler[20], and (B) Heyer *et al*.[15].

Table 1-1. Cardiovascular disease risk factors[1,3,58].

Non – Modifiable	Modifiable	Modifiable (Work-Related)
Age	Obesity	Chemical exposures
Sex	Physical inactivity	Noise
Family History	Smoking	Stress
	Abnormal lipoproteins	
	High blood pressure	
	Elevated heart rate	
	Illegal drug use	
	Caffeine	
	Alcohol consumption	
	Diabetes	

Chapter 2: Description of Firefighting Work

All three of the research chapters seek to measure occupational exposures among firefighters and determinants of these exposures. As such, it is helpful to have a detailed description of the nature of their work as a foundation for all three papers. The following section describes the basic organizational structure of most fire departments within British Columbia (BC), the daily activity and life of a firefighter, and some information on specific emergency calls.

2.1 Organization Structure

Fire departments within BC all follow a similar organizational structure that is overseen by a Fire Chief. Most fire departments are comprised of multiple departments with varying job tasks. Common departments within a fire department in BC can include:

1. **Suppression / Emergency Services**
   Suppression is the department primarily responsible for responding to emergency calls; suppression crews are stationed at various fire halls throughout the city/municipality.

2. **Training**
   The training department is responsible for coordinating/conducting training programs for suppression staff that may include fire training (theory and practical), auto extraction, technical rescue, hazardous materials response (HazMat), and/or medical training. They may also participate and/or organize training for other departments within their organization.

3. **Fire Prevention / Community Services**
   Fire prevention firefighters (otherwise known as fire wardens) act as liaisons for the community. They can be responsible for fire prevention, community services, public education and emergency preparedness. In some larger municipalities this may be broken into two separate units. Some of the duties include activities such as issuing permits, inspecting building with respect to fire codes, providing CPR and/or

extinguisher training, coordinating community events, and providing information to the public regarding fire safety and earthquake preparedness. They are also responsible for investigations following fires.

4. **Support Services**
   Support services includes technical staff within the fire department essential to its basic operation including mechanics, carpenters, information technology staff, and financial services.

5. **Human Resources**
   Human resource department is responsible for outreach and recruitment, and basic human resource responsibilities.

For the purposes of this field study we focused on the suppression and/or emergency services firefighters.

2.2 Fire Halls

Larger municipalities will have multiple halls within their fire department. The halls are typically strategically placed throughout the city and are each responsible for a particular geographic zone or area. At times there exceptions to this and fire halls will respond to calls outside of their zone such as the event of a multiple alarm (large event requiring multiple trucks or additional firefighters) or in situations where a neighboring unit has an emergency call and they are unable to respond (i.e. already attending an alarm).

The makeup of the fire halls varies with respect to the number of crew and fire trucks based on a number of factors (e.g. requirements for specialty teams, activity level of the area). Halls will staff a minimum of one fire truck (4 firefighters) in BC, which would include three firefighters and one captain. Halls with six or more firefighters typically will include one captain and lieutenant, with the remainder made up of firefighters.

Fire halls are designed to mimic residential homes, and are considered a second "home" to most firefighters. Halls can be either single or multiple levels but usually include a large kitchen, living room, office, bathrooms with showers, and sleeping quarters. In most of the fire halls, the living quarters is separated from the vehicle bays by closed doors to help reduce the exposure to diesel exhaust. To further reduce the exposure to exhaust, many of the halls in BC utilize movable ventilations systems that are attached to the fire truck exhaust pipes.

2.3 Fire Apparatus and Equipment

2.3.1 Fire Apparatus

Fire departments have a variety of truck types that generally respond to different call types. In most fire halls there will be an engine truck (truck able to pump water from holding source). For larger halls there may be additional trucks, which may include rescue, ladder, HazMat, wildlands, or quint (combination of an engine and ladder truck) trucks. In some instances, fire halls also have a fire boat to allow them to respond to marine fires on boats or in buildings along the shore. In BC almost all fire apparatus are diesel powered, which the exception being wildlands trucks (i.e. pickup trucks) and trucks driven by support staff such as Battalion Chief trucks which may be present in the fire halls.

2.3.2 Firefighting Equipment

During firefighting tasks firefighters may use a wide range of equipment; this may be motorized or non-motorized. Some of the types of non-motorized equipment used in firefighting may include: axes, hand saws, hooks, poke poles, sledgehammers, crowbars, knifes, ladders, ropes, and hose. Examples of motorized equipment used in firefighting include: hydraulic spreaders (e.g. "Jaws of Life"), hydraulic lifts, hydraulic rams (i.e. tools used for forcible entry, placed between a door and its frame), saws (e.g. chain or cutoff saws), fans for ventilating smoke filled areas, power pumps, cutters, concrete crushers, power wedges, and engine pumps.

2.3.3 Specialty Units

In instances there are specialty units where firefighters have received additional training. The more common examples of specialty units in BC include HazMat response, wildlands, marine, high angle rescue, technical rescue (ex. confined space), and auto extraction. HazMat response involves response to calls where hazardous chemicals or biological hazards may be present.

2.4 Work Schedule

Most career fire departments in BC work a standard 4 days on – 4 days off work schedule. This consists of two 10-hour dayshifts (~ 8:00 am – 6:00 pm), 24 hours off, two 14-hour nightshifts (6:00 pm – 8:00 am), followed by four days off. There are four shift crews (i.e. Shift A, Shift B, Shift C, and Shift D) which rotate through the shift schedule. Although fulltime firefighters are assigned to a particular shift/hall, they often work extra shifts to cover for firefighters who are sick, on vacation, or on leave.

2.5 Daily Activities and Tasks

Firefighters have many duties and tasks that fill their day while not attending emergency calls. A typical day for most departments will include time to perform station duties (cleaning, maintenance, cooking), partake in an exercise activity, perform engine checks, participate in training activities, and 'free time'. Firefighters during nightshifts tend to do less station duties on average as they incorporate sleep time into their schedule. Most firefighters are encouraged to go to bed at normal hours (10:00 – 12:00) and remain sleeping until morning if possible.

2.6 Emergency Calls

During their shift firefighters may be called to various types of calls. The majority of the calls firefighters attend are medical in nature. Other call types include motor vehicle accidents (MVA), hazardous materials releases, rescue operations (confined spaces, high angle, water, wilderness - cliff, etc.), and fires. Fire calls are also variable and can include wildland fires, structure fires (residential/commercial/industrial), dumpster fires, auto fires, and marine fires.

2.6.1 Fire Calls

Firefighting can be broken into two phases, knockdown and overhaul. Knockdown is the phase of active firefighting that involves search and rescue for trapped victims, and suppression of the fire. Overhaul is the phase of firefighting when the fire is extinguished and firefighters put out hot spots and begin the clean-up procedures. Previous research has shown that most contaminants were greater during knockdown than overhaul[138].

During fires, the duties and tasks are assigned based on seniority and job responsibility. There are several main tasks/roles during a fire call:

1. **Suppression**

   These individuals, usually firefighters, may enter the structure and search/rescue people trapped in the fire and conduct extinguishing tasks, which may include the use of hoses, axes, and other equipment to either suppress the fire or control its spread to other structures or areas.

2. **Support**

   These individuals typically remain at or near the fire trucks where they monitor the trucks (water supply) and hose lines. The engine truck driver is typically included into this category as they remain with the truck and operate the fire pump. They are characteristically senior firefighters. Lieutenants may also be included into this category, especially for small fires that involve few responding units.

3. **Command**

   Firefighters in the command role are usually the most senior firefighters (i.e. chiefs or captains). They work to coordinate the suppression activity and are responsible for maintaining contact with dispatch to report on the progress of the call. They rarely engage in suppression tasks and typically remain at or near the fire trucks.

2.6.2 Firefighter Personal Protective Equipment

When responding to all emergency calls except for medical calls, firefighters change into personal protective equipment termed turnout gear or bunker gear. In addition to their turnout gear firefighters also carry self-contained breathing apparatus (SCBA). Firefighters are encouraged to wear SCBA when in a carbon monoxide or smoke environment that could be dangerous to their health and safety. Research has shown that firefighters are diligent in donning their SCBA during knockdown activities however, research as indicated that they are less likely to wear SCBA during overhaul tasks[139]. In addition there is subjectivity with regards to when use of SCBA is required between departments and firefighters.

As previously mentioned, fire fighters in support and command roles tend to remain at or near the truck for the duration of the fire call. Firefighters working in these “stationary” positions tend not to wear personal protective equipment (i.e. SCBA) and may be at risk of exposure to elevated levels of contaminants.

Chapter 3: Characterization of Noise and Carbon Monoxide Exposures among Professional Firefighters in British Columbia

3.1 Synopsis

Noise and carbon monoxide (CO) have been associated with adverse health effects including cardiovascular disease. Due to the nature of their job, firefighters have the potential to be exposed to both noise and carbon monoxide at potentially dangerous levels. Currently little exposure information regarding noise and carbon monoxide levels are available among this occupational group therefore we aimed to characterize both noise and CO exposures among professional firefighters in British Columbia (BC), Canada.

Professional firefighters were recruited from 13 fire halls across three large municipalities in Metro Vancouver. Personal full-shift and noise and CO samples were collected using datalogging instruments on day and nightshifts. During sampling subjects were followed and determinants of exposure (DoE) information was recorded by trained research staff.

A total of 113 noise and 156 CO samples were collected from 45 male firefighters. We found that on average the noise levels were compliant however; 45% of our samples exceeded occupational limits when considering impact noise. Only 1% of CO samples were found to exceed occupational exposure limits. Determinants found to be associated with noise levels were the type of shift worked, if job title was a supervisory role, the type of fire apparatus assigned to, the number of emergency calls attended during sampling, the type of emergency calls attended, use of fire equipment, and participation in physical training. These results indicate that firefighters may be exposed to elevated levels of noise that may impair their health. Additional exposure studies are needed to further our understanding of the DoE to both noise and CO among firefighters.

3.2 Introduction

Firefighting is a diverse job that involves responding to a wide range of emergency calls including fires, building alarms, motor vehicle accidents (MVAs), medical emergencies, and technical rescues calls. In addition to responding to emergency calls, firefighters also routinely engage in training drills, fire hall/equipment maintenance, and community outreach activities that may contribute to their exposures. Two common exposures encountered during firefighting duties are noise and carbon monoxide (CO). Noise and CO have been associated with an increased risk of cardiovascular disease in epidemiological studies [59,60,62,100,106,107,140]. Research has also shown that noise-induced hearing loss can be potentiated by CO exposure[141,142].

The National Institute for Occupational Safety and Health (NIOSH) investigations of firefighters indicated noise exposures are below the Occupational Safety & Health Administration's 90-dBA exposure limit with time-weighted averages (TWA) ranging from 60 to 85 dBA and noted that exposures rarely exceeded NIOSH's recommended exposure level of 85 dBA[143–146]. However, Reischl *et al.* reported higher TWAs, ranging from 85 to 98 dBA among fire fighters[147]. Noise levels measured during simulated Code 3 responses (i.e. those involving lights, sirens, horns) ranged from 81 to 118 dBA suggesting there is potential for overexposure [143,147,148]. Further, firefighters experience accelerated hearing loss, supporting the potential for over exposure to noise[149–151].

Previous studies indicate that CO exposures during fires are highly variable ranging from <1 to as high as 15 000 ppm reported by Lowry *et al.* (1985)[138,139,152–156]. CO levels within fire halls have ranged from <1 to 5 ppm, but peaks of 300 ppm have been reported during daily truck checks within vehicle bays [157,158]. Sammons and Coleman (1974)[159] found that non-smoking firefighters had significantly higher carboxyhemoglobin levels compared to matched controls, 5 versus 2.3% of hemoglobin respectively. They report that exposures exceeded occupational biological exposure indices (3.5% of hemoglobin), suggesting an occupation cause.

Although it is known that firefighters are exposed to both CO and noise, few studies have measured exposure levels. The majority of existing evidence was obtained over 20 years ago and may not reflect current exposures due to changes in policies and procedures, fire equipment, and job duties. Further, little is known about the determinants of exposure (DoE) for these hazards. The aim of this study was (i) to characterize firefighters' exposures to noise and CO during typical work shifts, (ii) to determine if firefighters' exposures exceed workplace exposure standards, and (iii) to identify DoE for prevention or harm reduction strategies.

3.3 Methods

3.3.1 Study Sample

This was a sub-study of a larger study of exposure monitoring involving firefighters from three municipalities in Metro Vancouver that had an overall participation rate of 90%. For this sub-study, firefighters were recruited from 13 of the 15 original halls. Fire halls were selected from each municipality to represent different activity levels: high (i.e. 300+ calls per month), moderate to low (100–200 calls per month), and halls with specialty units (e.g. hazardous materials response, technical rescue, fire boat/marine). Where possible, at least four halls were targeted for each stratum. Personal sampling was conducted for one crew per hall over both 10-h day (8:00 a.m. to 6:00 p.m.) and 14-h nightshifts (6:00 p.m. to 8:00 a.m.) over four shifts.

Subjects were employed as a full-time professional firefighter including probationary firefighters (i.e. firefighters with <1-year professional experience), firefighters, lieutenants, or captains; held a job in fire suppression (i.e. non-administrative); and were scheduled to work during the selected sampling period. The study procedures were approved by the Clinical Research Ethics Board at the University of British Columbia (H07-01418) and by the participating fire departments, the International Association of Fire Fighters, and the British Columbia Fire Fighters Association.

3.3.2 Noise and CO Monitoring

Personal full-shift noise measurements were collected in accordance with CSA Standard Z107.56–94, Procedures for the measurement of occupational noise exposure, using datalogging Brüel and Kjaer 4436 Noise Dose Meters with 1-min logging intervals [160]. All dosimeters were calibrated with a certified calibration device before and after each sample. Personal CO measurements were collected using Dräger X-am® 3000 confined space monitors with internal pumps set with 30-s logging intervals. CO sensor measurement capabilities ranged from 1 to 1000 ppm. CO monitors were tested between each sampling set with standards at two exposure levels (10 and 98 ppm) to ensure calibration was maintained. Zero calibration was conducted prior to each sample. To conserve battery life of the CO monitors (~11 h, using internal pump) during the 14-h nightshifts, CO monitors were turned off when the subjects went to bed and turned back on immediately upon receiving an emergency call or when subject woke in the morning.

Participants were asked to participate in four full-shift sampling days; however, this was not always achieved due to absenteeism and equipment breakage and availability. Between zero and four noise samples, and at least one CO, samples were taken for each subject. Due to existing PPE and firefighting gear, CO monitors were placed on the outside of the subjects' thigh using modified athletic shorts with pockets. Noise monitors were placed in pouches that were attached to the waist. Both noise and CO sampling tubes were secured to the body to avoid being pinched by the firefighting gear and fitted on the subjects' uniform lapel at the start of shift. In the event of an emergency call (i.e. when subjects were required to don their PPE over their uniform), subjects were instructed to ensure the sampling tube inlets were not covered up by their firefighting gear (i.e. turn out gear) and were placed outside their collar.

3.3.3 Determinants of Exposure

Information on potential DoE was recorded through direct observation by trained researchers and hygienists throughout the duration of each subject's shift including runs, training activities, and fire hall activities. Variables that did not vary across samples included job title (probationary firefighter, firefighter, lieutenant, captain), type of truck assigned to (engine, quint, ladder, rescue), and municipality of employment. Each shift sample was further categorized for analysis as day- versus nightshift, use of fire-related equipment (yes/no), use of any motorized equipment (yes/no), participation in active firefighting training (yes/no), and whether they performed morning self-contained breathing apparatus (SCBA) checks (yes/no). Total number of calls over the sample was evaluated as a continuous variable up to six runs per sample. The sample shifts were also investigated by the type of emergency call attended as exposed at any time during the shift to an MVA (yes/no), medical, fire, routine, building alarms, or gas leak/electrical lines down emergency call.

3.3.4 Statistical Analysis

Outcome and exposure data were imported into SAS v9.1 (SAS Inc., Carry, NC, USA). Samples <4 h in duration were removed from the analysis as they were not considered representative of the shift. Data were evaluated using histograms and tests for normality (Shapiro–Wilk and Anderson–Darling) and log transformed where appropriate. For CO samples, data points less than the limit of detection (LOD) of 1 ppm were estimated as LOD/2.

Data considered normally distributed were evaluated using independent *t*-tests and one-way analysis of variance tests. Non-normal data were evaluated by differences in medians using Wilcoxon rank-sum and Kruskal–Wallis non-parametric tests. Correlations between the dependent variables and continuous/ordinal independent variables were evaluated using Spearman correlations. For all analysis, tests of significance were conducted at the 0.05 level.

DoE modeling was conducted for noise measurements using SAS Proc GLM with L_{eq} exposure as the dependent variable. There were insufficient CO measures above the LOD to conduct DoE modeling. Bivariate analysis between independent variables investigated correlations for collinearity and associations with chi-squared test.

British Columbia's provincial workers' compensation regulations, which are comparable to ACGIH TLV's, were used for compliance comparisons. CO exposure limits are 25-ppm 8-h TWA and 100-ppm 15-min short-term exposure limit (STEL). Noise limits are 85-dBA L_{ex}, 140-dBC peak, and a 3-dBA exchange rate where every 3-dBA increase in noise exposure is considered a doubling of exposure. To obtain the daily noise exposure level (L_{ex}), noise measurements (L_{eq}) were adjusted by a correction factor for shift length as per provincial regulations, where dayshifts were calculated as 10 h ($L_{ex\ day-10\ h} = L_{eq} + 1$ dBA) and nightshifts as 14 h ($L_{ex\ night-14\ h} = L_{eq} + 2.45$ dBA) in duration[161].

3.4 Results

3.4.1 Study Sample

Of those included from the main study ($n = 46$), only one participant refused to participate in this sub-study (98% participation). CO samples were collected from 45 male firefighters from April to November 2008, with a mean age of 41.0 ± 7.2 (standard deviation) and 14.2 ± 9.0 years of experience. Noise measurements were collected from 40 of these subjects (five were not measured due to lack of equipment availability); both groups were similar with respect to age and experience.

3.4.2 Noise

A total of 113 valid full-shift dosimetry samples were obtained from 40 subjects over 46 sampling days, with an average of 2.8 ± 1.1 samples collected per subject [11 samples were discarded from analysis due to inadequate sample duration ($n = 6$), calibration or equipment error ($n = 4$), and equipment overload ($n = 1$)]. Data were considered to fit a normal distribution based on histograms and tests for normality. The mean L_{eq} and peak noise levels were 81.1 dBA (range: 69.1–99.9 dBA) and 137.1 dB (range: 126.7–upper measurement level of 152.0 dB), respectively.

Noise exposure descriptive and simple linear regression results stratified by study variables (i.e. DoE variables) are illustrated in Table 3-1. Noise exposures were significantly higher during dayshifts compared to nightshifts, 83.5 and 78.8 dBA respectively ($P < 0.0001$), and explain ~25% of the variation in the noise exposures. Noise exposures did not differ significantly by job title (data not shown) but differences were more pronounced when collapsed into supervisory (captain + lieutenant) versus non-supervisory (firefighter +

probationary firefighter) groups, 79.2 and 81.5 dBA respectively ($P = 0.046$). Subjects riding rescue and engine trucks had over a doubling of exposure compared to those riding ladder trucks ($P = 0.02$ and $P = 0.03$, respectively). In addition, attending at least one MVA call, using or being near fire equipment during the shift, and participating in active training were significantly associated with noise exposure ($P < 0.05$). Municipality, number of calls attended, attending at least one building alarms call during the shift, and conducting morning SCBA checks appear to cause a notable but non-significant increase in noise exposure.

Multiple regression models were developed; however, the determinants variables are not unique and many overlap and are related to each other, making interpretation difficult. One notable observation was the reduced effect of municipality once entered with the other static job variables (e.g. job title, shift, truck) or number of calls attended over the measurement duration (data not shown).

The average number of dispatched calls was 2.2 ± 1.9 (range 0–8) calls per full-shift sample (Table 3-2). The most frequent type of call was medical emergency calls, followed by building alarms (i.e. alarms ringing in building with no reported sign of fire/smoke). There were statistically significant positive correlations between L_{eq} noise levels and the number of dispatched calls over the measurement period ($r = 0.21$, $P = 0.02$); when stratified by shift, the correlations became stronger for nightshifts ($r = 0.33$, $P = 0.01$) compared to dayshifts ($r = 0.13$, $P = 0.30$). When broken down by number of types of runs, MVAs ($r = 0.32$, $P = 0.0005$) and building alarms calls ($r = 0.19$, $P = 0.04$) were significantly correlated with noise level.

3.4.3 Carbon Monoxide

A total of 156 valid full-shift CO samples were obtained from 45 subjects over 50 sampling days, with an average of 3.5 ± 0.8 samples collected per subject [12 samples were discarded from analysis due to inadequate sample duration ($n = 10$) and equipment malfunction ($n = 2$)]. The full-shift CO data were highly skewed and remained skewed after log transformation (12% less than LOD). Instantaneous maximum/peak CO concentrations that were reached during the measurement duration were also skewed and log transformed for analysis.

Table 3-3 shows descriptive statistics for full-shift CO and peak CO exposures stratified by study variables. The mean full-shift CO exposure was 1.0 ppm [geometric mean (GM) = 0.7 ppm, geometric standard deviation (GSD) = 1.8 ppm] and ranged from <1 ppm to 28.7 ppm. The mean instantaneous peak CO concentration reached during the measurement period was 42.93 ppm (GM = 9.95 ppm, GSD = 5.57 ppm). No significant differences in full shift and peak CO levels were observed across the three municipalities, type of shift, type of truck, or job title; however, probationary firefighters' mean peak CO exposure was almost three times greater than lieutenants' exposure levels, 67.4 (GM = 14.8) and 24.5 (GM = 9.6) ppm, respectively. Subjects who rode on rescue trucks had the greatest peak exposure (mean = 74.3, GM = 12.2 ppm) compared to those who rode on ladder trucks (mean = 21.48, GM = 9.32).

The average number of dispatched calls during CO sampling was slightly lower than those observed in the noise data but followed similar patterns (Table 3-4). Both the full-shift and peak CO concentrations were positively correlated with number of calls; however, the relationship was not significant. Similar to noise, both number of MVA and building alarms calls were significantly associated with full-shift and peak CO concentrations.

3.4.4 Exposure Compliance

The mean shift-adjusted daily noise exposure level (i.e. L_{ex}) was 82.9 ± 4.4 dBA [95% confidence limit (CL) = 82.0–83.7 dBA], so the upper CL of the mean did not exceed 85 dBA; however, analysis of the L_{ex} by day- (84.5 dBA, 95% CL = 83.4–85.6) and nightshift (81.3 dBA, 95% CL = 80.1–82.4) suggests that dayshift noise levels may exceed occupational limits.

