

University of Brighton

Report: Heat Exposure and Immune Function in Fire

and Rescue Service Instructors

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Heat Exposure and Immune Function in Fire Instructors

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Background

Training new recruits to the fire service requires exposure to severe heat on successive days throughout an intense training programme. This protocol induces a significant degree of heat and physical stress on the trainees and the instructors (Barr et al., 2010; Williams-Bell et al., 2010). There is physiological evidence to suggest severe acute exposures of up to 200°C may reduce short term immune function (Barr et al., 2010; Reich, 1953; Scannell and Balmes, 1995; Sheppard et al., 1986; Shuster, 2000; Smith et al., 2005), while long term fire-fighting personnel may be at greater risk of respiratory (Sheppard et al., 1986) and cardiovascular diseases (Rosenstock and Olsen, 2007; Fahs et al., 2011; Fernhall et al., 2011; Reich, 1953). Previous work (Smith et al., 2005) has identified short term changes in immune function using basic inflammatory markers pre, post and after 90 minutes recovery from live fire-fighting drills. Smith et al. (2005) found significant leucocytosis and plasma adrenocorticotrophic hormone and cortisol immediately following exposure. Huang et al. (2010) also found increases in pro-inflammatory cytokines and decreases in lymphocytes after just one severe heat exposure in fire fighters. Fernhall et al. (2012) found developing

heart illness and diminished work capacity in fire fighters, while Fahs et al. (2011) found similar decrements in heart function. Webb et al. (2011) showed correlation between markers of immune and vascular function after controlled heat exposures in fire fighters. Authors concluded that elevations in cortisol and interleukin-6 (IL-6) and associated vascular markers support the suggestion that fire fighters are at greater risk of a cardiovascular event as a result of repeated physiological stress.

However, fire service instructors undertake severe repeated exposure protocols every working day throughout their career. Anecdotally, fire instructors report regular upper respiratory tract infections (URTI), severe fatigue and lethargy, yet many feel as though reporting these formally would affect how they are viewed in the service by colleagues. Therefore, this is difficult to objectively quantify due to lack of reporting. Concerns over fire instructor's health and the increased exposure of instructors compared to standard fire service personnel is the reason for the National Fire Service requesting the research team to investigate the instructor's heat exposure load and immune function. There is currently no research investigating such repeated exposure workloads on changes to immune function in fire service instructors using a field based fire scenario. This would therefore, be the first study to evaluate the health risks associated with the repeated severe heat exposure training protocol used by fire service instructors.

Quantifying the effect of severe heat exposure on physiological strain and immune function is an important step towards minimising these negative effects on instructors. Data from the pilot systematic measurement of physiological markers could be used to inform interventions based on innovations in body cooling strategies, clothing design and recovery methods. This in turn would make it possible to reduce staff tiredness, preventing unnecessary decision-making errors and thus injury, and sick leave due to decline in immune system function (Cheung et al., 2010).

Table 1: Participant information and heat exposures experienced within recent research.