Approximately 27% of the samples exceeded the exposure limit of 85 dBA (Table 3-5), and an additional 27% exceeded the action limit of 82 dBA. In British Columbia, a maximum peak exposure limit of 140 dBC is also regulated; 31% of our samples exceeded a 140-dB (linear) exposure limit. Combining both exposure limits, 45% of our samples exceed British Columbia occupational noise limits. Several Canadian, American, and International jurisdictions also use a 115-dBA maximum limit of continuous noise (i.e. non-impact, >1 s):

21% of our samples exceeded the 115-dBA maximum limit and increased the observed non-compliance by an additional 4%.

Only one sample (0.6%) exceeded the occupational exposure limit for CO (25 ppm) and another exceeded the 15-min STEL. No additional samples exceeded the action limit of 12.5 ppm.

3.5 Discussion

Our results show that firefighters are at an increased risk of over exposure to noise. The shift-adjusted noise exposures observed in our study are much higher than levels previously measured by NIOSH that rarely exceeded 85 dBA[143–146]. We anticipated that our noise levels would be lower than previous studies due to changes in truck designs over the last 20 years that were made to reduce noise (e.g. enclosed cabs, repositioned siren) and changes in equipment design. However, our L_{ex} measurements are comparable to those calculated by Reischl *et al.*[147]. One difference they reported was that captains had the highest exposure levels due to their proximity to the radio system within the trucks. Truck design changes since the Reischl study may explain why we did not observe this effect. Further, from our initial analysis, the upper CL of the mean noise exposures did not exceed occupational limits; however, noise exposures are more complex and we illustrated that perhaps a more detailed assessment of exposures is needed to determine compliance of noise samples, particularly in occupations that have the potential of frequent exposure to impact noise.

As expected, we found that noise levels were significantly greater during dayshifts compared to nightshifts and explained 25% of the variance in the noise exposures, which remained significant after adjustment for other study variables. In addition to the noise associated with attending calls, firefighters are engaged in other activities between calls during dayshifts that may result in added noise exposure including training, inspections, community service, and hall and equipment maintenance. Although these activities may take place for part of nightshifts, the majority of the nightshift is relatively quiet and firefighters are encouraged to sleep.

Firefighters in non-supervisory roles had significantly higher noise exposures than those in supervisory roles. Firefighters are typically involved in operating equipment and performing noisy tasks whereas captains/lieutenants are more likely to be coordinating/performing administrative tasks that may result in lower exposures. Although borderline significant, it is believed that the true effect may be attenuated by misclassification of exposure. For example, during large fires, multiple fire halls are dispatched to the fire; in these instances, the captains/lieutenants in the first trucks to arrive on scene fill the supervisory roles and the captains/lieutenants in subsequent trucks arriving on scene engage in fire suppression tasks, thereby potentially increasing their noise exposures. Regardless, it should be noted that the variability among the exposure groups is very wide; suggesting that grouping by job title may not be very helpful in describing exposure. Neitzel *et al.*[162] observed a similar effect among construction workers where exposures were also highly variable. They suggest the differences in noise exposures were most likely attributable to work environment factors rather than job title/tasks; this may also be true for firefighters.

In our study, rescue trucks had the highest exposure level, which was similarly observed in a study of Memphis firefighters conducted in 1985 when they restricted their analysis to non-airport halls[144]. Rescue trucks tend to have higher call volumes overall (3.7 ± 1.5 calls per shift) compared to other trucks (engine 2.3 ± 1.7, quint 1.6 ± 1.8, and ladder 0.7 ± 1.6 calls per shift); therefore, the number of dispatched calls may be driving this relationship. This hypothesis is supported by the fact that ladder trucks typically respond to the least number of calls, and had the lowest exposure levels.

Interestingly, we observed an increase in exposure among Municipality 2. Municipality 2 responded to more calls on average (3.3 calls per sample) than municipality 1 and 3 (1.6 and 1.8 calls per shift respectively). In addition, many of the calls attended in the highest exposed municipality involved MVAs (14% compared to 7 and 5%) and calls in commercial areas where traffic noise was present, which may be contributing to the increase in noise exposure. This would explain why municipality became unimportant once adjusted for other study variables such as number of calls.

As hypothesized, number of calls over the measurement period was correlated with L_{eq} noise levels (spearman correlation: $r = 0.214$, $P = 0.2$); however, when broken down into type of emergency calls, only number of MVA and building alarms calls were significantly correlated with noise levels. When type of run was collapsed into a dichotomous variable of exposure (yes/no), MVA and building alarms calls were also significant in simple linear regression. These results suggest that the number of runs, particular if at least one run was an MVA call, may be important for noise exposures. MVA calls are highly variable in nature; however, most occur on relatively busy roads. Some of the potential activities contributing to noise levels during MVAs (i.e. determinants) to investigate in future studies included general traffic noise and proximity to traffic, honking, other emergency vehicle sirens (police, ambulance, tow truck), clanging of metal (tow truck loading, car doors/hoods closing, prying metal with hand tools, or motorized equipment), bystanders/crowd control noise, and proximity to the running fire trucks. Building alarms calls often result in exposure to continuous ringing of building alarms while on scene; however, the duration of the ringing vary widely resulting in our observed positive but weak correlation with noise levels. Proximity to ringing and duration of ringing may be helpful with future determinants modeling. The number of (or yes/no—dichotomous variable) routine calls showed no relationship with noise levels. This was not surprising as routine calls do not involve siren or horn use; most of our routine calls were fire complaints (e.g. reported backyard fires, beach fires) or back up calls that were mostly cancelled before arrival on scene.

Use of any motorized equipment resulted in slightly increased exposures; however, it seems less important than fire-related equipment. Fire calls and use of fire-related equipment was strongly associated (chi square, $P < 0.0001$); however, whether a firefighter used equipment at the fire appears to be more important than if they just attended the call. To help tease out these relationships, a more detailed assessment is needed to identify specific exposures during these tasks, which may include proximity to determinants.

As previously mentioned, firefighters' daily activities are highly variable and many of the DoE overlap and/or are related in some way, which may have limited our ability to obtain meaningful multivariable models with the data at hand. However, we have identified potential areas to concentrate further efforts including MVA calls, building alarms calls, use of fire equipment, and training activities. It is important to note that we were unable to take PPE into consideration for our noise analysis. While riding in the fire truck, firefighters are supposed to be wearing headsets to (i) decrease noise exposure and (ii) provide a means of communication. The headsets have volume control, but it is unknown what their exposures were during these runs. Further, there are times when firefighters do not wear the headsets, primarily on route to fire calls, when they are busy putting on their personal protective equipment making adjustment difficult.

Full-shift CO concentrations were lower than expected and limited our ability to conduct modeling of exposures. Only two samples exceeded occupational exposure limits (1%); however, no other studies have published full-shift CO sampling for comparison. Unlike the results reported by Lucas[157] and Echt *et al.*[158], CO concentrations within the living quarters were not detected, except in the vehicle bays. All the halls within our study had ventilation systems that attach to the fire truck exhaust pipes to extract the diesel exhaust that may account for the lower exposures. We did observe occasional CO peaks approximately at the time of arrival back to the hall (data not shown). This may have occurred during the task of attaching the ventilation system to the truck exhaust pipe. Current policy among the fire departments in our study is to attach the ventilation hose to the truck prior to entering the vehicle bay. However, we observed frequent violations of this policy where the extractor arm was attached after the truck was parked within the vehicle bay, particularly during nightshifts. The observed peaks are similar to those reported by Lucas[157] who measured CO levels of 250–300 ppm during engine checks.

We were unable to present data of CO levels by activity, but observed peak exposure ranges similar to those reported during fires from previous studies[139,152,153,156]. Lowry *et al.*[155] and Treitman *et al.*[154] reported concentrations reaching much higher concentrations; however, this may be due to differences in duties performed by the subject, measurement technique, or the intensity of the fire/smoke measured during the measurement period.

A lack of a significant correlation between full-shift CO exposures and number of dispatched calls suggests that number of emergency calls is not a good measure of full-shift CO exposure. Further, the reasons for negative associations observed with CO exposure and medical emergency and gas/electrical/explosion is unknown. One potential explanation is that these call types were typically in residential areas that may result in lower vehicle exhaust emissions from traffic that are considered the most likely contributor to non-fire-related CO levels.

We were unable to take into account use of PPE (i.e. SCBA) in our CO analysis. During fires and other emergency events, firefighters may don SCBA, which would decrease, although not eliminate, their exposures to CO[138]. In cases where SCBA was used, subjects' CO exposures may be overestimated and provide a more conservative measure; however, this provides little difference in our study, as average CO levels are already low.

Our study design was developed to evaluate typical shifts; therefore, we were bound by the emergency calls and exposures encountered during sampling. Due to this, there were several activities, equipment usages, and call types that were not observed during our sampling period. Further, for many shifts, we experienced lower call volumes than anticipated based on historical data limiting the occurrences of potential determinants. The small cell sizes among our potential determinants, due to the lower than expected call volume, and highly variable work conditions, may have limited our ability to see true associations. A second limitation of our study was the potential for measurement error. It was possible that the sampling tube inlets were blocked (i.e. under PPE) by the firefighting gear during emergency events. The study staff attempted to check each subject to ensure the tubes were in the correct position after firefighters had donned their gear to minimize blockages; however, there were times when this was not possible and blockage may have occurred, thereby underestimating the exposure. Although subjects were observed during calls, there were times when they were not within view and research staff had to rely on subjects to recall the tasks they performed. Further, it is possible that research staff may have missed an activity/task undertaken during an event or training as there were up to four subjects to observe at one time. This would have most likely attenuated the relationships we observed.

For analysis, any sample over 4 hrs in duration was considered a valid sample to represent exposure over a shift. Firefighting activities and exposures are extremely varied and we feel that the sampling time including in this study adequately represents their exposures (mean sample duration for noise and CO samples were 10.3 ± 3.0 and 7.9 ± 2.3 hrs, respectively). Delays in donning equipment, subjects' relief arriving early, and battery life were the primary reasons for decreased sampling time. Further, during nightshifts, subjects turned off the CO monitors while they slept to preserve battery power. Through initial investigation and direct observation, we did not observe CO levels within the living quarters that exceeded the LOD (1 ppm) except within the vehicle bays; therefore, we feel that having the monitor off during this time would not have resulted in an increase in exposure and most likely would have caused an over estimate of exposure.

A culture of not wearing hearing protection during emergency calls due to the belief that it would interfere with their health and safety was evident among the fire departments enrolled in our study. Firefighters frequently commented that they rely on their ears when they can't see what is happening around them, particularly during fires when they are listening for cries for help or warning signs that the floor/roofs may collapse, and hearing protection would put them at risk for injury or death. However, from our observations, we identified five key areas where hearing protection may be possible to implement without putting firefighters at risk. These included times when firefighters are conducting weekly equipment checks, during fire pump operation, during MVA calls where traffic noise is present or mechanical equipment is being operated (e.g. jaws-of-life), during some training drills, and during SCBA checks. At the start of each shift, one firefighter, usually the most junior firefighter, checks each SCBA tank on all the fire trucks to ensure they are working. During this task, the tank alarm is triggered, which was measured to have noise exposures >112 dBA. Although the alarm is only triggered for a short time (~10 s), multiple tanks are tested which could significantly attribute to their full-shift exposure (i.e. dose). Implementation of hearing protection during these times may reduce firefighters' exposures below occupational limits. It is worth mentioning that PPE (i.e. hearing protection) is neither the only nor the most desired method to control/reduce noise exposures. Additional exposure reduction strategies should be evaluated such as engineering controls (e.g. purchase of quieter equipment) and administrative controls (e.g. education).

This study was the first to publish noise/CO exposures among Canadian firefighters and the only study to provide full-shift CO measurements to our knowledge. During sampling, we recorded determinants by direct observation, increasing the reliability of our data compared to studies using self-reported only. Our data suggest that either the firefighters in our sample are exposed to higher noise levels than those previously published in USA or potentially changes in technology and/or job duties over the past 20 years have increased their noise exposures. Due to the wide variability in firefighters' jobs, and hence exposures, we were unable to clearly identify DoE with our data; however, we have identified several areas where perhaps efforts could be concentrated in future studies.

Table 3-1. Descriptive statistics and simple linear regression of personal full-shift L_{eq} noise exposure levels (dBA) of firefighters stratified by work demographic characteristics and firefighting activities.

						Simple Linear Regression		
	N	Mean	Median	SD	Range	R^2	B-Estimate (SE)	*P*-value[a]
Overall	113	81.1	80.9	4.8	69.1-99.9			
Job group								
Supervisory	20	79.2	79.4	4.5	69.1-87.7	0.035	Ref	
Firefighter	93	81.5	81.3	4.7	72.6-99.9		2.3 (1.1)	0.05
Type of fire truck								
Engine	41	81.9	82.1	5.5	73.5-99.9	0.068	3.1 (1.4)	0.03
Ladder	15	78.8	78.7	4.0	72.6-86.4		Ref	
Quint[b]	33	80.2	79.9	4.3	69.1-91.3		1.5 (1.4)	0.31
Rescue	24	82.3	82.5	3.8	74.0-88.2		3.6 (1.5)	0.02
Type of shift								
Dayshift	55	83.5	83.2	4.0	77.5-99.9	0.247	4.7 (0.8)	<0.0001
Nightshift	58	78.8	78.4	4.3	69.1-92.2		Ref	
Municipality								
Municipality 1	29	80.4	80.3	4.4	73.5-87.7	0.029	Ref	
Municipality 2	32	82.4	81.1	5.7	74.0-99.9		2.0 (1.2)	0.10
Municipality 3	52	80.7	81.1	4.2	69.1-89.2		0.3 (1.1)	0.76
Used/near motorized equipment[c]								
No	87	80.9	80.8	4.5	69.1-99.9	0.008	Ref	
Yes	26	81.9	82.2	5.6	72.6-92.3		1.0 (1.1)	0.36
Used/near fire equipment[d]								
No	88	80.5	80.8	4.3	69.1-89.2	0.060	Ref	
Yes	25	83.3	83.2	4.7	76.3-99.9		2.8 (1.0)	0.009
Participated in active training[e]								
No	81	80.5	80.7	4.3	69.1-92.2	0.035	Ref	
Yes	32	82.5	82.7	5.5	72.6-99.9		2.0 (1.0)	0.05
Conducted morning SCBA checks								
No	80	80.7	80.7	4.5	69.1-92.3	0.018	Ref	
Yes	32	82.1	82.2	5.2	73.5-99.9		1.4 (1.0)	0.15
Total number of calls (Continuous)						0.030	0.4 (0.2)	0.07
Attended MVA during shift								
No	92	80.5	80.2	4.8	69.1-99.9	0.073	Ref	
Yes	21	83.8	83.9	3.4	78.0-92.3		3.3 (1.1)	0.004
Attended MESA call during shift								
No	55	80.9	80.3	5.6	69.1-99.9	0.001	Ref	
Yes	58	81.3	81.4	3.8	73.5-89.2		0.3 (0.9)	0.72
Attended Fire call during shift								
No	84	80.9	80.8	4.9	69.1-99.9	0.006	Ref	
Yes	29	81.7	81.5	4.4	75.0-92.2		0.9 (1.0)	0.40
Attended a Routine call during shift								
No	106	81.1	81.0	4.8	69.1-99.9	0.00002	Ref	
Yes	7	81.0	79.4	3.6	78.1-88.2		-0.1 (1.9)	0.96

						Simple Linear Regression		
	N	Mean	Median	SD	Range	R^2	B-Estimate (SE)	*P*-value[a]
Attended building alarms during shift								
No	79	80.7	79.6	5.2	69.1-99.9	0.019	Ref	
Yes	34	82.1	82.3	3.5	74.5-92.2		1.4 (1.0)	0.15
Attended Gas leak/electric lines down call during shift								
No	107	81.1	80.9	4.7	69.1-99.9	0.0004	Ref	
Yes	6	81.5	79.4	5.8	76.5-92.3		0.4 (2.0)	0.83

dBA, decibels in A-weighting; n, number of measurements; SD, standard deviation; Ref, reference category; SE, standard error; SCBA, self-contained breathing apparatus

[a] *P*-value computed by independent t-test or one-way ANOVA

[b]Quint – a fire apparatus that has the function of both an engine truck and a ladder truck

[c]Motorized equipment includes operated/near ventilation fan, engine pump, fire boat, other motorized equipment including saws, vacuums, airbags and pumps, spreaders (i.e. jaws-of-life), etc.

[d]Fire equipment includes operated/near ventilation fan, engine pump, and used SCBA or charged fire hose in training or during fire calls (charged fire hose = fire hose with water).

[e]Active training is training involving actual firefighting activities (i.e. not classroom training/theory) such as mock rescue operations, fire suppression, vehicle extraction, ect.

Table 3-2. Descriptive statistics of call data by type of call and correlations of number of runs with full shift L_{eq} noise exposure levels (n=113).

	Mean	SD	Range	Spearman Correlation (r)	*P-value*
Total number of dispatched calls per sample	2.2	1.9	0 – 8	0.214	0.022
Number of calls by call type per sample					
Medical	1.1	1.4	0 – 6	0.077	0.42
Alarms Ringing	0.4	0.8	0 – 4	0.189	0.045
Fire	0.3	0.5	0 – 2	0.074	0.432
MVA	0.2	0.5	0 – 2	0.321	0.0005
Routine	0.1	0.3	0 – 2	-0.014	0.881
Gas leak, electrical lines, explosions	0.06	0.3	0 – 2	-0.031	0.742
Technical rescue	0.01	0.09	0 – 1	-0.107	0.258

MVA, motor vehicle accident call; SD, standard deviation; L_{eq}, noise exposure level

Table 3-3. Descriptive statistics of personal full-shift and peak CO exposure levels of firefighters stratified by work demographic characteristics.

	n	Full-shift CO Concentration (ppm)					Instantaneous Peak CO Concentration (ppm)				
		Mean	GM	GSD	Range	*P*-value[a]	Mean	GM	GSD	Range	*P*-value[b]
Overall	156	1.04	0.7	1.8	<1 - 28.7		42.9	10.0	5.58	<1 - >1000	
Job group											
Supervisory	41	1.4	0.7	2.1	<1 - 28.7	0.79	43.8	9.4	5.0	<1 - >1000	0.81
Firefighter	115	0.9	0.7	1.7	<1 - 8.0		42.6	10.2	5.8	<1 - 849	
Type of fire truck											
Engine	63	0.7	0.6	1.5	<1 - 3.4	0.60	31.6	9.8	4.9	<1 - 541	0.90
Ladder	22	0.8	0.7	1.6	<1 - 3.0		21.5	9.3	4.8	<1 - 126	
Quint[c]	41	1.7	0.8	2.3	<1 - 28.7		48.9	9.0	5.9	<1 - >1000	
Rescue	30	1.0	0.7	1.9	<1 - 5.4		74.3	12.2	8.0	<1 - 849	
Type of shift											
Dayshift	75	0.8	0.7	1.7	<1 - 4.7	0.65	46.7	11.5	5.4	<1 - 849	0.33
Nightshift	81	1.2	0.7	2.0	<1 - 28.7		39.5	8.8	5.8	<1 - >1000	
Municipality											
Municipality 1	48	0.7	0.6	1.4	<1 - 3.0	0.20	18.6	7.2	4.6	<1 - 145	0.17
Municipality 2	39	0.9	0.7	1.7	<1 - 3.4		56.4	14.6	7.3	<1 - 541	
Municipality 3	69	1.4	0.8	2.1	<1 - 28.7		52.3	9.9	5.2	<1 - >1000	

ppm, parts per million; CO, carbon monoxide; *n*, number of measurements; SD, standard deviation; GM, geometric mean; GSD, geometric standard deviation
[a] p-value computed by Wilcoxon-Mann Whitney test
[b] p-value computed by independent t-test
[c] Quint – a fire apparatus that has the function of both an engine truck and a ladder truck

Table 3-4. Descriptive statistics of call data by type of call and correlations of number of runs with average full-shift CO exposure levels (n=156).

	Mean	SD	Range	Spearman Coefficient (r)	*P-value*
Number of Calls Attended	2.3	2.0	0 – 7	0.132	*0.099*
Number of calls by call types					
Medical	1.0	1.3	0 – 6	-0.090	*0.263*
Alarms Ringing	0.4	0.8	0 – 4	0.293	*0.0002*
Fire	0.3	0.6	0 – 2	0.067	*0.402*
MVA	0.3	0.6	0 – 4	0.187	*0.019*
Routine	0.06	0.3	0 – 2	0.006	*0.941*
Gas leak, electrical lines, explosions	0.05	0.2	0 – 2	-0.056	*0.486*
Technical rescue	0.02	0.1	0 – 1	0.054	*0.504*

MVA, motor vehicle accident call; SD, standard deviation; CO, carbon monoxide

Table 3-5. Number of individual compliant noise exposure measurements with workplace exposure limits.

	n	%
Daily exposure limit compliance (85 dBA)		
Compliant (<85 dBA)	82	72.6
Non-compliant (85+ dBA)	31	27.4
Peak exposure limit compliance (140 dB)		
Peak <140 dB	78	69.0
Peak 140+ dB	35	31.0
Peak and/or daily exposure limit compliance		
Compliant	62	54.9
Non-compliant	51	45.1

n, number of measurements; %, percent; dBA, decibels in A-weighing

Chapter 4: Effects of Fast Rotating Shift Work on Cortisol Secretion in Professional Firefighters

4.1 Synopsis

Shift work has been associated with an increase in cardiovascular disease, thought to be possibly due to disruption of the circadian rhythm. Suppression firefighters traditionally follow a rotating shift schedule complicated with the ability sleep during their night shifts. We aimed to determine if firefighters working a fast rotating shift schedule have altered circadian rhythms measured by cortisol secretion.

Professional full-time employed male firefighters who were working in suppression were recruited in Metro Vancouver, British Columbia (BC). Firefighters provided six saliva samples for eight consecutive days (i.e. one work cycle). Values of the slope, area under the curve with respect to ground (AUC_g) and increase (AUC_i) were calculated for two time periods; the awakening response and the diurnal decline throughout the day (14 hour exposure). Changes were evaluated by day and between aggregated work and non-work days, and days working dayshifts and nightshifts.

We obtained 2411 of the 2592 expected saliva samples from 54 firefighters. As expected, the cortisol profiles of our subjects followed the predicted diurnal pattern, peaking after waking and slowly declining over the day. The most pronounced differences were observed on the first dayshift and days following nightshifts where significant increases in the cortisol awakening response were observed during the awakening response. In addition, AUC_i and AUC_g were significantly different on the first day off following the last night shift and on the first day shift. The cortisol awakening response (30min – waking) was significantly increased on work days compared to off days, and on mornings of dayshifts compared to nightshifts (p=0.02). AUC_g over decline over the day was also significantly increased on work days compared to off days (p=0.002). Our results show that despite the ability to sleep during nightshifts, firefighters still exhibit significantly altered cortisol secretion patterns over their work cycle.

4.2 Introduction

In 2005 approximately 28% (4.1 million) of Canada's working population and 66% of protective services workers (e.g. police, fire, security) worked a non-daytime shift (i.e. shift work)[163]. Firefighters, specifically firefighters who work in suppression (i.e. respond to emergency calls), traditionally work some type of rotational or irregular work schedule. In British Columbia (BC) most firefighters work a fast rotating shift schedule including two 10-hr dayshifts, followed by two 14-hr nightshifts and four consecutive days off work. However, unlike many other shift workers, firefighters are unique in that they are often able to sleep during their nightshifts when not attending emergency calls.

Shift work has been linked with multiple adverse effects including increased injuries, gastrointestinal diseases, metabolic syndrome, cancer, and cardiovascular disease[77,164–168]. Sleep deprivation leading to disruption of the circadian rhythm has been implicated as a possible mechanism for the adverse effects of shift work however, the evidence to support the claim has been inconsistent[169–172]. A review of the methodological aspects of shift work conducted by Knutsson[173] pointed out that inconsistencies in the relationship between shift work and circadian rhythm disruption may be a result of failure to account for the intra- and interpersonal differences in the biological measures, concluding that repeated samples are required to obtain a better picture of the issue. Cortisol, a hormone regulated by the hypothalamic-pituitary-adrenal axis (HPA) feedback system, is released in a typical diurnal pattern (lowest value in the middle of the night, slowly rising before waking and quickly increasing to a peak concentration approximately 30 minutes after waking, and then declining throughout the day) and has been thought to be a good measure of changes in circadian rhythms[174,175].

Several studies have shown that shift work may cause changes in cortisol secretion[176–178]. Touitou *et al.*[178] found that oil refinery workers with rapid rotating shifts had lower peak and higher trough serum cortisol levels (i.e. flattened response) when working nightshifts compared to controls (healthy males synchronized to standard daytime hours). Similarly, a laboratory-based study conducted by Griefahn and Robens[179] reported a significantly lower cortisol awakening response (CAR) following day sleep (i.e. nightshifts) compare to night sleep. Kudielka *et al.*[180] studied the effect of changing shift patterns on former and permanent day/nightshift workers and found that cortisol profiles were blunted during nightshifts and days off for night and day workers; however day workers were able to adjust quicker to the changing shift than night workers. A study of offshore workers found a similar effect where workers working nightshifts took longer to recover to baseline levels[181]. The results of these studies suggest that cortisol is a sensitive physiological measure of the effects of work shifts.

Previous research has established that shift work may influence circadian rhythms however many of these studies relied on limited sample days (i.e. one sample day/shift type) and often with limited samples per day. Further, to date no study has investigated the temporal changes of cortisol secretion among firefighters who have a rotating shift schedule complicated by interrupted sleep during nightshift. We aimed to determine if firefighters exhibited an altered cortisol secretion pattern due to exposure to shift work across their eight day work week. Our study improved upon previous studies by taking repeated measures of the same subject over a full shift cycle (i.e. eight days) to allow us to observe patterns of change within each subject. Specifically, we aimed to determine if there was a difference in secretion by (1) day over the eight dayshift cycle (2) work days compared to non-work days, and (3) dayshifts compared to nightshifts. The results of this project sheds light on the added health risks of firefighting as an occupation that experiences multiple exposures to health hazards causing similar effects as shift work.

4.3 Methods

4.3.1 Participants and Recruitment

Professional male firefighters were recruited from three municipalities in Metro Vancouver, BC, Canada from March to November 2008. To be eligible firefighters must have had been employed as a full-time firefighter in fire suppression (i.e. non-administrative) and scheduled to work during the sampling period. Job titles included captains, lieutenants, firefighters, and probationary firefighters (i.e. firefighters with less than one year of experience). Firefighters who were scheduled to be on vacation or who were transferred to another shift prior to sampling commenced were excluded.

Fire halls were selected to ensure a representative number of samples were obtained from halls with either high or low call volume (i.e. >300 calls/month vs. 100-200 calls/month), and halls with specialty units (e.g. hazardous materials response, marine/fireboat, wildlands, and technical rescue units including high angle rescue and auto extraction). Hall activity level was determined using 2005-2007 call volume statistics obtained from the fire departments. Where possible at least four halls were targeted in each stratum. From each selected hall, one crew was chosen for sampling based on a predetermined sampling schedule based on research staff availability

Fire captains were contacted from each participating hall/crew to arrange an information session about the study. Firefighters were then given a minimum of four days to consider participation in the study prior to the second site visit. On the second site visit up to four firefighters were recruited for participation, which included informed consent, training in sample collection, and the provision of a study kit containing their sampling materials and written instructions. The protocol was approved by the Clinical Research Board at the University of British Columbia (ethics certificate number H07-01518). Protocol approval was also obtained by the participating fire departments, the International Association of Firefighters (IAFF) local unions, and the BC Professional Firefighters Association.

4.3.2 Cortisol Sampling and Analysis

Saliva samples were collected six times a day for eight consecutive days (i.e. one work cycle) using cotton rolls (Salivette®; Sarstedt, Nümbrecht, Germany, tube # 51.1534) provided in an electronic monitoring device (MEMS 6; Aardex Ltd., Switzerland) that has been shown to improve subject compliance[182]. Samples were to be taken (1) immediately after awakening, (2) 30-min after awakening, (3) at the start of their work shift or 1.5 hours after awakening, (4) immediately before lunch, (5) at the end of their shift or immediately before supper time on days off, and (6) immediately before bed. Subjects were asked to avoid drinking, eating and brushing their teeth at least 30 minutes before a sample. Subjects were instructed to chew on the cotton roll for one minute and place it in an empty sample tube. Following collection samples were to be labeled with the date/time and recorded in a sampling diary (including sample number, time, and any physical activity or food/beverages consumed one hour prior to the sample), and to store saliva samples in a refrigerator to avoid mold growth during the sampling period.

Saliva sampling began (i.e. Day 1) on the subjects' first "day off" when they awoke at work after their second nightshift and concluded on the evening of their last nightshift (Figure 4-1). This included four days off work followed by two days of a 10-hr dayshift and two days of a 14-hr nightshift. All samples were collected on the subjects' last work shift and refrigerated and then frozen at -20^{o}C until analysis. Samples were shipped frozen and analyzed using a commercially available chemiluminescence-immuno-assay (CLIA; IBL, Hamburg, Germany) for salivary free cortisol (reportable range 0.1656 – 110.4 nmol/l).

Samples greater than 110.4 nmol/l were excluded from the analysis (n=3) and were thought to be due to contamination from hydrocortisone cream use (as noted in the sample diary). Samples less than 0.1656 nmol/l remained in the analysis if reportable levels were provided. To test for quality control, every 10th sample was re-analyzed to test for laboratory precision. No significant differences were observed between duplicate samples (test result p=0.31).

4.3.3 Questionnaire Data

A questionnaire to collect data on demographic characteristics was administered during the sampling period. In addition, participants were asked to keep a cortisol sampling diary to obtain information on activities that may influence cortisol levels over the day including wake time, time and date sample was taken, medications taken during the day, food eaten and exercise done within one hour prior to sample.

4.3.4 Cortisol Measures

The six daily cortisol samples were used to evaluate cortisol secretion patterns for two periods, cortisol awakening response (CAR) and cortisol decline over the day. The awakening response is thought to have intra-individual stability if measured over several days[183], although they are also thought to reflect anticipatory stress and may vary[184]. Cortisol decline throughout the day may be more sensitive to the activities of the current day.

For each period, the area under the curve with respect to ground (AUC_g), the area under the curve with respect to increase (AUC_i), and slope were calculated using methods described by Pruessner *et al.*[185]. AUC_g is commonly thought of a measure that reflects total hormone output over the measurement period and has been shown to be associated with physical complaints; whereas AUC_i is a measure of the changes over time and more associated with perceived stress levels[185].

In addition to AUC_g, AUC_i, and slope, the CAR (i.e. sample taken at 30 minutes post waking – awakening sample) was also measured as a continuous variable. An awakening sample taken within 10 minutes of waking, and sample 2 taken 30 minutes +/- 15 minutes after waking were considered compliant. Variables computed for the cortisol decline throughout the day were computed using sample 3 (1.5 hrs. after waking) as baseline and truncated at 14 hours to account for differing hours of duration between samples.

4.3.5 Statistical Analysis

Cortisol variables were calculated in Excel® (Microsoft, Redmond, WA, USA) and exported to SAS 9.1 (SAS Inc., Carry, NC, USA). Data were evaluated for normality through visual inspection of histograms. Paired t-tests were used to determine if there is a difference in means between (1) day of the work shift cycle (i.e. Day1 – Day 2, Day 2 – Day 3, etc., through Day 8 – Day 1), (2) the average cortisol values for work days compared to non-work day averages, and (3) day and nightshifts for each of the continuous cortisol outcome variables. In cases where data was not normal the non-parametric equivalent (i.e. Wilcoxon Rank Sum test) was used to determine the difference in medians. p-Values <0.05 were considered statistically significantly.

4.4 Results

4.4.1 Study Population

In total, 104 firefighters from 15 fire halls were invited to participate in the study. Of these, 68 were eligible, and 61 agreed to participate (90% participation rate). Of the 61 fire fighters who agreed to participate, 54 completed sampling. Reasons for not participating included: lack of equipment availability (n=3), and hall reassignment for the sample days (n=2). In addition, two participants did not complete sampling; one participant dropped out stating work load/commitment of sampling protocol was too great and another participant was excluded as they threw out their samples when left at home and grew moldy. Basic demographics and job characteristics of the remaining 54 participants are shown in Table 4-1. Firefighters ranged from 25 to 56 years of age with less than one year to 23 years of experience. Most firefighters were married, non-smokers, and had high job satisfaction.

4.4.2 Cortisol Samples

We obtained 2411 of the 2592 expected saliva samples from the 54 firefighters (i.e. 93%). On average firefighters returned 44.6 samples of the 48 requested. Firefighters were more likely to be noncompliant on work days than on off days and a general trend of decreasing compliance over the day was observed. As expected, the cortisol profiles of our subjects followed the predicted diurnal pattern, peaking after waking and slowly declining over the day.

4.4.3 Awakening Response

Of the 432 expected sample days (54 firefighters * 8 days) we were able to calculate 403 awakening responses (93%), of which 320 met the compliance requirements (74%). Evaluating the compliance by sample we observed that firefighters were more compliant in taking the waking sample (83%) than the 30 minute post waking sample (78%). Figures 4-2 through 4-4 illustrate the difference in the calculated cortisol measures for the awakening response including the cortisol increase (i.e. CAR), AUC_g, and AUC_i, respectively. Slope of the awakening response had a similar pattern and significance tests as CAR (data not shown).

Firefighters exhibited a significant increase in CAR on Day 5 (i.e. first dayshift) compared to Day 4 (i.e. last day off). CAR then decreased over the next two days and was comparable to "background" levels measured on Day 3 by Day 7 (i.e. when subjects awoke at home). CAR then significantly increased again on Day 8 when waking at work following the first nightshift and remained elevated on the morning of Day 1 following the second nightshift and then slowly decreases across days off work. In addition, CAR was significantly lower on off days (Day 1-4) compared to work days (Day 5-8), and on days of nightshifts (Day 7-8) compared to dayshifts (Day 5-6), p=0.02 (Table 4-2).

The AUC_g (i.e. total hormone output) pattern exhibited an opposite pattern to CAR, as expected, where the lowest hormone output during awakening was on Day 5 and Day 8 and Day 1 (i.e. mornings waking at work) and increases over Day 2-4 (i.e. days off). The AUC_i measure of the awakening response has a similar pattern over the work shift cycle to CAR in that we see a significant increase on Day 5 compared to Day 4 (median) and a decrease to approximately background on Day 7. No significant differences in days off/days on, or by dayshift days/nightshift days were observed for AUC_g or AUC_i.

4.4.4 Cortisol Decline

Compliance in obtaining measures throughout the day to allow for measurement of the cortisol decline over the day was greater than the awakening response (96% VS. 93%); 399 were included for analysis (92%). Nine measures were excluded as there was no baseline sample taken (i.e. no sample 3), and 5 contained only one sample following the awakening response. The AUC_g and AUC_i for the cortisol decline over the day are presented in Figure 4-5 and 4-6. Slope of the cortisol decline had a similar pattern across the eight-day work cycle (data not shown).

The AUC_g shows a slight increasing trend across the work shift cycle starting on Day 2 (i.e. second day off work) where we observe a significant increase in output on Day 5 compared to Day 4 and a significant decrease in cortisol output on Day 1 and Day 2. A significant decrease in AUC_i was observed during Day 5 compared to Day 4, which then significantly increased on Day 6. Overall cortisol output over the day was greater on work days compared to off days ($p=0.002$) and on days firefighter worked a nightshift compared to a dayshift ($p=0.09$); however, no significant differences were found for AUC_i or slope.

4.5 Discussion

This study aimed to determine if firefighters exhibited altered cortisol secretion patterns (the awakening response and the cortisol decline over the day) related to their fast rotating work schedule. Our results suggest firefighters' shift schedule may cause alterations in cortisol secretion, particularly on the first day of work (i.e. first dayshift) and on the mornings following nightshifts; however, the effects differed based on the time interval of cortisol secretion (i.e. awakening response vs. cortisol decline). A summary of the cortisol measures, time frames, and major findings are located in Table 4-3.

Firefighters experienced a non-significant decrease in total hormone secretion (AUC_g) and a significant increase in the pattern or rate of change (ie.CAR and AUC_i) of cortisol secretion during the awakening response on the first dayshift (i.e. first day back at work after 4 off) compared to the last day off. A study of offshore workers observed a similar effect where workers had a decrease in waking cortisol levels with an unchanged post waking (30 min) sample, which would result in an increase in CAR and a decrease in AUC_g as shown in our sample, for day workers first dayshift following days off[181]. A possible explanation for a heightened response following waking may be due to the anticipation of returning to work. The CAR was lower on the second dayshift compared to the first dayshift however it was still over three times greater than that observed on the last day off. The reason why the effect may not be as elevated as the first dayshift may be due to an effect of returning to work after four days off (i.e. heightened anticipation). In addition, during the day (i.e. cortisol decline) we observed a significant increase in total hormone output (AUC_g) and a steeper decline in the pattern of release (i.e. negative AUC_i).

Similar awakening patterns were observed on mornings following nightshifts where we observed progressively increasing CAR and AUC_i, and decreasing total hormone output across the mornings following a nightshift. AUC_i levels appeared to immediately return to background levels following two dayshifts when waking at home (i.e. on morning of Day 7); however we did not observe this effect following the nightshifts. Following the two nightshifts AUC_i did not return to "baseline" until Day 3 (i.e. the third day off. Potential reasons for this difference to return to baseline may be twofold: (1) on Day 7 firefighters are waking at home and are not anticipating going to work when they awake; (2) on Day 2 firefighters have not recovered from their two nightshifts, where sleep quality may be poor. This suggests that the time to recover from the two nightshifts for firefighters is two days and the third day off work following a four day rotating shift schedule may be the most accurate measure of baseline for comparisons. Recovery on Day 3 was much quicker than reported in offshore swing shift workers who returned to baseline after one week of returning home[181]. The quicker recovery may be due to the fact that firefighters have fast rotating shifts where they only work 2 consecutive shifts, while other shift workers may work 5-7 shifts in a row allowing their circadian rhythm to adjust to the shift, thus requiring a longer recovery time. This is consistent with findings that circadian adjustment was made in night workers by night five or six (i.e. no difference in cortisol secretion between day and night workers)[176]. Further Kudielka *et al.*[180] proposed that fast rotating shift work allows for quicker recovery periods than permanent night work.

It has been shown that workers have elevated cortisol measures on work days compared to leisure days[186–188]. Our results are consistent in that we observed a significant increase in CAR on work days compared to off days and an elevated AUC_g during the day. A study of firefighters and paramedics by Dutton *et al.*[189] in the 1970's found subjects secreted higher levels of urinary hydrocortisone on leisure days than work days; however, the difference was more pronounced for firefighters when compared to paramedics. The authors suggest that perhaps the lower workload of firefighters during their sampling may be an explanation for the lower levels compared to paramedics; paramedics attended 38 calls whereas firefighter attended only seven calls over the study period. The workload of our subjects was probably greater and the evolution of firefighting duties, which now include medical calls, may explain why we did observed a different effect.

In addition to observing a change in secretion patterns on work versus non-work days, we observed similar pattern changes by type of shift where dayshifts had significantly greater CAR, steeper awakening slopes, and a lower hormone output over the day (i.e. AUC_g of cortisol decline) than nightshifts. A laboratory study with controlled sleep cycles reported a similar pattern change[179]. However, another study indicated that cortisol secretion was generally lower during nightshifts compared to dayshifts, which was measureable on the first nightshift[180]. The reasons for the differences in the findings are unknown.

Some of the small differences between previous research findings and our findings may be due to the uniqueness of firefighters' shift schedule in that unlike most shift workers they have the ability/opportunity to sleep at night while not on a call; although they reported that their sleep quality is poor when sleeping at the fire hall. However, this also makes interpretation of the effects of shift work more difficult. Unfortunately there are no other studies of populations with this work arrangement for comparison to our knowledge. In future studies perhaps monitoring or recording the duration of sleep for each shift would help tease out the relationship between shift work and cortisol disruption.

We obtained a lower compliance rate than expected from this occupational group given that it is one where rules and procedures are commonly followed for safety reasons. However, compliance regarding the timing of sample collection is a limitation of most circadian research when time highly influences hormone levels. To help improve compliance we (1) provided subjects with both written and verbal instruction and notified the of the importance proper protocol adherence and reporting; (2) provided their samples in an electronic recording device so times marked on the sample tubes and diaries could be checked; and (3) informed them we were monitoring their compliance with the recording device as research has shown that subjects aware of compliance monitoring systems tend to be more complaint[190]. Further, even with the electronic monitoring devices we still have to depend on proper reporting of waking time. Overall we found firefighters were complaint in taking most of the samples (93%). However, they often took them too late or too early, making them unusable. It should be noted that firefighters may have been woken from their sleep in the fire hall by an alarm. In these instances firefighters were not able to take their morning cortisol samples immediately. In most cases firefighters returned to bed to resume sleep and cortisol samples were taken later when they awoke. In the situations where firefighters remained awake, they took their samples as soon as possible however they most likely would not have been categorized as compliant for the awakening response and the samples would have been lost. Unfortunately due to their job there was no way to obtain these samples. In future studies additional compliance items may help improve compliance such as alarmed watches to remind subjects to take their samples.

This study was exploratory in nature and we did not control for potential confounding factors that may have influenced our results. Stress, physical exertion, food/beverage intake, health status, age, smoking, sleep duration and quality, and noise exposure are just some of the factors shown to influence cortisol levels[191–194]. Future work will utilize the demographic questionnaire and diary data to investigate workplace and non-workplace factors associated with cortisol levels among firefighters. Another limitation of this study was the use of salivary cortisol as a measure of free cortisol. However, previous research has shown a strong correlation between saliva and blood cortisol levels in populations working different shifts and concluded that salivary cortisol is still an appropriate measurement method of adrenal activity during shift work[177].

Our sampling protocol was one of the more comprehensive sampling protocols studying the effects of shift work on cortisol secretion, entailing eight consecutive days. Most other studies have measured one or two dayshifts and days off, adding reliability to our study measures. Our robust protocol provided us with a clearer picture of the temporal relationship of cortisol secretion over a full work cycle. In addition we standardized our sampling to commence the morning of their first day off work and collected samples for one full work cycle avoiding problems with comparing different leisure or work days across individuals. Another strength of our study is that it was a field study providing actual responses of workers working in everyday life rather than a laboratory study where subjects are being put into an environment that may affect their natural cycle.

We conclude that cortisol output is affected by exposure to a fast rotating shift schedule of two 10-hr dayshifts followed by two 14-hr nightshifts that may put them at risk of experiencing adverse effects. We identified that firefighters appear to recover from their fast rotating shift schedule by the third day off work; therefore, we suggest that the third day off work may be the most appropriate baseline comparison of cortisol levels in future studies where full work cycles are not being sampled. Future research is necessary to shed more light on the effects of sleeping during nightshifts in this unique population and how it may affect cortisol secretion.