Author	Participants	Heat Exposure
Budd (2001)	21 male professional fire fighters (four seven-man crews). Average age 26	The crews worked for 30 - 230 minutes at an energy expenditure of ~500 watts, equivalent to 45% VO max. Fire fighters experienced air temperatures
	years old, 71kg body mass, 14%body fat content, 47 ml.kg-1.min-1	of ~29°C, radiant temperature of ~66°C, water-vapour pressure ~15°C, wind speed ~1.2 m.s-1 and WBGT of 26°C. With the hottest fires developing a
	VO max.	head-fire intensity of up to 3280 kw.m-1.
Huang et al. (2010)	9 professional fire fighters, age 33.4 \pm 5.1 years, height 178.3 \pm 8.0 cm,	Testing included I session of 37 minutes of cycling at 60% VO2max, exercise alone condition (EAC) and I session of 37 minutes cycling at 60%
	body mass 88.1 \pm 9.5 kg, fire- fighting experience 11.3 \pm 7.5 years, VO max	VO2max followed by 20 minutes based fire- fighting strategies and tactics drill (FSTD) that served as a mental challenge.
	36.9 ± 5.6 ml.kg-1.min-1.	
Fahs et al. (2011)	69 male career and volunteer fire fighters, aged between 18-64 years,	Participants were tested 3 hours pre and post live-fire training exercises in a specialized training building. Drills varied throughout and included 4-5
	currently in active service and medically cleared by their home department	evolutions typically lasting 15-25 minutes each separated by 10-15 minutes of rest. The training evolutions included coordinated fire ground
	to participate in live-fire activities.	operations (obtaining water, advanced hose, extinguishing fire, forcible entry, search and rescue, and ventilation tasks). The fire- fighting scenarios
		included fires involving a simulated basement, restaurant, single family dwelling, a two-story taxpayer and standpipe operations. Participants wore full
		fire- fighting gear that was compliant with National Fire Protection Association (NFPA) 1971 standards and carried a self-contained breathing
		apparatus (SCBA) during all fire- fighting activities.
Fernhall et al (2012)	Forty male career and volunteer fire fighters, age 27.4 \pm 6.4 years.	Same method as Fahs et al. (2011).
	Participants were limited to those who were between 18 and 64 years old	
	and cleared to serve as a fire fighter by their home department.	
Perroni et al. (2012)	20 male Italian fire fighters, aged 32 \pm 1 years, height 1.77 \pm 0.06 m, body	Specific fire- fighting activities (climb a firemen's ladder, descend a three-storey building carrying a 20 kg dummy, run for 250 m, complete a maze in
	mass 77.2 \pm 8.7 kg; BMI 24.7 \pm 2.1, HR 176 \pm 9 b.min-1 and VO peak	a dark chamber, run for 250 m) were performed in a circuit session with no rest. Ambient temperatures were $13 \pm 1^{\circ}$ C and relative humidity was $63 \pm 1^{\circ}$ C and relative humidity humidity was $63 \pm 1^{\circ}$ C and relative humidity
	43.1 ± 4.9 ml.kg-1.min-1.	1%. Intensities were calculated and expressed as percentages of individual's HR
		шах
Sal et al. (2009)	13 male military fire fighters aged 36.3 \pm 6.9 years, nude body mass 81.7 \pm	Acclimation phase consisted of standing for 5 minutes wearing full protective equipment, work phase included fire- fighting drills including carrying a
	7.7 kg, height 1.77 \pm 0.07m, BMI 26.08 \pm 2.55, percentage of body fat 23.61	hose for 20m, pushing a water pump trailer for 10m, pulling a hose towards the fie, fire extinguishing a 20L iron tank of kerosene and return all
	\pm 2.59 %, experience 16.8 \pm 7 years.	equipment, within 85% relative humidity, 23.15°C and 0 to 8 knots wind speed, and recovery phase included the post 24 hours.
Smith et al. (2005)	11 healthy male, professional fire fighters.	Fire fighters performed several live drills to simulate real fire situations, each of the three trials consisted of the same five tasks, carrying a hose up four
		flights of stairs, hoisting a hose, discharging a pump can, ragging a hose dummy and chopping on a block of wood, with ten minutes rest separated the
		trials. After initial measurements were obtained (baseline heart rate, core temperature, blood samples and a pre-task self-report measure) participants
		ascended an interior stairwell from the first to the fourth floor (15 steps per floor) carrying a high rise pack of 1.5-inch hose (27.6 kg). The subjects
		proceeded to an outdoor balcony of the fourth floor, hoisted a 19.5 kg hose up from the second floor balcony, a distance of 8.4 m, and then lowered it
		back to the second floor balcony in a controlled manner. While still on the fourth floor participants discharged a pump can for 1 minute. They then
		descended the interior stairwell from the fourth to the third floor and performed the chopping task which involved moving a 109.1 kg wooden log
		152.4 cm along a sled using a 7.3 kg sledge. Subjects then descended the interior stairwell from the third to the second floor where they performed the
		dummy drag. The dummy drag entailed dragging, on hands and knees, a 24.1 kg hose dummy around the perimeter of the room two times. At the end
		of the trial, subjects descended the stairs and returned to the testing station. Blood draws and psychological measurements were initiated within 30
		seconds of leaving the training course and were completed within 2 minutes. No rest was permitted between the first and second trials, however they
		were allowed 10 minutes between the second and third trial.
Webb et al. (2011)	Twelve apparently healthy professional fire fighters, aged 33.75 ± 4.87	Same method as Huang et al. (2010)
	years, height 179 \pm 7 cm, body mass 91.47 \pm 11.68, resting heart rate 71.83	