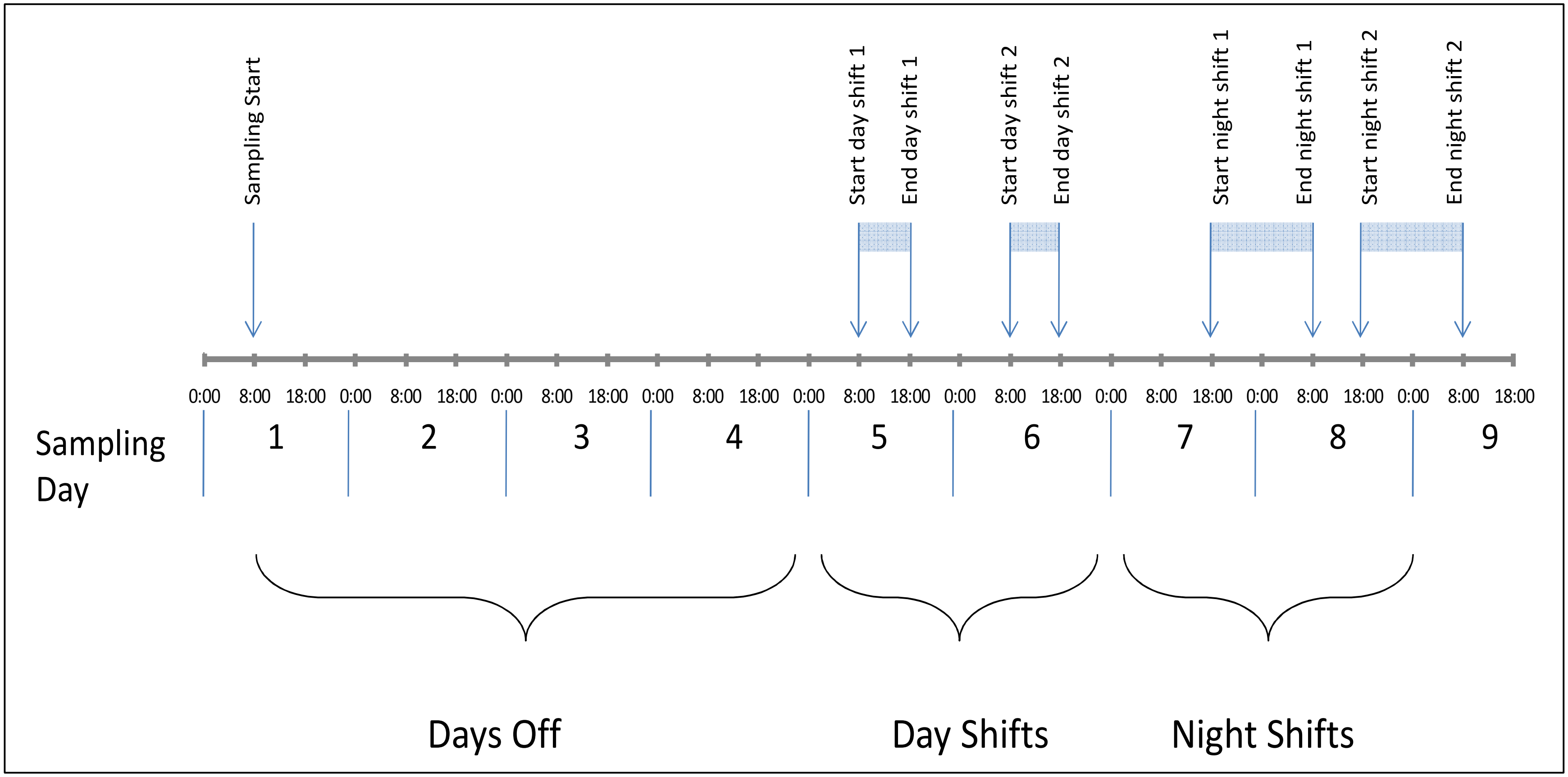
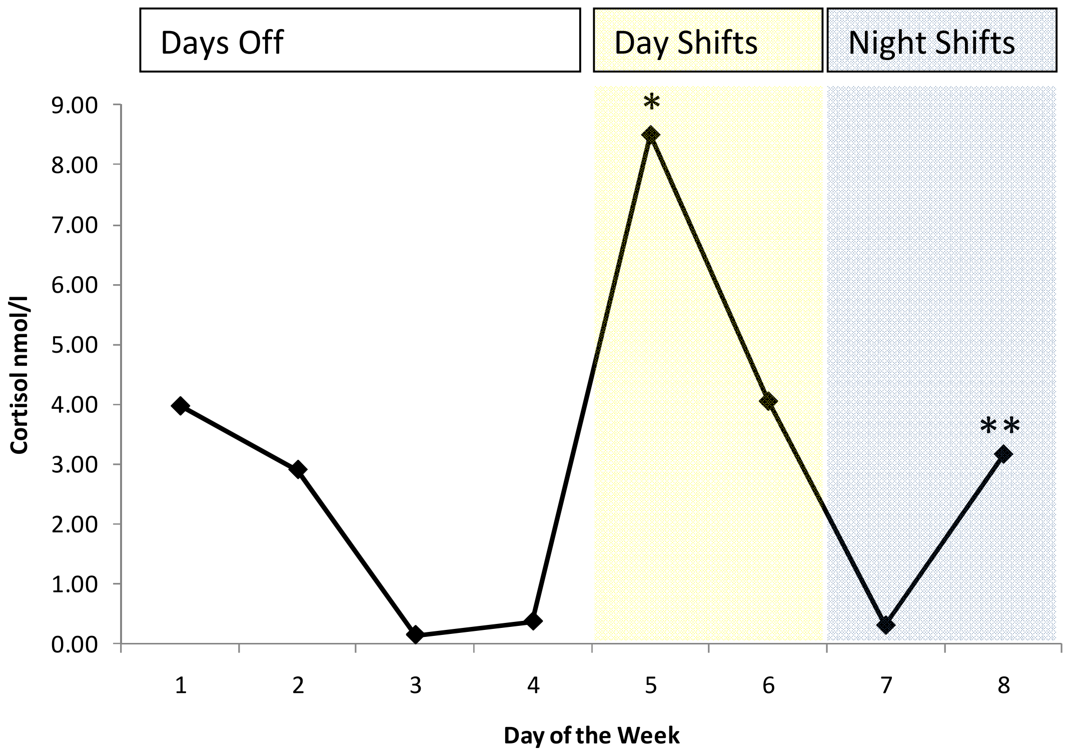


Figure 4-1. Eight day sampling timeframe and firefighting work schedule.

Table 4-1. Demographic and work characteristics of study population.

Characteristic	**Mean and Range or Percent (%)**	
Age in Years	41	(25 - 26)
Years of Experience	7.7	(<1 - 23)
Body Mass Index	28	(22 - 36)
Abdomen to Wrist Ratio	5.3	(4.5 - 6.4)
Marital Status (%)		
Married/Common Law	87	
Separated/Divorced	7	
Single	4	
Widowed	2	
% Smokers	2	
Physician Diagnosed High Blood Pressure (%)	5	
Alcohol Consumption (%)		
1 or less/week	46	
<7 times/ week	51	
Daily	4	
Caffeine Consumption (%)		
1 or less/week	4	
1 or less/day	47	
2+/day	49	
Job Title (%)		
Fire Fighter	75	
Lieutenant	7	
Captain	18	
Job Satisfaction (%)		
Very Satisfied	69	
Satisfied	25	
Neither Satisfied nor Dissatisfied	4	
Dissatisfied	2	
% Work Second Job	46	

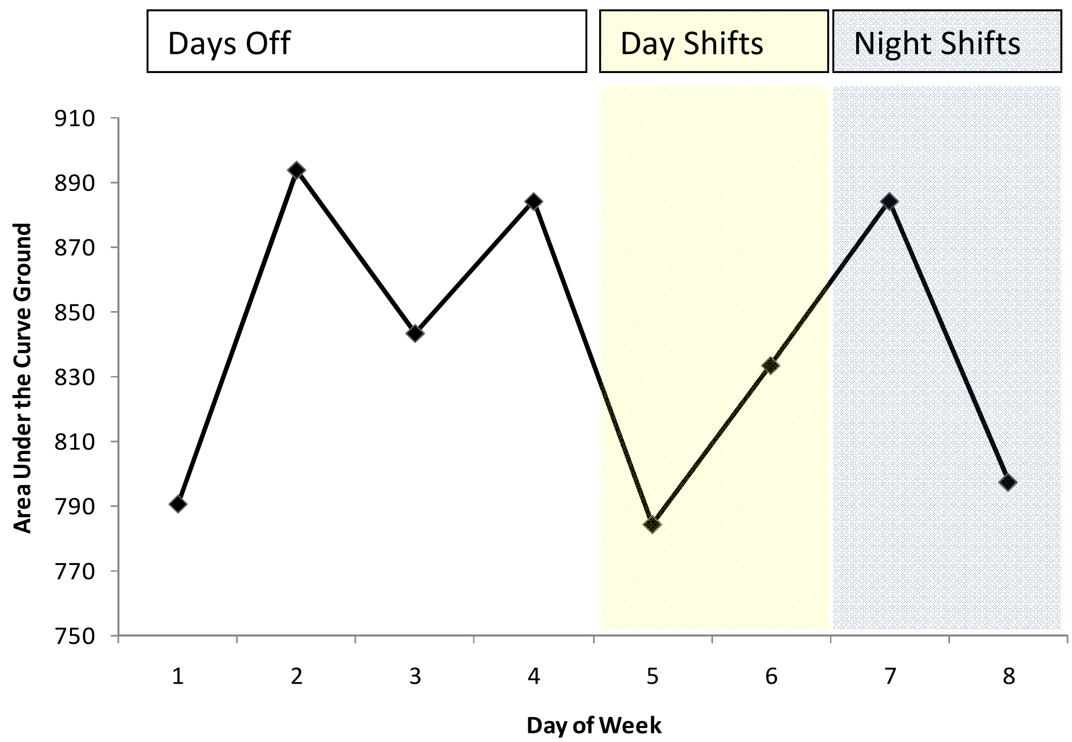
%, percent



*p=0.003: Change from Day 4 (last day off work) to Day 5 (first day shift)
**p=0.03: Change from Day 7 (first night shift, start at 6pm) to Day 8 (second night shift, first shift waking at work)

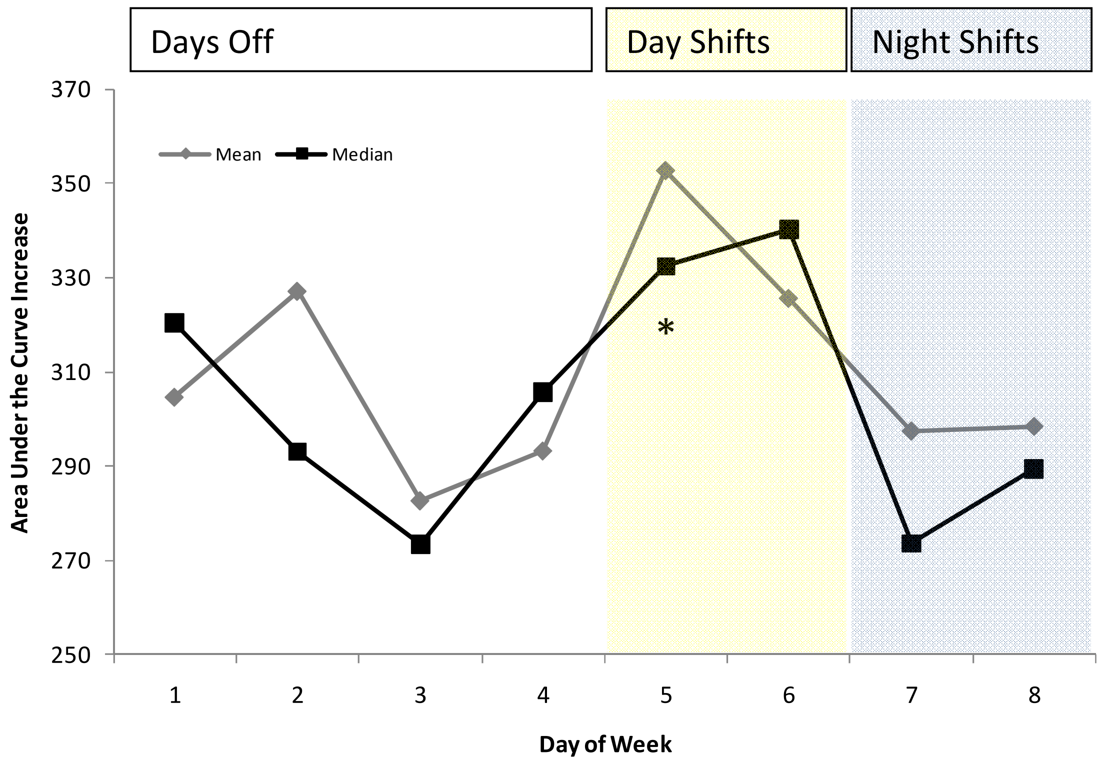
Day	Description	N	Mean	Standard Deviation	Minimum	Maximum	Range
1	Day Off	42	3.97	10.37	-20.76	29.11	49.87
2	Day Off	45	2.91	10.06	-14.84	43.52	58.35
3	Day Off	45	0.15	9.78	-20.98	18.33	39.31
4	Day Off	40	0.37	10.37	-27.45	28.18	55.62
5	Day Shift	44	8.51	13.09	-22.54	39.26	61.81
6	Day Shift	33	4.05	11.72	-16.18	28.66	44.84
7	Night Shift	35	0.31	13.24	-32.34	35.55	67.89
8	Night Shift	36	3.17	10.98	-23.47	22.96	46.43

Figure 4-2. Cortisol awakening response (CAR) by day of the week.



Day	Description	N	Mean	Standard Deviation	Minimum	Maximum	Range
1	Day Off	42	791	374	22	1618	1596
2	Day Off	45	894	434	16	1874	1858
3	Day Off	45	843	394	36	2090	2054
4	Day Off	40	884	320	121	1642	1522
5	Day Shift	44	784	378	22	1612	1589
6	Day Shift	33	833	426	21	1767	1746
7	Night Shift	35	884	396	259	1693	1434
8	Night Shift	36	798	408	16	1637	1621

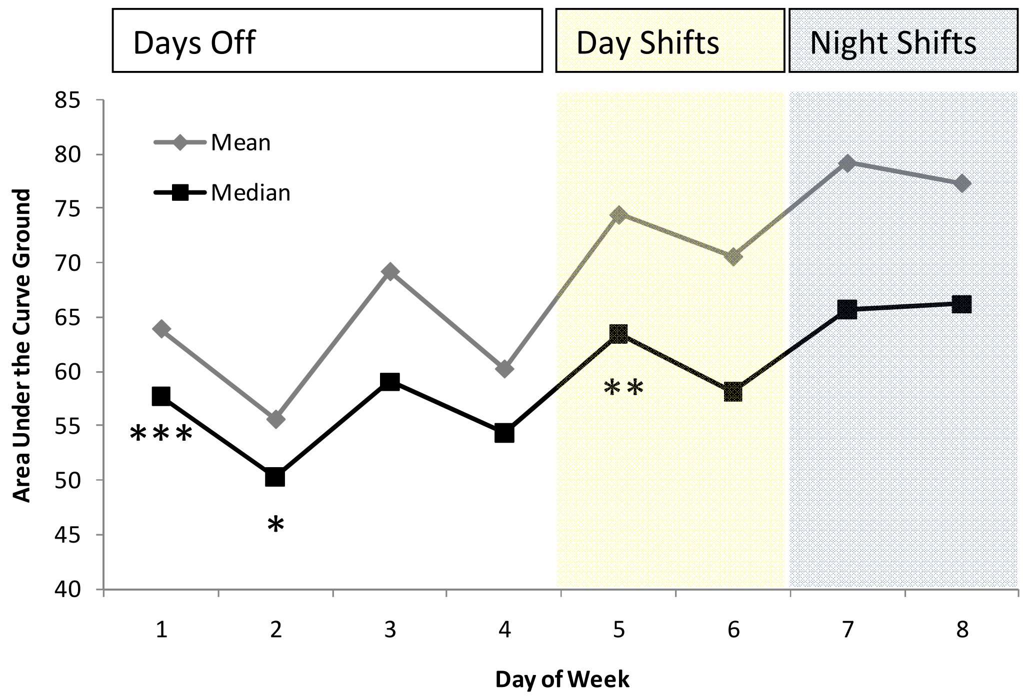
Figure 4-3. Area under the curve with respect to ground of awakening response by day of the week.



*p=0.04: Change from Day 4 (last day off work) to Day 5 (first day shift) using Wilcoxon test for differences in medians.

Day	Description	N	Mean	Median	Inter Quartile Range	Variance
1	Day Off	42	305	320	232	22881
2	Day Off	45	327	293	213	29621
3	Day Off	45	283	273	213	30701
4	Day Off	40	293	306	154	16864
5	Day Shift	44	353	332	207	41055
6	Day Shift	33	326	340	249	54622
7	Night Shift	35	297	274	236	36099
8	Night Shift	36	298	289	219	33787

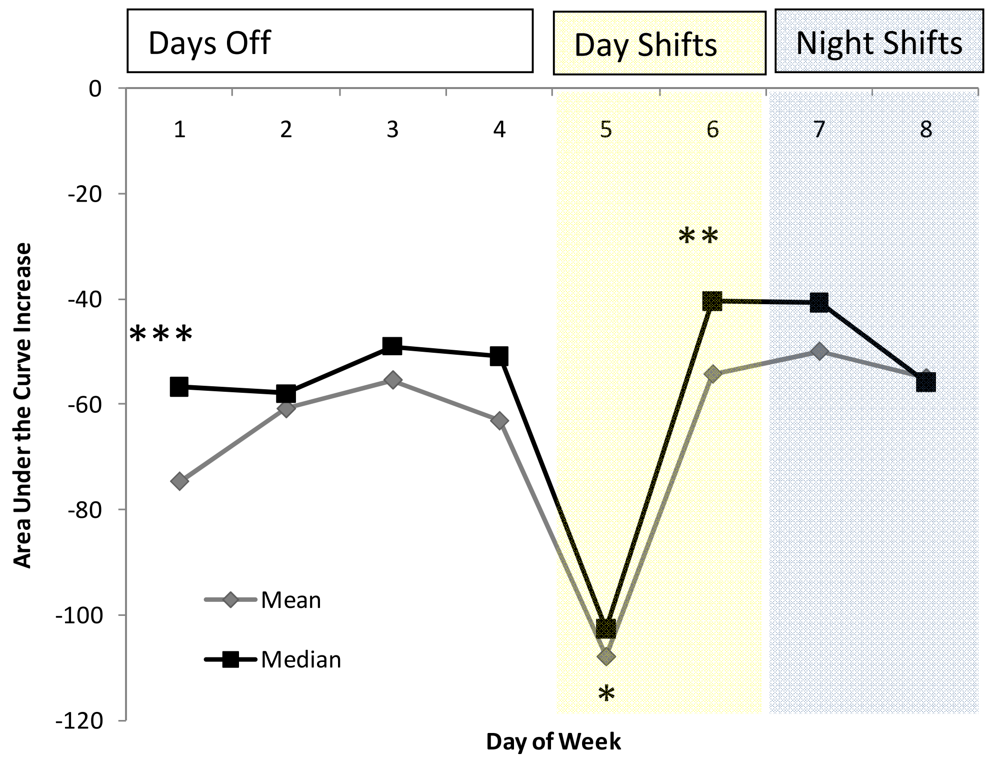
Figure 4-4. Area under the curve with respect to increase for awakening response by day of week.



*p=0.1: Change from Day 1 (first day off work, but wake at work) to Day 2 (second day off)
**p=0.01: Change from Day 4 (last day off work) to Day 5 (first day shift)
*** p=0.03: Change from Day 8 (second night shift, first shift waking at work) to Day 1 (first day off work, but waking at work)

Day	Description	N	Mean	Median	Inter Quartile Range	Variance
1	Day Off	47	63.9	57.7	33.2	1276
2	Day Off	51	55.6	50.2	37.2	1157
3	Day Off	49	69.2	59.0	30.6	2735
4	Day Off	48	60.2	54.4	37.5	827
5	Day Shift	52	74.4	63.4	45.2	1573
6	Day Shift	53	70.5	58.1	38.2	2056
7	Night Shift	48	79.2	65.7	56.1	2267
8	Night Shift	51	77.3	66.2	62.1	1943

Figure 4-5. Area under the curve with respect to ground for cortisol decline over the day by day of week.



*p=0.007: Change from Day 4 (last day off work) to Day 5 (first day shift)
Change from Day 1 (first day off work, but wake at work) to Day 2 (second day off)
**p=0.001: Change from Day 5 (first day shift) to Day 6 (second day shift)
*** p=0.07: Change from Day 8 (second night shift, first shift waking at work) to Day 1 (first day off work, but waking at work)

Day	Description	N	Mean	Median	Inter Quartile Range	Variance
1	Day Off	47	-74.6	-56.8	66.2	5438
2	Day Off	51	-60.9	-58.0	67.2	3909
3	Day Off	49	-55.4	-49.0	56.8	4473
4	Day Off	48	-63.2	-51.0	69.9	4970
5	Day Shift	52	-107.8	-102.7	125.5	8752
6	Day Shift	53	-54.3	-40.4	100.1	8964
7	Night Shift	48	-50.0	-40.7	93.7	7373
8	Night Shift	51	-55.1	-55.9	83.0	4750

Figure 4-6. Area under the curve with respect to increase of cortisol decline throughout the day by day of the week.

Table 4-2. Mean cortisol measures for the awakening response and cortisol decline over the day by (1) days off vs. work days and (2) days workers work days shifts compared to nightshifts.

	Days Off VS. Work Days					Dayshifts VS. Nightshifts				
	Days Off	(sd)	Work Days	(sd)	*P*-value	Dayshifts	(sd)	Nightshifts	(sd)	*P*-value
Awakening Response										
CAR (nmol/l)	1.5	(7.0)	5.4	(9.4)	0.02	6.2	(9.7)	1.8	(11.4)	0.02
AUC_g	865	(315)	823	(334)	0.33	784	(335)	820	(298)	0.48
AUC_i	301	(115)	332	(171)	0.88	330	(175)	291	(160)	0.27
Slope	67	(309)	243	(435)	0.02	274	(442)	88	(534)	0.04
Cortisol Decline										
AUC_g	61.6	(24.6)	75.4	(35.8)	0.002	73.3	(36.1)	80.5	(43.2)	0.09
AUC_i	-62.8	(35.8)	-68.4	(53.7)	0.81	-80.0	(75.7)	-60.3	(77.3)	0.16
Slope	-0.50	(0.27)	-0.55	(0.34)	0.57	-0.59	(0.47)	-0.54	(0.53)	0.60

sd, standard deviation

Table 4-3. Summary of study findings and descriptions of AUCg and AUCi cortisol measures for the cortisol awakening response and cortisol decline throughout the day.

Cortisol Measure	Description of Measure	Time Frame	Description of Time Frame	Hypothesis	Main Study Findings
AUC_g	Reflects total hormone output; more associated with physical complaints.	The cortisol awakening response	Typically stable across days and therefore a good measure of chronic stress[183] however, is sensitive to short term differences. Can reflect anticipatory stress[184].	• A study of off shore workers observed significant effects on the first dayshift following days off[181].	• Non-significant decreases in hormone output were observed on: ○ The morning of the first day of work following days off. ○ Mornings following nightshifts when waking at work.
		Cortisol decline throughout the day	More sensitive to the activities of the current day (i.e. acute stressors), particularly in the late afternoon[195].	• Several studies have reported elevated levels on work days compared to days off[188,187,186]. • Significantly elevated on first day back to work[188]	• Significantly elevated levels were observed on: ○ Work days compared to days off. ○ Days working dayshifts compared to nightshifts. ○ The first day of work following four days off.
AUC_i	Measure of rate of change; more associated with perceived stress levels.	The cortisol awakening response	As above.	• Increase in rate of secretion from wake and 30 minutes was greater on work days compared to days off[187].	• Significant increase on ○ The first day of work following days off. ○ Mornings following night shifts, when waking at work.
		Cortisol decline throughout the day	As above.	• Data not available.	• Non-significant increase on days working nightshift compared to dayshifts. • Significant decrease on first day of work following days off.