	\pm 7.32 b.min-1, VO max 35.74 \pm 5.57 ml.kg-1.min-1.	
Williams-Bell et al. (2010)	33 men and 3 women professional fire fighters aged 41.5 \pm 6.5 years old,	A simulated subway scenario was developed for testing procedures. Participants wore full protective clothing weighing 9.2kg with an integrated
	179.2 \pm 5.9 cm, 89.0 \pm 11.4 kg, 51.6 \pm 6.8 ml.kg-1.min-1, with 0.5 to 30	Cosmed K4b2-SCBA system weighing 8.4kg. Participants were paired and completed the following protocol: 1; 1 floor descent (11.6m) whilst
	year of fire service,	carrying an additional 22kg pack of hose nozzle and 2 lengths of 44mm hose. 2: walk 183m into the station and pick up the specialised ladder and walk
		an additional 101m. 3: Drop the 22kg pack and attach the ladder to the subway car. 4: Perform a 555m search for victim. 5: Rescue a 75kg mannequin
		27.5m away whilst the other fire fighter tackles the fire and obstacles. 6: descend the stairs and walk 284m to the stairwell. 7: Ascend 1 story to a safely
		exit.

Introduction

Fire service instructors undertake severe repeated exposure protocols constantly throughout their working career. This process induces a significant degree of heat and physical stress on the instructors (Williams-Bell et al., 2010). There is physiological evidence to suggest such severe acute exposure may reduce short term immune function (Barr et al., 2010) while long term fire-fighting personnel may be at greater risk of respiratory (Sheppard et al., 1986) and cardiovascular diseases (Fernhall et al., 2011).

Fire instructors are exposed to sever metabolic and environmental thermal loads during their instructional duties, these stresses are paired with reductions in heat dissipation and increased energy expenditure due to their protective clothing. Several studies (Bennett et al., 1994; Smith et al., 1997) have displayed higher heart rates and core temperatures within trainees during simulated fire drills, thus imposing greater strains placed upon the body. However, it has also been noted that even though fire instructors are not as physically active during exercises as their trainees, they experience greater thermal strains due to the duration within the uncompensable environmental conditions (Williams et al., 1996).

There is currently no research investigating such immediate and repeated exposures on acute and chronic changes to immune function in fire service instructors using a field based fire scenario. This would therefore, be the first study to evaluate the health risks associated with the severe heat exposure training protocol used by fire service instructors.

Purpose of the Study

It is therefore, proposed that this project will quantify the physiological stress and immune function in a cross-section of fire service instructors and to provide data on these effects on health. Measures pre and post severe heat exposure sessions will be taken to indicate how instructors' ability to tolerate short term heat exposures changes over the course of repeated exposures.

Research Objectives

The subsequent objectives of this project are as follows;

- To quantify the acute and chronic changes in markers of inflammation, physiological strain, respiratory function, psychological perceptions of wellbeing and immune function with exposure to a single bout of severe heat exposure.
- To evaluate the changes in inflammation, physiological strain, cardiovascular fitness, respiratory function, psychological perceptions of well-being and immune function with 4 weeks of repeated exposures to severe heat.
- To evaluate changes in inflammation, psychological perceptions of well-being and immune function with a three week 'no heat exposure' period.