Chapter 5: Work-related Stressors and Their Effects on Salivary Cortisol During Firefighting

5.1 Synopsis

Work stress has been deemed a "worldwide epidemic" and has been associated with an increased risk of cardiovascular disease. However, work-related stress is often subjective in nature and more objective measures that may be potentially more accurate as a measure (i.e. hormones) of the physiological response to stress are available. Firefighters are an occupational group who encounter many stressors in the course of their work. We aimed to identify work-related determinants of work stress as measured by cortisol secretion among professional firefighters.

Fifty-four professional suppression firefighters were recruited from three large municipal fire departments in British Columbia (BC). Firefighters provided six saliva samples on two dayshifts. The areas under the curve with respect to ground (AUC_g) and increase (AUC_i) were calculated to represent the cortisol exposures throughout the shift (14 hour). Information on determinants was collected by direct observation throughout the shift and by questionnaires. Determinants of cortisol secretion modeling was done using generalized estimating equations for repeated measures.

In multivariable models, significant determinants identified for AUC_g included job role, rumination about work events, stress level of the most stressful event that occurred during the shift, whether the event occurred frequently or not, whether they attended a call involving death or near death of a patient, or participated in physical training during the shift. Determinants of AUCi were duration of employment in current job title, and social support of coworkers. These results suggest that both psychosocial and physical factors influence the stress response during firefighting in addition to personal factors; however, the determinants differ based on the measure of cortisol secretion.

5.2 Introduction

Stress is one of the most widespread occupational exposures in the world. In 1996 the World Health Organization stated that work stress was a "worldwide epidemic"; and it has been well documented to be associated with metabolic disease[196], mental illness (e.g. depression, anxiety)[197,198], increased accidents[199,200], reduced immune function[201], and cardiovascular disease[70,202,203]. Lopez and Murray estimated that in 2020 the top diseases/injuries contributing to the global burden of disease will be (1) ischemic heart disease, (2) unipolar major depression, (3) road traffic accidents, and (4) cerebrovascular disease [204], all of which are associated with exposure to stressors.

Salivary cortisol (a hormone produced by the hypothalamic-pituitary-adrenal feedback system) has become an important tool as a non-invasive technique to assess both the psychosocial and physical responses to work-related stressors[205]. However, the majority of the occupational studies have focused on evaluating changes in cortisol secretion related to psychosocial constructs of workplace stress such as work demands/control, effort/reward, and decision latitude[196,206–210], and have been inconsistent in their findings. Inconsistencies in the relationship between work stress and cortisol may be attributed to (1) lack of adjustment of other variables known to induce a stress response such as emotional and physical stressors, and (2) inconsistent methods of sampling and analysis.

Firefighters (and other emergency workers) inherently encounter significant emotional and physical stressors in addition to typical psychosocial work stressors due to their job. The critical nature of their job (i.e. responding to emergencies) reduces their ability to regulate their workload, further complicating their exposure to stressors. Ray *et al.* showed that the activities experienced by suppression firefighters were great enough to stimulate a statistically significant different hormone response compared to non-suppression firefighters (i.e. administrative firefighters)[211].

Suppression firefighting is a physically demanding job and firefighters can potentially reach maximal levels of physical exertion/strain during firefighting activities [212]. Smith *et al.* has shown that these firefighting activities (e.g. stair climbing, handling hose) result in measureable increases in cortisol secretion that can remain elevated following 90 minutes of recovery[213]. The psychosocial response during firefighting is less clear. However, Sluiter *et al.* found elevated cortisol secretion in paramedics after handling patients involving life-threatening compared to non-life-threatening situations[214]. Another study reported elevated daytime cortisol secretion among emergency dispatch workers when compared to research laboratory staff [215]. This epidemiologic evidence is supported by experimental studies; in a laboratory test, firefighters with concurrent stressors (i.e. physical and mental tasks) had an exacerbated cortisol secretion response to stressors[216].

Previous research has established that high work stress environments, with respect to psychosocial constructs and physical exertion may increase cortisol levels; however, few studies have investigated the changes in cortisol secretion due to combined exposure to these stressors. Further, to date no study has identified specific workplace factors (e.g. tasks / environmental factors) to explain changes in the stress response, specifically cortisol secretion. We aim to identify work-related psychosocial and physical determinants of cortisol secretion, as a physiological response to stress, among professional firefighters. Our study is an improvement on other studies as we are (1) measuring real work conditions rather than simulated tests and (2) simultaneously investigating both physical and psychosocial stressors. Identifying specific work tasks or work environment characteristic affecting workplace stress may prove helpful for the development of preventative measures to reduce exposure and ultimately disease.

5.3 Methods

5.3.1 Participants

The participants were 54 full-time professional male fire fighters from Metro Vancouver (Burnaby, Surrey, and Vancouver), Canada; their mean age and duration of firefighting experience was 41.2 (SD=7.2) years and 14.6 (9.5) years, respectively. Firefighters were recruited from 15 pre-selected fire halls that were stratified with respect to the number and type of emergency calls. One participant reported a history of anxiety and was currently taking antidepressants and therefore excluded from analysis. All participants were working in suppression (i.e. responds to emergency calls) and scheduled to work during the study period. The recruitment protocol is described in detail elsewhere[217]. Written informed consent was obtained from all participants, and the study was approved by the University's ethical committee (ethics certificate number H07-01518), participating unions, and municipal fire departments.

5.3.2 Cortisol Sampling and Analysis

Saliva samples were collected with Salivette samplers (Sarstedt Ltd., Germany) at awakening, 30 min after awakening, 1.5 hour after awakening, before lunch, before dinner, and before bedtime. Salivette rolls were provided in a MEMS6 electronic monitoring device to help improve and check for participant compliance. Participants were instructed to maintain their regular activities but were asked to avoid drinking, eating, or brushing their teeth for at least 30 minutes prior to taking a sample. Following sample collection (i.e. chewing on Salivette roll for one minute), participants were asked to record the sample in a sample diary and refrigerate the samples whenever possible. Each day participants recorded the time they awoke; whether the day was a "typical" day for them; their mood; use of medication; and cigarette and alcohol consumption over the day.

Subjects followed the protocol for one work week; this included two dayshifts (0800 to 1800), and two nightshifts (1800 to 0800). Analysis of cortisol samples was restricted to dayshifts only; nightshifts were not included in this analysis as the sampling protocol was insufficient in capturing all of the exposures during nightshifts and may have introduced misclassification into the study. All samples were collected from participants at the end of the sampling period and stored at the School of Environmental Health, University of British Columbia. Frozen samples were shipped to Dresden, Germany for chemiluminescence-immuno-assay (CLIA; IBL, Hamburg, Germany; *ref. RE62011*) analysis for salivary free cortisol.

5.3.3 Cortisol Exposure Measures

Two measures of cortisol exposure were calculated for each sample day using trapezoid methods described by Pruessner *et al.;* the area under the curve with respect to ground (AUC_g), and with respect to increase (AUC_i)[185]. AUC_g (Equation 5-1) is considered a good measure of total hormone output over the measurement period and has been shown to be associated with physical complaints. AUC_i can be calculated from the AUC_g as the amount of cortisol secretion above baseline (Equation 5-2) and is considered a good measure of the change of cortisol secretion over time. AUC_i has been better associated with perceived stress levels and is usually negative during the diurnal decline observed during the day[185].

$$AUC_G = \sum_{i=1}^{n-1} \frac{(m_{(i+1)} + m_i) * t_i}{2}$$

Equation 5-1

$$AUC_I = AUC_G - m_1 * \sum_{i=1}^{n-1} t_i$$

Equation 5-2

Where m_i represents the individual measurement, m_1 first measurement, n the total number of measurements, and t_i the individual time distance between measurements.

Cortisol decline throughout the day was chosen as the time-period for the AUC measures as it will capture changes in cortisol secretion due to the exposures during the work shift. AUC measures were computed using sample 3 (1.5 hr. after waking) as baseline (m_1) and truncated at 14 hours to standardize measurement duration, accounting for differing hours of time between samples. This time-period would capture cortisol secretion from approximately the start of the shift to the evening levels capturing some of the delayed effects after leaving work.

Of the 107 samples collected over the work-days, two were omitted because a diurnal decline could not be calculated (i.e. no baseline sample taken or the sample range was insufficient to represent the 14 hour period). Three samples were excluded from analysis as they were thought to be contaminated from hydrocortisone cream use (noted in the sample diary) and were above the reportable range (0.1656 – 110.4 nmol/l). Samples less than 0.1656 nmol/l remained in the analysis if concentrations were reported by the analytical laboratory.

5.3.4 Identification of Cortisol Determinants

Determinants of cortisol levels were compiled from four sources: the cortisol diary; an end-of-shift questionnaire; a demographic and psychosocial questionnaire; and direct observation by the researcher. Copies of questionnaires and observation tools are provided in Appendices C to G.

For each sample day participants were asked to record the time they awoke and sample information immediately after taking a sample in the cortisol diary. At the end of each day participants were asked to answer relevant information that might have affected their cortisol levels for the day such as mood, and alcohol intake. All subjects completed a short questionnaire at the end of each shift describing either exposure to physical exertion, negative affect, and stress levels during their shift. Subjects were asked to describe their average physical exertion and maximum level of physical exertion using a standard Borg Rating of Perceived Exertion (RPE) Scale, ranging from 6-20[218]. Negative affect was assessed using three Derogatis Affect Balance Scale dimensions including anxiety (nervous, tense, anxious), depression (unhappy, miserable, hopeless), and hostility (irritable, angry, bitter)[219]. Average stress levels experienced during the shift were described on a five-point Likert scale[220]. Subjects were asked to identify the most stressful event that occurred during their shift and describe that stress level on the same Likert scale.

Subjects were administered a questionnaire to determine basic demographic information, work history, health characteristics and psychosocial characteristics including age, ethnicity, duration of experience in current job, duration of experience as a fire fighter, job title, chronic illness (physical and mental), medication use over past month, smoking status, sleep patterns, and psychosocial items (e.g. rumination[221], satisfaction of life[222], unmitigated communion[223], and social support[224,225]).

Additional work determinants were collected through direct observation. During sampling each participant was followed throughout the duration of their work shift by trained research staff who recorded their work tasks and activities (e.g. training, equipment use, etc.) and work factors related to their activities that may influence their stress levels (e.g. age of victims, severity of injury, etc.). This list of work tasks and activities was generated in consultation with fire fighters as part of the development of the study protocol.

5.3.5 Statistical Analysis

All statistical analysis was performed using SAS 9.2 (SAS Inc., Carry, NC, USA). Data were evaluated for normality through visual inspection of histograms. AUC_g was log transformed to obtain an approximate normal distribution; AUC_i was approximately normal distributed and remained untransformed for analysis. Spearman correlations were used to assess correlations between continuous/ranked independent variables. Variables with a correlation coefficient ($r>0.7$) were considered highly correlated and only the variable that was more strongly associated on bivariate analysis was retained for analysis.

Analysis of the relationship between cortisol secretion and determinants of exposure was assessed using generalized estimating equations (GEE) for repeated measures to control for within subject correlations across days, using exchangeable covariance structure. All determinants were tested on bivariate analysis against both independent variables (AUC_g and AUC_i); variables with $P < 0.2$ were considered for inclusion to multivariable models.

Model building was conducted using a manual stepwise procedure. Variables considered essential were retained in the final models (AUC_g: age, time since awakening, and use of topical creams; AUC_i: age and time since awakening) regardless of significance. Subsequent variables were offered to the model by blocks of related variables including work-related (e.g. job title, duration of experience in current job), health/health behaviors (e.g. sleep quality, high blood pressure, rumination status), subjective stress levels (self-reported RPE, “stress” levels, negative affect during day), emergency call characteristics (e.g. number/type of calls, calls involving children and death), and task/activity characteristics (e.g. conducted training, performed administrative duties). Each variable that was significant in bivariate analysis (P<0.2) in the block was added individually to the existing model, after which all variables with a P <0.1 were re-offered to the existing model. Using a manual backwards stepwise procedure variables with a significance level of less than 0.1 were removed from the model. This procedure continued until all blocks were added and all variables had a P <0.1, this included categorical variables where at least one category was significant.

5.4 Results

In total, samples were successfully collected from 54 of the 58 fire fighters enrolled in cortisol study. Two participants were lost due to changes in hall assignment on sampling days, one dropped out due to protocol demands, and one participant destroyed their samples before collection.

Table 5-1 summarizes the characteristics of the study population (n= 54). Participants ranged in age from 25 to 56 years with <1 to 23 years of firefighting experience. In our sample only one firefighter reported being a current smoker; however, he was classified as an occasional smoker (i.e. does not smoke every day). Most fire fighters were Caucasian (89%), married (87%), and did not have a chronic illness (81.9%). Firefighters reported high levels of satisfaction with life; no firefighters were extremely dissatisfied and only 15% were dissatisfied or slightly dissatisfied with their life (data not shown). Further, firefighters reported relatively low stress levels throughout the day and the stress level of the most stressful event of the day was more strongly associated with cortisol secretion.

Daily self-reported and observed stress factors are presented in Table 5-2. The study participants reported low overall and maximum RPE levels (10.9 ± 1.9 and 11.5 ± 2.4 respectively), negative affect and stress levels during their shifts. Only during 6.8% of the shifts did firefighters report their stress levels to be greater than “a bit stressful” (i.e. answered “quite a bit” and “extremely” stressful). The number of emergency calls ranged from no calls (19.2% of shifts) to eight calls per shift, with an average overall call volume of 2.37 ± 1.99 calls per shift. The most common type of emergency calls were medical emergencies (40.5% calls), building alarms (25.5%), MVAs (18.6%), and fires (10.1%). Most calls involved people (61.5%) and interactions with other emergency workers (57.7%) including paramedics and police. Firefighters participated in training during 53% of the shifts and wore their turnout gear most days (74%). The most common activities and tasks conducted during their work shifts were carrying/lifting equipment (42.3% of shifts), administrating first aid (29.8%), and driving fire apparatus (25.0%).

The cortisol concentrations exhibited a typical diurnal pattern with a sharp increase shortly after waking and a slow decline throughout the day. AUC_g and AUC_i results in our sample were poorly correlated (r=-0.29, p=0.003). The slope of the diurnal curve was highly correlated with AUC_i (r=0.94, p<0.0001) and moderately correlated with AUC_g (r=-0.43, p<0.0001), which has been illustrated in another study[226]. Because of the high correlation between slope of the diurnal curve and AUC_i only one variable was selected for model building. Slope, as the variable most correlated with $AUC_{g,}$ was excluded for model building; therefore AUC was used for further analysis.

Table 5-3 reports the results of GEE analysis for the determinants of exposure for AUC_g (Model 1) and AUC_i (Model 2) cortisol measures. In the final multivariable model, cortisol output (AUC_g) decreased with time since wakening and increased with the use of topical cortisol creams. In terms of psychosocial/emotional measures, cortisol output decreased with higher rumination scores but increased with very stressful events at work as well as infrequent stressful events at work. In terms of work tasks/activities, cortisol output increased with participation in physical training and attending an emergency call that resulted in death, or near death of a patient. Several other work task/activity variables that were excluded from the model due to low cell counts (n=4) were observed to be significant when offered to the model, including the performance of CPR and tasks involving the use of motorized equipment during a shift (data not shown).

In the final model for change in the rate of cortisol (AUC_i) duration of employment in current job title was associated with a significant decrease in AUC_i; conversely, higher social support among coworkers was associated with an increase in AUC_i. Similarly with AUC_g models, two additional variables with low cell counts were considered important with the relationship of AUC_i when offered to the model, including the use of self-contained breathing apparatus (SCBA) during the shift, and calls that involved difficult or combative people (data not shown).

5.5 Discussion

The main purpose of this study was to identify the work-related determinants (e.g. work demographic, psychosocial, and physical factors) of cortisol secretion among professional firefighters during typical work shifts while controlling for personal factors (e.g. demographic, and health/health behavior factors). Our results suggest that psychosocial and physical factors influence the stress response during firefighting; however, the determinants differ based on the measure of cortisol secretion. These results strengthen the current body of literature that physical and psychosocial stressors should be considered in studies evaluating the hormonal response to workplace stress.

The cortisol profiles of our subjects followed the predicted diurnal pattern, adding validity to our sampling results, where we observed a gradual decrease in total cortisol output over the course of the day following the awakening response. Not surprisingly we found that subjects using any prescribed topical creams for skin conditions had elevated levels. We did have information on whether the topical cream contained hydrocortisone; however the relationship was not as strong as all topical cream use. This was most likely due to the fact that many people did not know if their cream contained hydrocortisone. We assumed that many topical creams for skin irritation contain steroids and therefore, we thought use of topical creams would be a better measure of hydrocortisone exposure than using the restricted variable. Research has shown that temporary increases in cortisol are measureable for up to 24 hours post application of cortisol-containing creams[227,228].

It has been shown that cortisol increases approximately 20-50% over a person's life course (20-80 years of age)[229]; however, in our study firefighters exhibited a very small, non-significant decrease in cortisol secretion with increasing age. The reasons for this finding are not known, however this may be due to the fact that our study sample had a relatively narrow age range. Touitou and Haus reported "subtle increase" in cortisol over age and implied that other circadian hormones are more significantly related to age (i.e. melatonin)[230]. This is also supported by research by Zhao *et al.*[231] who reported no significant difference in cortisol secretion with adults aged 30-60, which is representative of our study population.

As expected we observed a trend of increasing total cortisol output with increasing perceived level of stress of the most stressful event of the shift. Interestingly the average stress level of the day was not as strongly associated with cortisol levels (data not shown). Further, if the most stressful event occur infrequently (i.e. was not common) a further increase in total hormone output was observed. This suggests a physical adaptation to a stressor if it is experienced frequently. Increased frequency to the stressor increases a person's awareness (or familiarity) of the stressor and overtime people may develop ways to cope with or control the stressor, potentially decreasing its associated stress level.

Interestingly other commonly controlled variables in cortisol research (e.g. obesity, caffeine and alcohol intake, and sleep quantity and quality) were not significant in the multivariable models. There may be several reasons for this finding. Firstly, we only had average caffeine/alcohol intake and sleep quantity/quality information over the past month. In our study we did have alcohol consumption (yes/no) question on our daily cortisol diary, however, we had a large proportion of workers who omitted answering the questions on the daily sampling log at the end of the day on some sample days. Restricting the data to those with this information would have significantly reduced our sample numbers (~28%). Daily measures may have resulted in significant findings in the multivariable models; however, Adinoff *et al.*[232] found that moderate alcohol intake did not significantly alter cortisol secretion. In future studies, emphasizing the importance of this data to participants or having a check-in procedure at the end of the night to gather information over the phone might improve the completeness of the data for these variables. The impact of these variables may be less important when investigating cortisol changes associated with work as part of a multivariable model that includes both physical and psychosocial factors.

We found participation in physical training to be the only physical exertion factor to remain significant in the multivariable models; self-rated exertion over the shift and maximum exertion fell out at the multivariable stage. Jacks *et al.* found that high intensity exercise (for at least one hour) resulted in significant increases in cortisol secretion however; lower intensities or shorter duration had no significant effects[191]. The fact that many physical training drills are conducted for around an hour or more in duration helps support this finding. Although firefighters can reach maximum exertion levels during specific tasks, we found the duration of these tasks during non-training activities to be much shorter than one hour which may explain why many other physical exertion related determinants were not significant in the analysis. Further, wearing SCBA and performing CPR were significant in bivariate analysis but due to low cell counts were not offered to the multivariable models. Even though the variables had low cell counts, the fact that they were significant on bivariate analysis should not be ignored and suggests they may be important determinants in future studies.

Performing CPR during the shift was significantly related to an increase in total hormone output over the shift on bivariate analysis. This was not surprising as CPR (i.e. resuscitations) have been identified as one of the most physically demanding firefighting tasks[233]. In addition to the physicality of the task, there is an emotional aspect involved while dealing with life-threatening events, and firefighters require a high level of mental acuity to maintain tempo and pressure during compressions.

Wearing SCBA during the shift was associated with a significant change in the rate of cortisol secretion (i.e. AUC_i) on bivariate analysis. The fact that SCBA usage may alter cortisol secretion was not surprising. SCBA use not only increases the physical exertion required to complete a task and increases thermal load (placing additional stress on the body)[234,235], it also involves an emotional aspect of wearing the SCBA (i.e. fears of claustrophobia) and the fact that wearing SCBA usually involves entering a dangerous environment.

Attending an emergency call that involved a patient who died or was in critical condition showed a significant increase in total hormone output (AUC_g). This was expected as this type of call can be very stressful as a result of dealing with a dead patient and/or distraught family members, participating in CPR, or navigating fast paced activities to maintain patient status. Sluiter J.K. *et al.* reported similar findings where paramedics had elevated and prolonged cortisol output when handling patients in life threatening situations compared to non-life threatening situations[214]. Dealing with difficult or combative people also showed a significant change in the rate of cortisol secretion (AUC_i) during bivariate analysis but due to small cell sizes was not offered to the multivariate models. Dealing with difficult or combative people can introduce perceived loss of control over the situation causing cortisol secretion changes [236] due to the added unpredictability of the situation which may explain this finding.

Increasing rumination related to work (i.e. dwelling on past events or situations that occurred at work) showed a clear trend response with decreasing cortisol output (AUC_g). This is opposite of what was expected. Roger and Najarian[237] reported a positive correlation between rumination score and cortisol secretion ($r=0.59$, $p<0.01$). Zoccola *et al.*[238] supported this finding; they found that high scoring ruminators had a prolonged response to stress and suggest this is from a decreased ability to recover. Reasons for this opposite effect are unknown however, one explanation for this maybe be related the fact that firefighters are forced to deal with very serious events during their job which may have resulted in adaptation in their response. Further, it is possible that this is a unique trait of those who seek and remain employed in this type of job. Social support of coworkers was significantly associated with the rate of change in cortisol secretion (AUC_i), but not with total hormone output (AUC_g). This is supported by the fact that Roy *et al.*[239] reported that social support among firefighters was not correlated with cortisol levels. Further, Evans and Steptoe[186] reported no association between work social support and cortisol secretion on workdays; however, they found firefighters with high work social support had higher cortisol levels than firefighters reporting low work social support.

Finally, we found a significant increase in AUC_i (i.e. rate of change) from Work Day 1 to Work Day 2. This is in line with a previous study we conducted where we evaluated the effects of shift work on cortisol; we found that AUC_i significantly decreased on the first dayshift from the last day off work, and then significantly increased again on the second work day[217]. A similar effect was not seen with AUC_g.