Methods

Participants and Inclusion / Exclusion Criteria

The study was limited by the number of instructors employed by the service and able to undertake the protocol. Previous studies that have investigated stress hormones, immunological responses and physiological strains experienced by professional fire fighters have used a similar amount of participants and statistically powerful differences have been observed:

- Budd (2001) 21 professional fire fighters (four seven-man crews)
- Huang et al. (2010) 9 professional fire fighter
- Fahs et al. (2011) 69 career and voluntary fire fighters
- Fernhall et al (2012) 40 career and voluntary fire fighters
- Perroni et al. (2012) 20 professional fire fighters
- Sal et al. (2009) 13 military fire fighters
- Smith et al. (2005) 11 professional fire fighters
- Webb et al. (2001) 12 professional fire fighters
- Williams-Bell et al. (2010) 33 male and 3 female professional fire fighters

Participants were excluded from the research study if:

- they were unsure of the test protocol and the possible risks and discomforts designated on the participant information sheet;
- the answers given on the medical consent form or informed consent form did not meet the required criteria;
- they had been verified, or documented as having any blood carried infections (Hepatitis), are diabetic, or obese (body mass index > 30), or have a known history of haematological, cardiac, respiratory, or renal disease;
- they had been subjected to any form of heat illness or injury within the last 6 months;

Participant Recruitment

Participants were recruited from the Fire Service College, Moreton in Marsh, Gloucestershire. Participation information packs (Appendix A) were distributed via email and post to the Fire Service College, Moreton in Marsh Training Centre to all the new and current fire fighter personnel.

Participants

Six male fire instructors (FI) recruited from the Fire Service College (Moreton-in-Marsh, England) and six control participants were recruited from a pool of lecturers a the University of Brighton. The baseline values for the participant groups is presented in Table 2. The research study was approved by the University of Brighton Ethics Board and each participant gave written informed consent.

Table 2: Participant baseline descriptive data.

	Fire Instructors	Control
Age (yrs)	41 ± 4	40 ± 3
Height (cm)	178 ± 0	178 ± 0
Body Mass (kg)	83 ± 11	78 ± 6
$BMI (kg/m^2)$	26 ± 2	24 ± 1
VO max (ml/kg/min)	49.4 ± 0.6	54.3 ± 0.3
2		

Experimental Design

The study used a cross-section design, where control group participants had no previous heat exposure and fire service instructors had a vast range fire service history (2, 2, 5, 7, 7, 10 yrs). Male participants were used to enable a comparison of thermoregulation without the need for control of menstrual cycle phasing.

Initial health based markers including respiratory function (FVC, FEV₁, FEV₁/FVC, PEF and CO) and immune function (C-reactive protein (CRP), cortisol (Crt), inter leuken-6 (il-6), tumor necrosis factor–alpha (TNF- α) and immunoglobulin (IgG), white blood cells (WBC), white blood cell content (neutrophils, eosinophils, basophils, lymphocytes and monocytes), red blood cells (RBC), haemoglobin (Hb), haematocrit (Hct) and platelet count (PLT)) were recorded at the end of the fire instructors previous heat exposure instruction course.

This was repeated after a seven week wash out period, during which the instructors experienced no heat exposure, but were allowed to maintain a normal exercise routine. After the wash out period fire instructors and control group participants completed a maximal oxygen uptake test to measure their cardiorespiratory fitness level.

The following day, fire instructors completed a fire behaviour and fire attack exercise, in which immune markers, respiratory function, hydration status, cardiovascular measures and core temperature were recorded pre and post. This was followed by a 4 week fire instructing course which included ~15 heat exposures per fire instructor.

At the end of the 4 week course, fire instructors completed a search and rescue hot fire exercise in which immune markers, respiratory function, hydration status, cardiovascular measures and core temperature were recorded pre and post. Additionally, a post maximal oxygen uptake test was completed. Figure 1 (below) displays a schematic design of the overall study.



Figure 1: Schematic of the testing protocol.