We implemented a flexible sampling schedule outside of the morning awakening samples to help enhance participation and to account for complications arising from the firefighters' work duties. Previous research has shown that flexibility in sampling increases compliance and reliability of the cortisol results obtained over the day[185]. We believe that our more flexible sampling schedule increased participation as firefighters were less compliant in taking the awakening samples compared to non-awakening samples; however we still obtained poor compliance with relaxed inclusion rules (89%)[217]. To address this we relaxed our sample inclusion criteria and included subjects into the analysis if they had at least two reliable cortisol samples to calculate AUC measures. We checked our model validity by restricting the analysis to a more stringent set of sample rules; the restriction made no notable changes in regression estimates but did strengthened some p-values suggesting the less compliant samples are attenuating our results. Lack of sample compliance is common in non-laboratory studies. We utilized quality control measures (i.e. electronic monitoring system) to help determine compliance. However, most noncompliance came from firefighters forgetting to take their samples at the appropriate time and catching up by taking two or three samples in the late evening. We would suggest implementing the use of a digital device (ex. cell phone, programmable watch, etc.) to help improve this type of non-compliance in future studies.

Although we were able to obtain significant findings in our study, are analysis was limited by the number of samples. A larger study with more firefighters would most likely decrease some of the variability in our measures and potentially result in improved determinants of exposure models.

Despite these limitations, the results of this study provide an interesting contribution in understanding the potential determinants of cortisol secretion with respect not only to psychosocial factors, but also work-related factors such as measures of physical exertion, and which are important when all factors are considered. This is the first study to our knowledge identifying physical, personal, and psychosocial determinants. Our results identify several tasks/activities that may be targeted for stress reduction strategies such as CPR protocols. Further, our sampling strategy allowed us to evaluate determinants of cortisol secretion in firefighters' natural work environment, which gives us a truer picture of the stress response than laboratory or simulated studies.

Our findings suggest that salivary cortisol levels may be influenced by personal, psychosocial, and physical related factors; and that different factors are associated with total hormone output compared to the rate of change of cortisol secretion. This indicates that AUC_g (measure of total hormone output) and AUC_i (measure of the rate of change/decline) are measuring different aspects of the circadian rhythm and a better understanding of each is required to fully utilize salivary cortisol as a measure of stress, particularly with regards to AUC_i. Additional research evaluating the determinants of cortisol secretion is needed to fully understand the relationship with personal, work and psychological characteristics. Particular attention towards exploring the differences between the different measures of cortisol secretion, AUC_g and AUC_i, is needed to fully understand the implications of these results.

Table 5-1. Demographic, work, and health related characteristics of the study population (n=54).

Characteristics	Mean ± SD or N (%)
Demographic	
Age (Years)	41.2 ± 7.2
% Caucasian [A]	48 (88.9)
% Married	47 (87.0)
Work	
Experience In Firefighting (Years)	14.6 ± 9.5
Duration In Current Job Title (Years)	9.3 ± 13.8
Job Title	
Probationary Firefighter	5 (9.3)
Firefighter	33 (61.1)
Lieutenant	8 (14.8)
Captain	8 (14.8)
% Work Second Job	24 (44.4)
Hours Worked In Second Job (N=24)	18.5 ± 10.9
Hours Of Firefighting Overtime/Month	8.9 ± 22.5
Health/Health Behaviors	
Body Mass Index (Unit)	28.0 ± 3.0
Abdomen-Wrist Ratio (Unit)	5.3 ± 0.4
Volume Body Fat (Unit)	19.9 ± 5.5
% Current Smokers	1 (1.9)
% High Blood Pressure	3 (5.6)
% Mental Illness	1 (1.9)
% Chronic Illness	10 (18.9)
% Uses Topical Creams	13 (24.1)
Average Hours Of Sleep (Hrs.)	
Days Off	6.7 ± 1.3
Dayshifts	5.9 ± 1.3
Nightshifts	3.9 ± 1.4
Sleep Quality [B]	4.7 ± 2.2
Average Alcohol Consumption (Frequency)	
<= 1//Month	8 (14.8)
<=1/Week	17 (31.5)
2-3/Week	22 (40.7)
>3/Week	7 (13.0)
Average Caffeine Intake (Frequency)	
<=3//Week	12 (18.5)
1/Day	15 (27.8)
2-3/Day	20 (37.0)
>3/Day	7 (13.0)
Satisfaction With Life [C]	25.6 ± 5.2
Unmitigated Communion [D]	3.3 ± 0.5
Rumination (Work Specific)	

Characteristics	Mean ± SD or N (%)
Non Ruminator	36 (66.7)
Neutral	15 (27.8)
Ruminator	3 (5.56)
Social Support [E]	
Supervisor Social Support	19.8 ± 5.8
Co-Worker Social Support	25.8 ± 3.9
Informational/Emotional Support	22.5 ± 7.3

[#]NOTE: Sums Not Adding To 100 Represent Non-Responses.
[A] Non-Caucasian Included Asian, African, Caribbean, And Mixed Races
[B] Sleep Quality Construct Is Sum (0-12) Of Three Sleep Quality Variables Including Difficulty Falling Asleep, How Refreshing Sleep Is, And Difficulty To Stay Awake, Where Increasing Value Represents Worsening Sleep Quality.
[C] Satisfaction Of Life Construct Is Sum Value Ranging From 5-35, Where Increasing Values Represent Higher Satisfaction With Life.
[D] Unmitigated Communion Construct Value Ranges From 1-5, Where Increasing Values Represent An Increasing Focus And Involvement With Others (To The Exclusion To Self).
[E] Social Support Construct Values Range From 5-25, 5-30, And 0-32 Respectively, Where Increasing Values Represent Increasing Social Support.

Table 5-2. Characteristics of work stress factors of dayshifts (n=104; 4 missing days due to absence from work) of the study population (n=54).

Characteristic	Mean ± SD or N (%)
Subjective Physical And Emotional Stress Measures	
Overall Rated Physical Exertion [a]	10.9 ± 1.9
Maximum Rated Physical Exertion [a]	11.5 ± 2.4
Negative Affect [b]	12.9 ± 5.1
% Felt Ill During Shift	7 (6.7)
Average Stress Level During Shift	
Very Low	22 (21.2)
Low	49 (47.1)
Average	29 (27.9)
High	2 (1.9)
Very High	0 (0.0)
Most Stressful Event Of The Shift	
Event Occurs Often (No)	80 (37.2)
Stress Level Of Event	
Not At All	19 (18.3)
Not Very	34 (32.7)
A Bit	41 (39.4)
Quite A Bit	6 (5.8)
Extremely	1 (1.0)
Normal Stress Level Of Event	
Not At All	14 (13.5)
Not Very	34 (32.7)
A Bit	40 (38.5)
Quite A Bit	10 (9.6)
Extremely	1 (1.0)
How Much They Dwelled On Event	
Not At All	58 (55.8)
A Little	23 (22.1)
Somewhat	14 (13.5)
Moderately	2 (1.0)
A Lot	3 (2.9)
Level Of Control Over Event	
Not At All	24 (23.1)
A Little	17 (16.3)
Somewhat	19 (18.3)
Moderately	13 (12.5)
A Lot	27 (26.0)

Characteristic	Mean ± SD or N (%)
Emergency Call Characteristics	
Number Of Emergency Calls	
All Calls	2.37 ± 1.99
Medical Emergency	0.96 ± 1.26
Fire	0.24 ± 0.47
Building Alarms	0.60 ± 0.97
Motor Vehicle Accident	0.44 ± 0.75
Gas Leaks / Electrical Lines Down	0.05 ± 0.21
Routine	0.06 ± 0.23
Emergency Call Involved (% Yes)	
People	64 (61.5)
Young People	3 (2.9)
Elderly People	19 (18.3)
Difficult/Combative People	4 (3.9)
Death	11 (10.6)
Interaction With Other Emergency Workers	60 (57.7)
Interactions With Crew (Negative [c])	14 (13.5)
Task/Activity Characteristics (% Yes)	
Training	
Participated In Any Training	53 (51.0)
Participated In Physical Training	48 (46.1)
Participated In Theoretical Training	22 (21.1)
Equipment Use	
Scba	4 (3.9)
Motorized Equipment	4 (3.9)
Fire Hose	17 (16.3)
Wore Turnout Gear	77 (74.0)
Activities	
Caught A Fire Hydrant	9 (8.7)
Operated A Fire Pump	7 (6.7)
Drove Fire Apparatus	26 (25.0)
Conducted Cpr	3 (2.9)
Administered First Aide	31 (29.8)
Conducted Traffic Control	10 (9.6)
Handled/Lifted Patients	20 (19.2)
Climbed Stairs	14 (13.5)
Carried Fire/Emergency Equipment	44 (42.3)
Administrative Duties	23 (22.1)

[* #]NOTE: sums not adding to 100 represent non-responses.

[a] Physical exertion using a borg scale ranges from 6-20, where 20 represents maximum exertion possible by subject.

[b] Negative affect construct values range from 9-63, where increasing values represent increasing negative affect.

[c] Negative interactions with crew included times when there were obvious arguments or disagreements noted by research staff, or if reported on the end of shift questionnaire.

Table 5-3. Bivariate regression estimates and multivariable models for log(AUC_g) (Model 1) and AUC_i (Model 2) and work-related determinants of cortisol secretion.

Parameter	Bivariate Analysis			Multivariable Model 1		
	β estimate	SE	*P*-value	β estimate	SE	*P*-value
Model 1: Log (AUC_g)						
Age (Years)	-0.009	0.007	0.23	-0.016	0.011	0.15
Time Since Awakening (Hrs.)	-0.091	0.131	0.49	-0.133	0.087	0.13
Uses Topical Creams (ref No)	0.333	0.134	0.01	0.468	0.101	<0.0001
Job Role (ref Support)						
Back Of Truck	0.437	0.217	0.04	0.062	0.181	0.73
Command	0.449	0.205	0.03	0.307	0.162	0.06
Driver	0.570	0.218	0.009	0.334	0.152	0.03
Rumination (ref Non-Ruminator)						
Neutral	-0.067	0.144	0.64	-0.204	0.104	0.05
Ruminator	-0.574	0.423	0.17	-0.633	0.241	0.009
Stress Level Of Most Stressful Event Of The Shift (ref Not At All Stressful)						
Not Very Stressful	0.254	0.128	0.05	0.235	0.135	0.08
A Bit Stressful	0.235	0.120	0.05	0.290	0.119	0.01
Quite A Bit Stressful	0.628	0.161	<0.0001	0.631	0.179	0.0004
Most Stressful Event Does Not Occur Often (ref Occurs Often)	0.175	0.098	0.07	0.229	0.092	0.01
Attended A Call Involving Death Or Near Death (ref No)	0.281	0.138	0.04	0.321	0.154	0.04
Participated In Physical Training (ref No)	0.227	0.106	0.03	0.213	0.105	0.04
Intercept				4.376	0.529	<.0001
QIC/Qicu					102.2/109.0	

Model 2: AUC_i						
Age (Years)	-0.2	1.1	0.84	-0.7	1.0	0.48
Time Since Awakening (Hrs.)	35.1	14.3	0.01	26.6	14.3	0.06
Work Day 2 (ref Work Day 1)	52.4	16.0	0.001	45.7	16.3	0.005
Duration In Current Job Title (Years)	-0.7	0.4	0.05	-1.1	0.3	0.0004
Social Support Coworkers Score	4.2	2.0	0.04	4.6	1.9	0.02
Intercept				-235.3	75.2	0.002
QIC/QICu					105.6/109.0	

SE, standard error

Chapter 6: Conclusion

6.1 Overview

The intention of this chapter is to synthesize the overall findings of the dissertation into the context of current knowledge, to discuss and the unique challenges and broad issues that arose during this research, to highlight strengths and limitations, and to offer suggestions for future research that arose from this work.

6.2 Objectives and Key Findings

The objectives of this dissertation were: (1) to characterize firefighters' exposures to noise and CO during typical work shifts; (2) to determine if firefighters' exposures to noise and CO were compliant with occupational exposure limits; (3) evaluate the effect of fast rotating shift work on firefighters' circadian rhythm measured by cortisol secretion; and (4) to determine what work-related demographic, psychological and physical factors influence cortisol secretion on dayshifts as a measure of stress.

In summary, we found that firefighters experienced elevated noise levels, a risk factor for adverse cardiovascular events (46% noise samples non-compliant with occupational exposure limits). Firefighters exhibit an altered cortisol secretion pattern that is most likely due to their work shift schedule; with the greatest effects observed on the first day shift and mornings following night shifts. In addition, physical, psychosocial, work demographic and personal factors are all important determinants of cortisol secretion during day shifts.

6.3 Scientific Contributions

6.3.1 Characterization of Carbon Monoxide and Noise Exposures (Chapter 3)

We found that firefighters had low carbon monoxide (CO) exposures however noise exposures exceeded occupational limits in 45% of our samples. The most significant factors associated with increased noise exposures were (i) working dayshifts (compared to nightshifts),(ii) job titles that were non-supervisory (i.e. firefighters including probationary firefighters), (iii) working on engine and rescue truck (compared to ladder trucks), (iv) the number of emergency calls, (v) participating in active training during the shift, and (vi) using equipment related to fire calls. This was the first study measuring noise among firefighters in Canada, and the first published results of noise exposures among firefighters in over 15 years providing updated information on current noise exposure risk.

The measured noise results in this study were higher than previously reported in past health hazard evaluations conducted by the National Institute of Occupational Safety and Health (NIOSH), even with the engineering controls made to reduce exposures on fire apparatus. The reasons for increases in noise exposures over time are not fully understood. We postulate that the change in duties (ex. increased medical calls) over the past 15 years may be the main contributor to the increase in our noise exposures.

Job title, which is commonly used as an internal comparison group, was identified as a poor noise metric. Similar findings in the construction industry[162] have speculated that this may be due to the influences of the activities taking place around the worker. Like construction sites, firefighters are exposed to the changing environment, which accounts for some of the variation observed in their noise exposures. The activities taking place around the firefighters in addition to their actual duties/tasks are important and further studies need to account for firefighters' surroundings during sampling.

6.3.2 Effects of Shift Work on Cortisol Secretion (Chapter 4)

This study found that working a fast rotating shift schedule, even with the opportunity to sleep during nightshifts, was associated with alterations in cortisol secretion patterns over firefighters' eight-day work cycle. The most significant conclusions of this study was that cortisol secretion was most affected on the first day of work following days off and on mornings following nightshifts. In our study we identified that three days following two night shifts were needed to return to the individuals' baseline cortisol activity. This suggests that Day 3 (i.e. the third day off work) would be the most appropriate selection of a baseline measure in future studies.

A study of offshore workers[181] reported similar patterns of cortisol secretion on the first day of work. Anticipation or apprehension of returning to work following days off may explain this observation. One significant difference noted between the offshore workers and firefighters is that offshore workers took one week to return to baseline compared to the three days in this study, which may be an effect of the shift rotation pattern[180]. Elevated cortisol levels observed on work days compared to days off are similar to other studies[186–188]; however a study of firefighters and paramedics report opposite results[189]. Inconsistencies in the literature regarding cortisol levels on work days compared to days off (i.e. leisure days) may be due to differences in work load and other demographic characteristics of the study population.

Regardless of the similarities we observed with other studies, other small differences in results were observed. The uniqueness of firefighters' shift schedule with the ability to sleep during their night shifts may be the contributing to these small differences and suggests the need for further studies on workers with this unique sleep schedule.

6.3.3 Identification of Determinants of Cortisol Secretion (Chapter 5)

We found that several work-related demographic, psychosocial, and physical factors were important in explaining cortisol secretion patterns during dayshifts in multivariable models when controlling for personal factors; however, the determinants were dependent on the type of cortisol measure (i.e. area under the curve with respect to ground (AUCg), or with respect to increase (AUCi)). This is most likely due to the fact that these variables are measuring different aspects of the stress response: total hormone output and rate of change in secretion. Currently little is known about what these two measures are capturing however, total hormone output has been linked to physical complaints (ex. headaches, sensitive skin, etc.) and rate of change has been more linked to perceived stress levels. Further study to identify the differences in these measures is needed to fully understand how to control for these stressors.

This was the first study (to my knowledge) investigating determinants of the stress response, measured by cortisol, incorporating all of physical, psychological, demographic and personal factors simultaneously As such, it is an improvement on other studies that focus on one or two aspects of the stressors that may influence the stress response. Further studies on determinants of actual stressors are needed to help identify areas where control measures can be focused to help decrease the effects of work stress and ultimately disease.

6.4 Challenges, Limitations and Strengths

The notable challenges, limitations and strengths of the individual studies are covered in detail in their respective Chapters (i.e. Chapter 3-6); however, there were several overarching challenges and strengths of this dissertation on which I reflect here.

6.4.1 Conducting Exposure Assessment Studies on Firefighters

Firefighting is unpredictable and often occurs in hostile environments, which may be one of the factors that contribute to the lack of exposure data readily available for this occupational group given their suspected exposures. This impacted our study in several ways.

Firstly, exposure studies evaluating firefighters must consider the environment in which firefighters work when selecting sampling equipment and developing sampling methodologies. Most exposure monitoring equipment is robust however, firefighting environments can be extreme and heat, humidity, and particulate levels need to be considered when selecting equipment as these factors can influence the functionality of the monitors. Furthermore, the equipment must be robust as it may be jarred/banged around due to the nature of firefighters' work tasks. To address this we selected equipment that used sampling tubes to provide some additional protection from the environment (ex. internal microphone). During emergencies firefighters wear and carry a complex set of gear and protective equipment. Do to the complexity of the gear, which is not modifiable, there are difficulties in fitting subjects with monitors.

When this study was launched in the fall of 2007 we underwent several meetings with the fire departments and their safety specialist in order to address monitor placement to ensure they would not restrict firefighters' movements/job. This is very important with this occupation as the smallest changes could significantly influence their safety. During our pilot testing, it was determined the only place the monitors could be fit that did not alter their job would be the outer thigh. With the aid of the fire staff we fashioned specialized shorts to be worn by the firefighters during sampling with pockets sewn into the outer thigh to address the issue of monitor placement. However, even with the robustness of the instruments and strategic monitor placement we still lost samples and had damaged equipment which limited the number of samples we collected over the duration of the study. Increased samples may have given us the opportunity to conduct multivariable modeling on our noise data and allowed us to capture more determinants.

Secondly, conducting monitoring on firefighters involves logistic challenges. Due to the hostility of their work environment, and the potential dangers encountered, it is often not possible for research staff to observe research subjects. We were able to obtain permission from the participating fire departments to accompany our subjects throughout their shift while at the fire hall, during training, and during emergency calls (i.e. ride along) on both day and nightshifts. This not only allowed us to directly observe their tasks and document potential determinants of exposure but provided us with a better understanding of their work environment and social interactions. Although we were able to accompany firefighters on emergency calls, there were certain circumstances where we were not able to follow our subjects for our own safety. This included entering structure fires and building alarm calls until deemed safe for our entry. During this time subjects may not have been in view and we had to rely on self-reported information regarding determinants, which may have resulted in some loss of information. The loss of information may have led to misclassification of exposure, which may have resulted in attenuation of our results.

There were other instances when research staff had to rely on self-report of activities and exposures. During sampling there were up to four subjects to monitor at one time by one research staff member; although stationed at the same hall, often the subjects were assigned to different fire apparatus. There were occasions when two or more apparatus were dispatched to different calls and research staff could not be in attendance at both emergency calls. In addition, at larger emergencies it was common for all the trucks stationed at a fire hall to be dispatched and all subjects would be in attendance making it difficult to observe up to four subjects concurrently. Given the logistic challenges with studying firefighters we still were able to conduct a very thorough investigation in the potential determinants and gained valuable information about the occupation to improve future studies.

Lastly, firefighting is unique compared to many occupations due to the unpredictability of their job (i.e. emergency nature). The unpredictability in firefighting introduces a vast amount of variability in their tasks/activities, hence determinants; however, we were unable to capture all the *a priori* determinants we anticipated to occur in their job. In addition, the fire halls were not as busy as predicted by previous run data reducing the frequency counts of our determinants. One of the issues with the determinants modeling we encountered is that many of the determinants overlapped making modeling difficult with so few occurrences of determinants. However, like all occupational exposure studies conducted during regular operation, our analysis was bound by the exposures measured. Although our study was restricted in our ability to fully evaluate determinants it is one of the first studies on firefighters identifying determinants of exposure, adding important information to the gap of research in this area.

6.4.2 Studying Cortisol Secretion Among Firefighters

The major challenges with sampling cortisol experienced in this study were similar to most studies evaluating cortisol secretion. One particular challenge we faced related to the sampling methodology and timing of samples to capture the effects of shift work. Consultation on sampling methodology was sought to ensure we were able to evaluate the effects of shift work on our population. Because firefighters are unusual in that they are permitted to sleep at work during their nightshifts, it is uncommon for firefighters to sleep during the day. This was beneficial to us as we were able to implement a standard sampling protocol across all days with flexible sampling times following the awakening response. Our complication came into effect when firefighters were awoken in the middle of the night or early morning to attend an emergency call. Due to the emergency nature of the event we did not request they take a saliva sample upon waking; in most cases this would likely not have been possible. This may have influenced our ability to fully determine the effects of nightshifts among our group. In most cases firefighters returned to bed and took awakening samples when waking later in the morning.

One limitation of our cortisol sampling protocol was that we were unable to evaluate determinants of exposure over nightshifts. The cortisol variables were developed using the samples throughout the day; therefore, it was unclear how to capture cortisol secretion during nightshifts as events may have been occurring when no cortisol samples were available to reflect the exposures. One thought was to evaluate the awakening response following a nightshift. This is a reasonable solution but it is unclear if this would allow us to evaluate both day and nightshifts in one analysis. One potential solution would be incorporate additional samples into the protocol during work shifts to allow us to better capture changes over the shift.

The firefighters in our study were less compliant than we anticipated given that they are an occupation used to following strict rules and procedures. Most firefighters were diligent in recording the times when they took their samples accurately, and in taking the appropriate number of samples over the course of the day, as expected due to the use of compliance aides[182]. However, firefighters were not compliant on taking the samples at the appropriate times and often took 2-3 samples in a short period of time (2-4 hours) in the evening to ‘catch up’. This may have occurred for several reasons; firstly subjects may have simply forgotten to take the samples, and secondly they may not have fully understood the importance of the sample timing. In the future, fully explaining the reasons for the sample timing and using reminder devices (i.e. alarmed watches or phones) may help increase the compliance in this respect. Regardless of the non-compliance, the firefighters in our study did perform well considering the rigorous sampling protocol our study employed.

The lack of compliance in cortisol studies can impact the analysis of results. In this study we utilized several methods during analysis to adjust for this. In the first cortisol study we limited our analysis to paired t-test between progressive days and evaluate the data in a more qualitative way. Restricting the data to individuals with complete data would have resulted in significant loss of information. Likewise, in our determinants modeling we were able to compensate for some missing data by utilizing general estimating equations (GEE) for our determinants sampling. GEE modeling provides a greater flexibility for missing data and non-normal distributions[240].

6.5 Unanswered Questions and Future Research Directions

These study results raised many questions and identified several areas where future studies could be concentrated. These ideas are discussed below.

6.5.1 Noise Exposure Studies

Due to the very limited amount of published noise exposure measures, and based on the high noise levels measured in our study, additional exposure studies should be conducted. Future research should aim at characterizing noise exposures during typical firefighting work. Although simulated firefighting work is useful in understanding the roles and tasks, it may not accurately reflect real-world exposures as firefighters are exposed to many external exposures that may contribute to their noise exposures. Some suggestions for improvements from this study would be to: (1) increase the number of samples taken to help account for the variation in firefighting work; (2) develop a preformed field sampling sheet with a list of determinants to decrease the likelihood of missing an exposure; (3) limit the number of subjects observed at one time and to those assigned to the same fire apparatus, (4) to sync noise instruments and study watch/clock (for researcher) with fire department time system in order to obtain measures of frequency and duration of noise determinants to develop time activity patterns; and (5) investigate alternative methods to evaluate the occurrence of impulse noise during firefighting.

In addition, future analyses of the data will include an investigation of the relationship between noise exposures and physiological response including cortisol, heart rate variability, and blood pressure as previous research has identified a relationship between noise exposures and physiological response[236,241–243]. Although I am limited to relatively few daytime noise samples (n=55) the results may support the findings reported by other researchers.

6.5.2 Cortisol Studies

Cortisol studies for the evaluation of the effects of work stress measured by the job-demand or effort-reward constructs are common; however other studies are needed to better understand what occupational exposure stressors (other than subjective work stress) significantly influence the stress response. Information on the determinants of exposure to stress can be used to develop policies and controls to mitigate stress's contribution to cardiovascular disease. Being that stress is one of the most common exposures in the world, and on the rise, the results of determinants studies may be applicable to other occupations.

With respect to firefighters, further studies are needed to support my findings. The fact that we obtained low frequency counts of the determinants limited our ability for analysis and may have influenced my results, suggesting that a greater number of sample days are needed to increase the chance of capturing determinates. Many stressors occur in the evening therefore designing studies to incorporate nightshift samples may be beneficial. In addition, it may be beneficial to conduct sampling for acute stress responses among this occupational group. Acute stress response studies may help identify the magnitude of the effect of specific calls or stressors, and the duration of the effect. Further, the information obtained from acute stress sampling may help us determine the optimum sampling protocol to capture the effects of stress during work shifts.

Pursuing the research directions suggested by the work of this thesis will advance the understanding of modifiable work-related cardiovascular risk factors among professional firefighters to provide better evidence for the formation of appropriate internal comparisons for epidemiological studies. Detailed call data from fire departments are needed for future studies to identify the presence of these determinants. However, the consistency of data collection in terms of the variables and the level of detail recorded in the standard fields varies widely both between and within fire departments. There is a need for fire departments to improve their recording of these variables in their emergency call data for research purposes.

6.6 Research Implications

The findings of this dissertation have implications for exposure assessment methodology among firefighters and for potential exposure reduction strategies, as described in the following sections.

6.6.1 Firefighting Exposure Assessment Studies

As previously noted exposure assessment measurements among firefighters are limited and the reason for this is thought to be partly due to logistical challenges in their work environments. Based on this study we offer several recommendations for conducting exposure assessments among firefighters and in firefighting work environments.

One of the most important factors for exposure monitoring among firefighters involves equipment selection. This study used monitoring equipment placed inside of the turnout gear. For future studies we recommend that robust equipment using internal sensors (e.g. internal microphones, internal pumps) be used with strategic monitor placement to help prevent damage from the environment and successful sample collection.

When conducting exposure monitoring for the purposes of determinants of exposure identification, this study found direct observation to be key in identifying determinants. This not only improved the understanding of the work tasks but also allowed for observations with respect to external exposures, social interactions, and factors that may not be recorded by the fire department (e.g. personal protective equipment use, proximity to exposure sources). Future studies would benefit from direct observation and the use of an observation checklist. A checklist of determinants may reduce lost determinants information and help account for differences between research staff, allowing for a more consistent collection methodology. Further, the large amount of variability encountered during firefighting we observed signifies the need to significantly increase the number of samples for determinants modeling.

With regards to studying cortisol among firefighters, this study identified two main implications for future studies focused around (1) sample times and days needed for analysis, and (2) compliance.

For evaluating the effects of shift work, this study identified that three days following two night shifts appeared to return cortisol levels to baseline. This indicates that for future studies with the same shift schedule, the third day off could be used as a comparison (i.e. baseline) to work days, reducing the number of sample days. Further, the cortisol determinants study was restricted to evaluating day shifts only due to limited samples taken during the "exposure" period. Advanced planning is required to capture the cortisol secretion to reflect work periods, which may require either (1) an altered sampling protocol on day versus night shifts; or (2) additional samples to be taken during the work period.

One limitation of this dissertation was a lack of compliance with saliva sampling and recording, which resulted in a loss of data. To avoid loss of data, implementation of digital reminder devices and an end of day phone in protocol could significantly increase compliance.

6.6.2 Prevention

This dissertation has identified areas where harm reduction policies could be implemented or investigated to help decrease exposures, thereby potentially leading to prevention of disease. Here we summarize the implications for exposure prevention discussed in the research chapters.

Chapter 3 "Characterization of Noise and Carbon Monoxide Exposures among Professional Firefighters in British Columbia", identified potential determinants (i.e. tasks and work situations) where noise reduction strategies may be useful:

- Weekly Equipment Checks: Engineering, administrative, and personal protective equipment controls are viable options during these checks. Control strategies could include the purchase of quieter equipment, increased maintenance, limitation of bystanders not involved in task, job/task rotation, and use of hearing protection during the task. It is important to note that implementation of engineering controls would also help reduce exposures during operation at emergency calls and training.

- Fire Pump Operation: Improving hearing protection such as the use of ear muffs with integration of the radio will reduce noise exposure without interfering with communication. Use of higher level controls in this situation may not be possible due to training requirements to operate the pump and difficulties implementing engineering controls.
- MVA Calls: Although personal protective equipment is the last resort of control options, in this situation may be the best option due to the fact that many of the potential noise sources (ex. traffic noise, sirens from other emergency vehicles, clanging metal, and noise from bystanders) are external and difficult to address with engineering controls.
- Training Drills: Training drills resulted in exposure to most of the noise sources encountered during firefighting; however, unlike emergency calls they are conducted in a controlled environment, reducing the danger of the situation. In most training drills the use of hearing protective devices may be possible without interfering with the training drill.
- SCBA Checks: Although short in duration, the noise levels of these checks conducted in the vehicle bays of the stations are elevated and significantly contribute to noise dose. Use of hearing protective devices during this task is highly recommended. Further control options such as job rotation and engineering controls to reduce the noise exposure level should be explored.

CO levels in this study were low; however other studies have reported elevated levels within the living quarters[157,158]. The use of extractor exhaust ventilation systems used in the study halls is most likely the explanation for the lower levels of CO exposures observed in this study. Utilization of these ventilation systems and development/enforcement of policies for their use would most likely lead to reduce exposures to CO within fire halls.

Chapter 4 and 5 evaluated the stress response with the use of salivary cortisol as a measure of stress. From these studies, several determinants explaining changes in cortisol secretion point to areas where stress reduction strategies and policies may be beneficial. Stressors that were identified as being potentially important in changing the cortisol response include:

- Firefighting tasks involving physical exertion as well as a psychosocial aspect (e.g. conducting CPR, wearing SCBA, and participating in physical training). Possible stress reduction strategies, using CPR as an example, may include: changing the duration firefighters perform compressions (ex. from 2 minutes to 1 minute) to reduce the exertion requirement to complete the task; increasing practical and theoretical training to help make firefighters more confident in their abilities; training and support involving methods to cope with the events.
- Complications or factors encountered during emergency calls (e.g. calls involving death or near death situations, difficult/combative people, and young people). Possible stress reduction strategies would most likely be focused on training and support for coping with these types of events.
- Psychosocial aspects related to the individual (e.g. perceived relationships with co-workers and supervisors, rumination traits, and stress levels of the most stressful event of the shift and how frequent the event occurs). Similar to the complications encountered during emergency calls, the focus would be training and education.
- Working an altered shift (i.e. shift work) leading to sleep disruption. Due to the nature of the occupation, shift work is unavoidable; however, research into shift schedules resulting in the least disruption to the circadian rhythm would be beneficial. Further, promotion of a healthy lifestyle can help reduce the effects of shift work.

This study was exploratory in nature and hence, these results are preliminary and must be replicated in other studies to support the conclusions of this study.

6.7 Conclusion

The purpose of this PhD dissertation was to characterize firefighters' exposures to CO, noise, and to determine the effects of firefighting activities on cortisol secretion as a measure of the stress response to help inform future research on appropriate exposure groupings for cardiovascular risk factors. This study provides evidence that firefighters are exposed to increased exposures of cardiovascular risk factors and identifies several factors that (1) increase the exposure to physical and chemical agents and/or (2) influence the stress response measured by cortisol secretion that may be used to develop internal comparisons in future epidemiological studies. These findings help support research previously stating that myocardial infarctions are largely due to the stresses (i.e. physical and/or psychological) encountered during firefighting[26,27], further suggesting that the exposures firefighters experience during firefighting activities may increase their risk of cardiovascular disease.

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Appendices

Appendix A - Recruitment Brochure

HELPFUL RESOURCES AND LINKS

Heart and Stroke Foundation of Canada:
www.heartandstroke.ca

- Provides information regarding heart disease and prevention

Canadian Health Network:
www.canadian-health-network.ca

- Provides comprehensive information on various health matters including workplace health and disease prevention.

Health Check:
www.healthcheck.org

- Contains a variety of online programs to help develop and monitor a healthy eating lifestyle including grocery lists, menu planning, eating tips, recipes, and physical activity guides.

WHERE CAN I LEARN MORE?

You can find out more about our study on our website, **www.cher.ubc.ca/firefighters**.

All fire fighters who participate in the study will be provided with a summary of their own measurements, as well as a summary of the overall project findings. All reports associated with the study will be posted on our website.

If you would like more information about the study, or if you have questions, please contact the study coordinator. She would be happy to speak with you.

Barbara Karlen, Study Coordinator
bjkarlen@interchange.ubc.ca
604-822-0837

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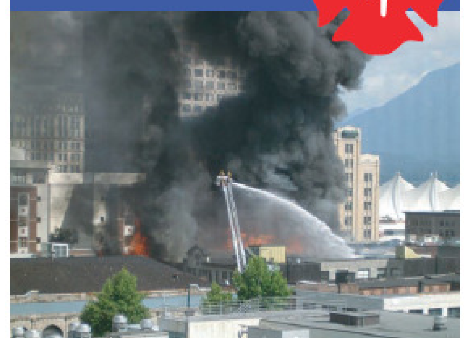
photos courtesy City of Vancouver

CARDIOVASCULAR RISK FACTORS AMONG FIRE FIGHTERS



Your work as a fire fighter may affect your cardiovascular health. Find out how you can help researchers learn more.

UBC

CHER

ARE YOU A PROFESSIONAL FIRE FIGHTER?

Are you interested in work exposures that may affect your cardiovascular health?

If so, you might be interested in participating in a UBC research study that is investigating fire fighters' exposure and response to cardiovascular stressors.

WHAT IS THE PURPOSE OF THIS STUDY?

We want to better understand the amount of particulate matter, carbon monoxide, noise, physical exertion, and stress professional fire fighters encounter in their jobs.

This will help us better understand the potential heart health risks associated with fire fighting.

WHO CAN PARTICIPATE?

To participate in this study, you must be a professional fire fighter who works a regular schedule in emergency services.

We encourage fire fighters of various ranks to participate including chief, captain, lieutenant, and fire fighter.

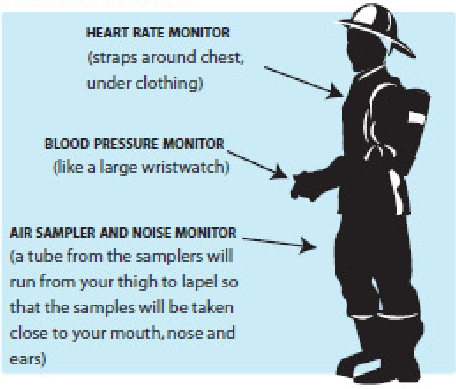
DO I HAVE TO TRAVEL TO UBC?

No. We will visit you at your work to begin sampling and collect all your saliva samples at the end of your sampling session.

WHAT WOULD I NEED TO DO?

Your participation would involve:

- Providing six saliva samples per day for 8 days (4 consecutive work shifts and 4 days off);
- Keeping a brief log of your activities during this time;
- Completing a questionnaire about yourself and your home and work environment;
- Wearing several monitors for four full shifts at work. Combined, the monitors weigh less than two pounds (see below);



- Taking your own blood pressure measurements at set times through out the day, with help from the study staff for 4 work shifts and 1 day off; and
- Answering a short questionnaire at the end of your shift regarding your work exposures during the day.

HOW WILL MY PRIVACY BE PROTECTED?

Participation is voluntary, and you can withdraw at any time. All your personal information, and the data collected about you, will remain confidential.

Any results published of yours will be combined with other fire fighters' and could not be used to identify you. None of your personal information or results will be shared with another fire fighter, your employers, or union.

WHY IS THIS INFORMATION NEEDED?

The information we are collecting is all related to factors associated with an increased risk of heart disease:

- **Stress:** We are measuring cortisol levels in saliva as an indicator of stress. Cortisol is a hormone produced by your body every day. When you experience physical or traumatic stress, you produce more cortisol.
- **Noise:** Chronic exposure to increased levels of noise has been linked to heart disease.
- **Blood pressure:** With high blood pressure, your heart has to work harder, increasing your risk of heart problems.
- **Poor air quality:** Pollutants such as carbon monoxide are associated with combustion, and have been linked to heart problems.
- **Personal characteristics:** Things like your age, gender, family history, and health status may all have an influence on your likelihood of developing heart problems.

Appendix B - Saliva Sampling Instructions Provided to Subjects

Saliva Sampling Instructions

When to take your measurements:

For each of the eight days you will need to take 6 samples. Samples should be taken at the following set times:

On days off, or when on your night shift:

- **Sample 1. immediately upon awakening,**
- **Sample 2. 30-min after awakening,**
- Sample 3. 1 hour following previous sample (Sample 2),
- Sample 4. immediately before you eat lunch,
- Sample 5. immediately before you eat supper, and
- Sample 6. immediately before bed.

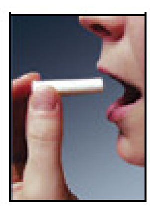
On days you work day shift:

- **Sample 1. immediately upon awakening,**
- **Sample 2. 30-min after awakening,**
- Sample 3. at the start of your shift,
- Sample 4. immediately before lunch,
- Sample 5. at the end of your shift, and
- Sample 6. immediately before bed.

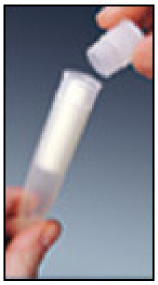
How to take your measurements:

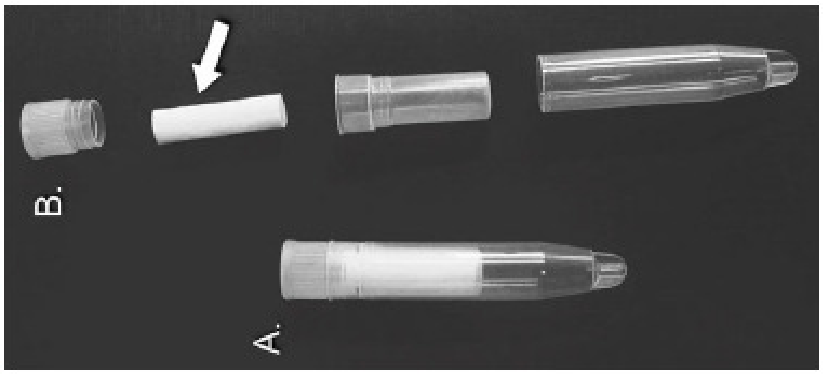
1. Wash hands and rinse mouth twice with cool water (if desired).
2. Open your sample container and remove one cotton roll.

3. Place cotton roll in your mouth and chew for 1 minute.



4. Spit cotton roll into the **TOP** part of an empty Salivette® sample holder and seal with lid as illustrated below. PLEASE DO NOT PUT ROLL INTO THE BOTTOM SECTION.





5. Write date and time on the Salivette® sample holder label.

6. Peal off remaining label and fasten to sampler.

7. Place sample back in bag and store in refrigerator if possible.

8. Record time and sample number in your Cortisol Log.

Things to consider when taking a sample:

1. Do not eat or drink immediately prior to collecting your sample (at least 30 minutes).

2. Do not brush or floss your teeth within one hour (30 minutes minimum) of your samples if possible.

3. Creams used for treatment of skin conditions or to moisturize your skin sometimes contain hormones. If using a cream, make sure to wash your hands with soap and water before handling the saliva samples to avoid contaminating the sample.

4. Store your used samples in the fridge whenever possible to avoid mold contamination.

5. Timing of the sample is important, but knowing the precise time is more important. Therefore if you are late in taking your sample please record the actual time of the sample to allow for the most confidence in the data.

Appendix C - Cortisol Diary (Sample Page)

STUDY ID # ____________________

Saliva Sampling Log

HOME – DAY ONE

Date: (___/___/__)
(dd/ mm/ yy)

Sample Number	Time Sample Taken (i.e. 0800 hr)	Please list in the space below________ taken and/or performed in the hour prior to taking the sample:	
		Food or Beverages	Exercise
1			
2			
3			
4			
5			
6			

Please answer the following Questions:

1. What time did you wake up today? (i.e. 0800) ______________________________.
2. Was this a typical day for you in terms of how busy, pressured, or stressed you felt?
   ☐ No ☐ Yes
3. How much did you feel happy, excited, or content when you woke up?
   ☐ Not at all ☐ Somewhat ☐ Very Much ☐ Extremely
4. How much did you feel worried, anxious, or fearful when you woke up?
   ☐ Not at all ☐ Somewhat ☐ Very Much ☐ Extremely
5. Did you take any prescription medications?
   ☐ No ☐ Yes → If Yes, please list in the space provided below.
   Medications taken:____
   ____

6.Over the course of the day did you:
   a. smoke any cigarettes? ☐ Yes ☐ No
   b. consume any alcohol? ☐ Yes ☐ No
   c. do any vigorous exercise today? ☐ Yes ☐ No

7. Please think about the most stressful event of your day and answer the following questions.
   a. What time did it occur? (i.e. 0800) ________________________________
   b. How stressful was this event?
   ☐ Not at all ☐ Somewhat ☐ Very Much ☐ Extremely

Version 2.0 Cortisol Sampling Diary DAY 1
Last saved on 12/04/2007

Appendix D - End of Shift Questionnaire

End of Shift Self Report Questionnaire   Study ID# __________

1. PHYSICAL EXERTION

1.1. Thinking of the whole day. What was your **overall** level of **physical activity**?
(i.e. How much activity did you do today?)

☐ Very Light ☐ Light ☐ Medium ☐ Heavy ☐ Very Heavy

1.2. Thinking of the whole day. **On average**, how **physically exerting** was today?
(i.e. how hard you feel your body and muscles worked on average?)

- ☐ 6 (no exertion at all)
- ☐ 7
- ☐ 8
- ☐ 9 (very light – for a healthy person, it is like walking slowly for some minutes)
- ☐ 10
- ☐ 11 (light)
- ☐ 12
- ☐ 13 (somewhat hard - but it still feels OK to continue)
- ☐ 14
- ☐ 15 (hard or heavy)
- ☐ 16
- ☐ 17 (very hard – a healthy person can still go on but he has to push himself)
- ☐ 18
- ☐ 19 (extremely hard - for most people this is the most strenuous exercise they have ever experienced)
- ☐ 20 (maximum exertion)

1.3. Thinking about all of the fire fighting activities that you did today, which one required the most physical exertion? ________________________

____

____

1.3.1. Thinking of this activity, what was the **maximum** degree of physical exertion you experienced today?

- ☐ 6 (no exertion at all)
- ☐ 7
- ☐ 8
- ☐ 9 (very light – for a healthy person, it is like walking slowly for some minutes)
- ☐ 10
- ☐ 11 (light)
- ☐ 12
- ☐ 13 (somewhat hard - but it still feels OK to continue)
- ☐ 14
- ☐ 15 (hard or heavy)
- ☐ 16
- ☐ 17 (very hard – a healthy person can still go on but he has to push himself)
- ☐ 18
- ☐ 19 (extremely hard - for most people this is the most strenuous exercise)
- ☐ 20 (maximum exertion)

2. STRESS AND HEALTH

2.1. Please mark on the scale the degree to which each feeling describes your mood during your shift.

	Not at All			Somewhat			Very Much
a. unhappy	1	2	3	4	5	6	7
b. miserable	1	2	3	4	5	6	7
c. hopeless	1	2	3	4	5	6	7
d. nervous	1	2	3	5	5	6	7
e. tense	1	2	3	4	5	6	7
f. anxious	1	2	3	4	5	6	7
g. irritable	1	2	3	4	5	6	7
h. angry	1	2	3	4	5	6	7
i. bitter	1	2	3	4	5	6	7

2.2. Did you feel ill during your shift today?

☐ Yes ☐ No

If yes:

2.2.a. Describe how you felt (e.g. nauseated, fatigue, headache):

____

2.2.b. Describe the cause of your illness (ex. cold, flu, run down):

____

2.3. What was your average level of stress today?

☐ Very Low ☐ Low ☐ Average ☐ High ☐ Very High

2.4. What was the most stressful activity at work today?

____

2.4.a. How stressful was this event?

☐ Not at all stressful ☐ Not very ☐ A bit ☐ Quite a bit ☐ Extremely stressful

2.4.b. Does this event occur often? ☐ Yes ☐ No

2.4.c. How stressful is this event normally for you?