Experimental Procedures

Fire Instructing Drills

Three fire instruction exercises were performed and repeated over the course of the 4 weeks of fire exposures, these consisted of fire behaviour (FB), fire attack (FA) and search and rescue hot fires (HF). During the heat exposure all the fire instructors wore their standard fire protective clothing and self-contained breathing apparatus (SCBA), which weighed ~9kg and ~12kg, respectively. Typically, exercise durations were ~40 minutes, occurred within ~200°C and were conducted once or twice a day.

Fire Behaviour (FB): This exercise consisted of ~40 minutes exposure within a modified container (see below for photo) at temperatures exceeding 200°C. This exercise demonstrated the behaviour of the fire within an enclosed space and the effects of a fire build up and consequently back draft. The fire instructor predominantly worked in pairs, which were positioned at the front of the container controlling the fire or at the rear observing the students.



Fire Attack (FA): This exercise consisted of ~40 minutes within the same modified container and temperatures of the FB. The exercise included fire instructors observing students attacking the fire and suppressing the flames with correct hose techniques (see picture below).



Search and Rescue Hot Fires (HF): This exercise occurred within a purpose built fire house (See picture below) for ~40 minutes at various temperatures depending on where the students and fire instructors were (~200°C). The exercise involved may fire instructors who set up and controlled the fires, monitored students and observed search and rescue objectives.



Fire Exposure Measures



A: Immune Function, Respiratory (FVC, FEV₁, FEV₁/FVC, PEF and CO), Cardiovascular (HR, BP, SaO₂), Psychological (RPE, TSS, MFSI-SF), Hydration Status (U_{osm} , U_{col} , U_{sg}) Core Temperature, Body Mass B: Heart Rate C: Sweat Rate

Figure 2: A schematic diagram of the measures recorded pre, during and post fire exposures.

Thermal Measures

Core temperature (T_r) was measured using a Henley single use rectal temperature probe (449H, Henleys Medical, Hertfordshire, UK) placed ~10cm past the anal sphincter pre and post exposure. Core temperature was displayed on logging monitors (YSI, 4600 series, YSI, Hampshire, UK). Physiological strain index (PSI) was estimated using Moran, et al., (1998) equation; $PSI = 5 (T_{ret} 2 T_{re0}) \cdot (39.5 - T_{re0}) -1 + 5 (HR_t - HR_0) \cdot (180 - HR_0) -1$

Where T_{re0} and HR_0 are initial resting values, and T_{ret} and HR_t were measured posttest. Heat strain was measured on the PSI scale from 0 (little) to 10 (very high).

Cardiovascular Fitness Assessment

Cardiovascular fitness was assessed pre and post the four weeks of the heat exposure course using an incremental maximal oxygen uptake (VO_{2max}) test. Running VO_{2max} tests were conducted within the fitness suite inside the leisure club which is onsite at the Fire Service College for the fire instructors and within the University of Brighton Research laboratory for the control participants. The tests occurred on a Technogym (Technogym U.K. Ltd., Bracknell, Berkshire) and Woodway ELG2 treadmill (Woodway, GmbH), set at 1% incline reflecting outdoor running conditions (Jones and Doust, 1996). The test started at 8km.hr⁻¹ and increased in running speed by 1km.hr⁻¹ every minute until 16km.hr⁻¹, where gradient was subsequently increased by 1% each minute until voluntary exhaustion. Heart rate (b.min⁻¹) and rating of perceived exertion (RPE) (Borg, 1982) were recorded at the end of every minute stage. Fire instructors and control group participants were fitted with a breathing mask (Hans Rudolph, 8900 series) and a heart rate monitor (Accurex+, Polar Electro, Oy, Kempele, Finland), prior to starting a warm up. Pulmonary gas exchange measurements (volume of oxygen (VO₂), volume of carbon dioxide (VCO₂), respiratory exchange ratio (RER) and ventilation rate (VE)) were recorded continuously throughout the test using a Cortex Sport Metalyser (Cortex, Cranleigh Ltd., UK) in which values were averaged for each 30 second period. The Cortex Sport Metalyser (Cortex, Cranleigh Ltd., UK) was calibrated at the start of each test following the manufacturer guidelines, for volume, using a Hans Rudolph 3 litre syringe (Hans Rudolph, series 4900, Kansas City, USA) and gas, using a known concentration for gas calibration (17.1% VO₂ and 5.0% VCO₂). This metabolic analyser has previously been reported to be valid and reliable when adhering to this process (Meyer et al., 2001). The test continued until volitional exhaustion, where criteria for determining VO_{2max} was a plateau in oxygen uptake volume, with \leq 50 ml.min⁻¹ rise, maximum heart rate within ~10 beats.min⁻¹, a RPE of 20 and a respiratory exchange ratio of \geq 1.15 (Astorino, et al., 2000).



Cardiovascular Measurements

Blood pressure (BP, mmHg) was measured using a Boso automatic monitor (Boso, Bosch-Sohn, Medicus, Germany) and oxygen saturation (SaO₂, %) was measured using a fingertip pulse oximeter (Model 2500, Nonnin Medical Inc., Minneapolis, MN, USA), these were recorded pre and post fire exposures and cardiorespiratory tests. Heart rate (HR, b.min⁻¹) was continuously measured using telemetric monitors (Accurex+, Polar Electro, Oy, Kempele, Finland), before, during (every 7 seconds) and

after the heat exposure, to identify differences in resting state during exposure and the individual's capacity to recover,

Blood Measures

Blood measures were taken from the ante-cubical vein inside of the elbow joint using a 20ml syringe; prior to a 7 week wash out period, post 7 week wash out period prior to first heat exposure, post 1^{st} heat exposure, post 4 weeks instruction course prior to 2^{nd} heat exposure and post 2^{nd} heat exposure, while participants were sitting upright and resting. These blood samples were separated into five 5ml EDTA tubes and of which 4 were placed into a centrifuge (5702R, Eppendorf U.K Ltd., Stevenage). The resultant plasma concentration was pipetted (3ml Pauster pipette) into a microvette (1.5 µl, Western Lab Service) and stored in a freezer at -86°C for analysis at a later date within the University of Brighton, Welkin Laboratories.





The blood samples were analysed for markers of immune function and physical stress. Interleukin-6 (IL-6) is a marker released to stimulate the immune response, Tumor Necrosis Factor- α (TNF- α) is also a marker primarily involved in the control of immune system cells. C-reactive protein (CRP) is another marker which is expressed in the presence of dead or dying cells. Cortisol (Crt) is a hormone released in

response to physiological stress, which suppresses immune function. Measuring the blood based proteins, allows identifications of any alterations to immune function, whether acute or chronic impairments have occurred with repeated exposures. The remaining 5ml whole blood sample was assessed for blood cell count using



automated flow cytometry with electrical

impedance and light detectors. Values for white blood cells (WBC), white blood cell content (neutrophils, eosinophils, basophils, lymphocytes and monocytes), red blood cells (RBC), haemoglobin (Hb), haematocrit (Hct) and platelet count (PLT) were recorded.

Respiratory Measures

Lung Functional measures including forced vital capacity (FVC), forced expiratory volume at 1 second (FEV₁), FEV₁ / FVC ratio and peak expiratory flow (PEF) were recorded using a hand held MicroPlus spirometer (Micro Medical Ltd., Cranleigh Ltd., U.K). These measures were recorded pre and post heat exposures and maximal oxygen uptake tests. Additionally carbon monoxide (CO) was measured using a piCO⁺ Smokerlyzer[®] (Bedfont, Scientific Ltd., Maidstone, Kent, U.K) by slowing breathing into a breath monitor tube to assess levels of carbon monoxide poisoning.