☐ Not at all stressful ☐ Not very ☐ A bit ☐ Quite a bit ☐ Extremely stressful

2.4.d. When thinking about it afterward, did your thoughts tend to dwell on particular aspects of the event?

☐ Not at all ☐ A little ☐ Somewhat ☐ Moderately ☐ A lot

2.4.e. With this event today, how much control or influence did you feel you had over the way that the event was handled?

☐ Not at all ☐ A little ☐ Somewhat ☐ Moderately ☐ A lot

Appendix E - Main Study Questionnaire

THE UNIVERSITY OF BRITISH COLUMBIA

College for INTERDISCIPLINARY Studies

Collaboration • Innovation • Solutions

School of Occupational & Environmental Hygiene
2206 – East Mall, Third Floor
Vancouver, BC Canada V6T 1Z3
Phone 604822-9595 • Fax 604-822-9588
Website: www.soeh.ubc.ca

Fire Fighters' Field Study Questionnaire

Study ID# _______________

Section A. Work Environment

We'd like to begin by asking you a few questions about your job and work environment.

A.1. How old were you when you started fire fighting? _______ Years

A.2. What is your current job title? Please specify: _____________________________

A.3. How long have you held that title? _______ Years

A.4. On average, how many hours of fire fighting overtime do you work each month? (Include time spent doing affiliated fire fighting activities such as training and union hours)

_______ Overtime hours each month

A.5. Are you currently a member of a specialty team?

☐ No

☐ Yes. Please specify: ______________________________________

A.6. Do you currently have a second job in addition to fire fighting?

☐ No

☐ Yes.

<u>If Yes</u>

A.6.a. How many hours a week on average do you work at other jobs?

____________________ hours/week

A.7. How satisfied are you with your job in general?

☐ Very satisfied
☐ Satisfied
☐ Neither satisfied or dissatisfied
☐ Dissatisfied
☐ Very dissatisfied

A.8. Thinking about your main job. Would you say that most days at work were:

- ☐ Not at all stressful
- ☐ Not very stressful
- ☐ A bit stressful
- ☐ Quite stressful
- ☐ Extremely Stressful

A.9. Below are statements that you may or may not agree with. Please indicate your agreement with each statement by circling the appropriate number, between 1-5.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
a. My attention is often focused on aspects of myself I wish I'd stop thinking about	1	2	3	4	5
b. I always seem to be rehashing in my mind recent things I've said or done at work	1	2	3	4	5
c. Sometimes it is hard for me to shut off thoughts about myself	1	2	3	4	5
d. Long after an argument or disagreement is over with that occurred at work, my thoughts keep going back to what happened	1	2	3	4	5
e. I tend to "ruminate" or dwell over things that happened to me at work for a really long time afterward	1	2	3	4	5
f. I don't waste time rethinking things that happened at work that are over and done with	1	2	3	4	5
b. Often I'm playing back over in my mind how I acted in a past work situation	1	2	3	4	5
g. I often find myself reevaluating something I've done at work	1	2	3	4	5
h. I never ruminate or dwell on myself for very long	1	2	3	4	5
j. It is easy for me to put unwanted thoughts about work out of my mind	1	2	3	4	5
g. I often reflect on work episodes in my life that I should no longer concern myself with	1	2	3	4	5
h. I spend a great deal of time thinking back over my embarrassing or disappointing moments that happened at work	1	2	3	4	5

A.10. Do you find that you are still thinking of the events (i.e. runs) of a shift the following day?

- ☐ No
- ☐ Yes, sometimes. Please specify type of event: ________________________________
- ☐ Yes, frequently. Please specify type of event: ________________________________

A.11. Thinking about the different types of events you respond to, please **circle** how stressful you normally find each of the following call types **on average** (please circle N/A if it is not applicable):

Type of Run	**Stress level** Not Very Stressful -------------> Extremely Stressful	
Fire	1----- 2 ----- 3 ----- 4 ----- 5	N/A
MVA	1----- 2 ----- 3 ----- 4 ----- 5	N/A
Medical	1----- 2 ----- 3 ----- 4 ----- 5	N/A
Alarm	1----- 2 ----- 3 ----- 4 ----- 5	N/A
High Angle Rescue	1----- 2 ----- 3 ----- 4 ----- 5	N/A
Haz Mat	1----- 2 ----- 3 ----- 4 ----- 5	N/A

A.12. Other than type of run, are there other work-related factors that increase your stress level during a call Please specify:

____

____

____

Section B. Health Information

Next we would like to ask you some personal questions about your habits and your health that can affect your cortisol level such as food, alcohol, and caffeine consumption.

Diet and Exercise

B.1. During the past 12 months, how often did you drink alcoholic beverages?

- ☐ Less than once a month
- ☐ Once a month
- ☐ 2 to 3 times a month
- ☐ Once a week
- ☐ 2 to 3 times a week
- ☐ 4 to 6 times a week
- ☐ Every day

B.2. During the past 12 months, how often did you drink caffeinated coffee, tea, and soda?
- ☐ Less than once a week
- ☐ Once a week
- ☐ 2 to 3 times a week
- ☐ Once a day
- ☐ 2 to 3 times a day
- ☐ 4 to 6 times a day

B.3. In general, would you say your health is:
☐ Poor ☐ Fair ☐ Good ☐ Very Good ☐ Excellent

B.4. Do you consider yourself:
- ☐ Underweight
- ☐ Slightly Underweight
- ☐ Just about right
- ☐ Slightly Overweight
- ☐ Overweight

B.5. In general, would you say your fitness level is?
☐ Poor ☐ Fair ☐ Good ☐ Very Good ☐ Excellent

B.6. On average, how many times a week do you exercise outside of work for 30 minutes or more of continuous activity?
☐ <1 ☐ 1-2 ☐ 2-3 ☐ 3-4 ☐ >5

Illness and Medication

B.7. Do you have physician diagnosed high blood pressure?
☐Yes ☐No ☐Don't Know

If yes,

B.7.a. How old were you when you were first diagnosed?
____________ Age in years

B.8. Do you have any other long-term physical or mental health condition that has been diagnosed by a health professional?
- ☐ No
- ☐ Yes
- ☐ Don't Know

If yes,

Please specify condition(s): ____
____
____

B.9. In the past month, did you take (If yes, tick all that apply):

- ☐ Pain relievers
- ☐ Anti depressants
- ☐ Medicine for the heart
- ☐ Steroids
- ☐ Sleeping pills
- ☐ Tranquilizers
- ☐ Other prescription medication
  - **If yes to other**, specify medication type ______________________________________

B.10. Do you use any topical creams for the treatment of skin irritation?

- ☐ No
- ☐ Yes

If yes,

B.10.a. To your knowledge do the creams you use contain hydrocortisone?
(For example: Aveeno®, Emocort®, Epifoam®, Sigmacort®, Hyderm®, NovoHydrocort® Cortoderm®, Efcortelan®, Fucidin-H®, Cortizone-10®, Cortaid®, and Lanacort®)

- ☐ No
- ☐ Yes
- ☐ I am not sure

Section C. You and Your Home Environment

We are now going to ask you some questions about you and your home situation to better understand the type of people included in the study and to identify baseline stress levels.

General Background Information

C.1. What is your gender? ☐ Male ☐ Female

C.2. What is your date of birth? (i.e. dd/mm/yyyy) __ __ / __ __ / __ __ __ __

C.3. People living in Canada come from many different backgrounds. What country or countries reflect your heritage best? Please specify:

____

____

C.4. What is your current marital status?

- ☐ Single, never married
- ☐ Living Common Law. Please specify number of years you have been common law: ____ yrs
- ☐ Married. Please specify number of years you have been married: _____yrs
- ☐ Divorced/Separated. Please specify number of years you have been divorced/separated: ___yrs
- ☐ Widowed. Please specify number of year since you have been widowed: _____yrs
- ☐ Other. Please specify: ____

C.5. Do you have children?
- ☐ No
- ☐ Yes

If yes,
C.5.a. Do your children live with you?
- ☐ Yes, Full time
- ☐ Yes, Part-time
- ☐ No

C.6. Do you have stepchildren?
- ☐ No
- ☐ Yes

If yes,
C.6.a. Do your stepchildren live with you?
- ☐ Yes, Full time
- ☐ Yes, Part-time
- ☐ No

Sleep and Stress

C.7. How long do you usually spend sleeping nights you do not work the following day? (i.e. non work nights)
- ☐ Under 2 hours
- ☐ 2 hours to less than 3 hours
- ☐ 3 hours to less than 4 hours
- ☐ 4 hours to less than 5 hours
- ☐ 5 hours to less than 6 hours
- ☐ 6 hours to less than 7 hours
- ☐ 7 hours to less than 8 hours
- ☐ 8 hours to less than 9 hours
- ☐ 9 hours to less than 10 hours
- ☐ 10 hours to less than 11 hours
- ☐ 11 hours to less than 12 hours
- ☐ 12 hours or more

C.8. How long do you usually spend sleeping nights you work day shift the following day?
- ☐ Under 2 hours
- ☐ 2 hours to less than 3 hours
- ☐ 3 hours to less than 4 hours
- ☐ 4 hours to less than 5 hours
- ☐ 5 hours to less than 6 hours
- ☐ 6 hours to less than 7 hours
- ☐ 7 hours to less than 8 hours
- ☐ 8 hours to less than 9 hours
- ☐ 9 hours to less than 10 hours
- ☐ 10 hours to less than 11 hours
- ☐ 11 hours to less than 12 hours
- ☐ 12 hours or more

C.9. How long do you usually spend sleeping **during** your night shift?

☐ Under 2 hours
☐ 2 hours to less than 3 hours
☐ 3 hours to less than 4 hours
☐ 4 hours to less than 5 hours
☐ 5 hours to less than 6 hours
☐ 6 hours to less than 7 hours
☐ 7 hours to less than 8 hours
☐ 8 hours to less than 9 hours
☐ 9 hours to less than 10 hours
☐ 10 hours to less than 11 hours
☐ 11 hours to less than 12 hours
☐ 12 hours or more

C.10. Do you normally nap or sleep during the day on or before your night shift?

☐ No
☐ Yes

If yes,

C.10.a. Please specify duration of time spent napping/sleeping during the day.
_________________ hours/day

C.11. How often do you have trouble going to sleep or staying asleep?

☐ None of the time
☐ A little of the time
☐ Some of the time
☐ Most of the time
☐ All of the time

C.12. How often do you find your sleep refreshing?

☐ None of the time
☐ A little of the time
☐ Some of the time
☐ Most of the time
☐ All of the time

C.13. How often do you find it difficult to stay awake when you want to?

☐ None of the time
☐ A little of the time
☐ Some of the time
☐ Most of the time
☐ All of the time

C.14. Do you ever take medications or other sleeping aids to help you sleep?

☐ Never ☐Rarely ☐ Sometimes ☐Frequently ☐All the time

C.15. Thinking about the amount of stress in your life would you say that most days are:

☐ Not at all stressful
☐ Not very stressful
☐ A bit stressful
☐ Quite stressful
☐ Extremely Stressful

C.16. Below are 5 statements about how you perceive your current life situation which you may or may not agree with. Please indicate your agreement with each statement by circling the appropriate number, between 1-7.

	Strongly disagree	Disagree	Slightly disagree	Neither agree nor disagree	Slightly agree	Agree	Strongly agree
a. In most ways my life is close to my ideal	1	2	3	4	5	6	7
b. The conditions of my life are excellent	1	2	3	4	5	6	7
c. I am satisfied with my life	1	2	3	4	5	6	7
d. So far I have gotten the important things I want in life	1	2	3	4	5	6	7
e. If I could live my life over, I would change almost nothing	1	2	3	4	5	6	7

C.17. Below are statements relating to your current work situation, which you may or may not agree with. Please indicate your agreement with each statement by circling the appropriate number, between 1-5.

	Strongly disagree	Slightly disagree	Neither agree nor disagree	Slightly agree	Strongly agree
a. My job requires that I learn new things.	1	2	3	4	5
b. I am exposed to hostility or conflict from the people you worked with.	1	2	3	4	5
c. My supervisor is concerned about the welfare of those under him	1	2	3	4	5
d. My supervisor pays attention to what I am saying	1	2	3	4	5
e. I feel appreciated by my supervisor	1	2	3	4	5
f. My supervisor is successful in getting people to work together	1	2	3	4	5
g. My supervisor is helpful in getting the job done	1	2	3	4	5
h. People I work with are helpful in getting the job done	1	2	3	4	5
i. People I work with take a personal interest in me	1	2	3	4	5
j. I feel appreciated by my colleagues	1	2	3	4	5
k. If I have problems in my job, I can ask others for help	1	2	3	4	5
l. People I work with are friendly	1	2	3	4	5
m. People I work with are competent in doing their jobs	1	2	3	4	5

C.18. Below are statements which you may or may not agree with. Similar to question 16, please indicate your agreement with each statement by circling the appropriate number, between 1-5.

	Strongly disagree	Slightly disagree	Neither agree nor disagree	Slightly agree	Strongly agree
a. I *always* place the needs of others above my own	1	2	3	4	5
b. I never find myself getting overly involved in others' problems	1	2	3	4	5
c. For me to be happy, I need others to be happy	1	2	3	4	5
d. I worry about how other people get along without me when I am not there	1	2	3	4	5
e. I have *no* trouble getting to sleep at night when other people are upset	1	2	3	4	5
f. It is impossible for me to satisfy my own needs when they interfere with the needs of others	1	2	3	4	5
g. I can't say no when someone asks me for help	1	2	3	4	5
h. Even when exhausted, I will always help other people	1	2	3	4	5
i. I often worry about others' problems	1	2	3	4	5

C.19. Please indicate how often each of the following kinds of support is available to you if you need it:

	None of the time	A little of the time	Some of the time	Most of the time	All of the time
a. Someone you can count on to listen to you when you need to talk?	1	2	3	4	5
b. Someone to give you advice about a crisis?	1	2	3	4	5
c. Someone to give you information in order to help you understand a situation?	1	2	3	4	5
d. Someone to confide in or talk to about yourself or your problems?	1	2	3	4	5
e. Someone whose advice you really want?	1	2	3	4	5
f. Someone to share your most private worries and fears with?	1	2	3	4	5
g. Someone to turn to for suggestions about how to deal with a personal problem?	1	2	3	4	5
h. Someone who understands you problems?	1	2	3	4	5

C.20. Are you aware of any work-related employee assistance programs that are available to you for stress or stress related problems?

☐ No
☐ Yes

C.21. Have you ever utilized any of these programs in the past?

☐ No
☐ Yes

If yes,

C.21.a. how often over the past 5 years have you utilized one or more of these programs?

- Please Specify Total Number of Visits:___________________________

C.21.b. Did you find these programs beneficial in reducing your stress/stress related problems?

☐ No
☐ Yes

Section D. Smoking Information

Lastly we are going to ask you about your smoking history. Smoking is known to be a cardiovascular disease risk factor and also affects your cortisol levels.

D.1. In your lifetime, have you smoked a total of 100 or more cigarettes (about 4 packs)?

☐ Yes
☐ No

D.2. At the present time, do you smoke cigarettes daily, occasionally or not at all?

☐ Daily
☐ Occasionally
☐ Not at all?

D.3. Have you ever smoked a whole cigarette?

☐ Yes
☐ No

D.4. Have you ever smoked cigarettes daily?

☐ Yes
☐ No

D.5. Do you currently smoke cigar or pipe tobacco?

☐ Yes
☐ No

Appendix F - Field Sampling Collection Form

Fire Fighters' Field Study – Sampling Forms

Study ID #____________
Color ____________

General Information

Height: ______ ft ________ inches _______________ cm Calculated BMI:
Weight ______ lbs _______________ kg __________

Abdomen measurement: ________ cm Wrist measurement: ________ cm
Hip measurement: ______________ cm Chest measurement: ________ cm
Abdomen/wrist ratio: _______

Day Shift 1 (Date)___________ Day Shift 2 (Date)___________
Night Shift 1 (Date)___________ Night Shift 1 (Date)___________

1 2 3 4 5 Sample Short Size Worn: S M L XL

Cortisol Sampling

MEMS ID: _________________
Field Blank Present? Y N
Samples Refrigerated? Y N
Sample logs all present? Y N

Blood Pressure Monitoring

SN: _______________________

Day Off Date: ________ # of Samples: ____ File Extension: _________________________
Day Shift 1 # of Samples: _________ File Extension: _________________________
Day Shift 2 # of Samples: _________ File Extension: _________________________
Night Shift 1 # of Samples: ________ File Extension: _________________________
Night Shift 2 # of Samples: ________ File Extension: _________________________

CO Monitoring

Sample 1
Monitor ID ________________ Last Calibration Date: _________________
Start Time: ________________ End Time: ___________________________
Fresh Air Cal done? Y N
File Extension: _______________________________

Sample 2
Monitor ID ________________ Last Calibration Date: _________________
Start Time: ________________ End Time: ___________________________
Fresh Air Cal done? Y N
File Extension: _______________________________

Sample 3
Monitor ID ________________ Last Calibration Date: _________________
Start Time: ________________ End Time: ___________________________
Fresh Air Cal done? Y N
File Extension: _______________________________

Sample 4
Monitor ID ________________ Last Calibration Date: _________________
Start Time: ________________ End Time: ___________________________
Fresh Air Cal done? Y N
File Extension: _______________________________

Fire Fighters' Field Study – Sampling Forms

Study ID #___________
Color ___________

Heart Rate Monitoring

Watch SN: ______________________ **Transmitter SN:** ________________________

Day off Sampling Date: ______________ Sample Duration: ________ hr
File extension: _____________________

Day Shift 1:
Start Time: ________ End Time: ________ File extension: _______________________

Day Shift 2:
Start Time: ________ End Time: ________ File extension: _______________________

Night Shift 1
Start Time: ________ End Time: ________ File extension: _______________________

Night Shift 2
Start Time: ________ End Time: ________ File extension: _______________________

Noise Monitoring

Day Shift 1
Monitor ID ______________
Pre Calibration Adjustment:_______ Post Calibration Adjustment: _______
Start Time: ______________ End Time: _____________________
Download File Name: ____________________________
Overall Dose: _________ Peak exceeded? Yes / No

Day Shift 2
Monitor ID ______________
Pre Calibration Adjustment:_______ Post Calibration Adjustment: ______
Start Time: _____________ End Time: _______________
Download File Name: _______________________
Overall Dose: _________ Peak exceeded? Yes / No

Night Shift 1
Monitor ID ______________
Pre Calibration Adjustment:_______ Post Calibration Adjustment: _______
Start Time: ______________ End Time: _____________________
Download File Name: ____________________________
Overall Dose: _________ Peak exceeded? Yes / No

Night Shift 2
Monitor ID ______________
Pre Calibration Adjustment:_______ Post Calibration Adjustment: _______
Start Time: ______________ End Time: _____________________
Download File Name: ____________________________
Overall Dose: _________ Peak exceeded? Yes / No

Appendix G - Emergency Run Data Collection Form

Fire Fighters' Field Study – Event Form Date ______________________

Event Type: __________________ Incident Number: ____________________
Begin Time: ________________ Response Time: _____________
End Time: __________________ Total Duration: ______________

Address of Event: ____
Description of Event: ____
____
____

Casualties? Y N P
Apparatus Dispatched: ____
____

Siren Activated during trip: ☐ No ☐ Yes, approximate duration: ________

Supplemental Sheet: ☐ No ☐ Yes

Study #: _________ **Role on scene:** _________________________________

Tasks Performed:

1. ____ Duration: _____________
2. ____ Duration: _____________
3. ____ Duration: _____________
4. ____ Duration: _____________
5. ____ Duration: _____________

Equipment Used:

List: type used	Approximate duration	HP?
1. _______________	_________________________________	No / Yes
2. _______________	_________________________________	No / Yes
3. _______________	_________________________________	No / Yes
4. _______________	_________________________________	No / Yes

SCBA used?: ☐ No ☐ Yes, approximate duration: _______________________
# of tanks used: __________________
Start Time: ________________ End Time: ______________________

Study #: _________ **Role on scene:** _________________________________

Tasks Performed:

1. ____ Duration: _____________
2. ____ Duration: _____________
3. ____ Duration: _____________
4. ____ Duration: _____________
5. ____ Duration: _____________

Equipment Used:

List: type used	Approximate duration	HP?
1. _______________	_________________________________	No / Yes
2. _______________	_________________________________	No / Yes

Last Saved on: 04/21/08 Hall #:________

3. _______________ _________________________________ No / Yes
4. _______________ _________________________________ No / Yes

SCBA used?: ☐ No ☐ Yes, approximate duration: _________________________
# of tanks used: __________________
Start Time: ________________ End Time: _____________________

Study #: _________ **Role on scene:** _________________________________

Tasks Performed:

1. ____ Duration: _____________
2. ____ Duration: _____________
3. ____ Duration: _____________
4. ____ Duration: _____________
5. ____ Duration: _____________

Equipment Used:

List: type used Approximate duration HP?
1. _______________ _________________________________ No / Yes
2. _______________ _________________________________ No / Yes
3. _______________ _________________________________ No / Yes
4. _______________ _________________________________ No / Yes

SCBA used?: ☐ No ☐ Yes, approximate duration: _________________________
# of tanks used: __________________
Start Time: ________________ End Time: _____________________

Study #: _________ **Role on scene:** _________________________________

Tasks Performed:

1. ____ Duration: _____________
2. ____ Duration: _____________
3. ____ Duration: _____________
4. ____ Duration: _____________
5. ____ Duration: _____________

Equipment Used:

List: type used Approximate duration HP?
1. _______________ _________________________________ No / Yes
2. _______________ _________________________________ No / Yes
3. _______________ _________________________________ No / Yes
4. _______________ _________________________________ No / Yes

SCBA used?: ☐ No ☐ Yes, approximate duration: _________________________
# of tanks used: __________________
Start Time: ________________ End Time: _____________________

Additional Comments: ____
____
____

Fire Fighters' Field Study – Supplemental Form   Date __________________

Incident Number: ____________________

Fire Fire Type:
☐ Structure ☐ Automobile ☐ Bush ☐ Marine ☐ Industrial ☐ Other, specify: ________________________________
Substance burning (if known): ____ ____ ____ Fire Size / Intensity: ____ ____ ____ Number of trucks responding: ____ **Structure Fire:** Type of structure: ____ # floors: _______________ Fire Location: __________________________________ **Industrial Fire:** Type of industrial site: ____ Fire location within facility: ____ ____ ____

Additional Comments:____

____

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Last Saved on: 04/21/08   Hall #:_________