Psychological Measures

Psychological Feeling State was assessed using a modified version of the Profile of Moods States (POMS, McNair et al., 1971) questionnaire pre and post exposure. This modified questionnaire displays short and longer term levels of perceived tension, depression, anger, vigour, fatigue and confusion using the MFS-SF questionnaire pre and post the hot exposure. Thermal sensation (TSS, Young, et al. 1987) using a scale from 0 (unbearably cold) to 8 (unbearably hot) measured the fire instructors perceptions of the thermal stress. Ratings of perceived exertion (RPE) was measured on a scale from 6 (no exertion) to 20 (maximal exertion) (Borg, 1982) which measured the amount of strain experienced during the exercise. These were recorded pre and post heat exposures and during maximal oxygen uptake tests.

Hydration Status Measures

Prior to each heat exposure fire instructors produced a fresh urine sample. This was measured for urine colour (U_{col}), urine osmolality (U_{osm}) and urine specific gravity (U_{sg}) using a urine colour chart (Armstrong, 2000), Pocket Pal-Osmo (Vitech Scientific, Ltd) and a specific gravity hand refractometer (Atago Co., Tokyo, Japan), respectively. Criteria determining an adequate hydration status were set at 1-3 urine colour, <700 mOsm.kg⁻¹ and < 1.020 (Casa, et al., 2005). Nude body mass (kg) was also recorded using Detecto physician scales (Detecto Scale Company, USA) pre and post heat exposure to measure sweat rates, calculated as follows; Sweat Rate = (Body mass pre – Body mass post) / Time (minutes).



Statistics

Data were appropriately checked for normality and sphericity. Comparison over time and between groups was performed using two way analysis of variance. Bonferroni pairwise comparisons were used to identify differences between specific time points. Relationship between variables was evaluated using Pearsons Product Moment Correlation Coefficient. Statistical analysis was undertaken using SPSS (Version 16), a standard statistical software package. Data are presented as the mean \pm SD.

Location

All fire instructors testing occurred at the Fire Service College, Moreton in Marsh, Gloucestershire, GL56 ORH. Control group maximal oxygen uptake tests, physiological measures and immune markers were taken within the Welkin Laboratories, University of Brighton.

Data Protection

In accordance with the Data Protection Act 1998 all participants data obtained from testing remain anonymous, be saved and stored on data protected folders on a secure PC. Hard copies of data will be locked in an office to which only the principal investigator has access. Data will be retained for one year after the conclusion of the research project and then deleted appropriately. The privacy, rights and dignity of the participants will be maintained at all times.

Results

Screening Tests – Pre and Post 4 weeks Fire Instruction

Basic Physiological Measures

Screening measures of height, weight, BMI, lung function (FVC, FEV1, PEF, FEV1/FVC), Blood pressure, carbon monoxide and VO₂max were taken before and after the 4 weeks of the instructor workload. Baseline measures were not different between groups, shown in Table 1. These physiological measures did not change significantly over time in either group. When disregarding the smoker (outlier) there were no differences between groups or over time for CO (Table 3).

	Pre 4 weeks Instruction		Post 4 weeks Instruction	
Variable	Fire Instructors	Control	Fire Instructors	Control
Body Mass (kg)	83.3 ± 11.4	78.3 ± 6.1	83.1 ± 11.2	78.3 ± 6.1
CO (ppm)	5 ± 8	2 ± 3	5 ± 5	2 ± 0
Systolic Blood Pressure (mmHg)	134 ± 16	140 ± 22	138 ± 12	140 ± 8
Diastolic Blood Pressure (mmHg)	81 ± 9	87 ± 9	82 ± 7	86 ± 8
Oxygen Saturation (%)	98 ± 1	98 ± 1	99 ± 1	97 ± 2
Heart Rate (bts.min ⁻¹)	72 ± 12	69 ± 8	70 ± 11	65 ± 7

Table 3: Physiological changes over the 4 weeks for fire instructors and controls

Respiratory Function Measures

FVC was found to be significantly (p<0.05) lower post 4 weeks in the fire instructors $(4.73 \pm 0.7 \text{ vs } 4.16 \pm 0.65 \text{ L})$. This indicates that there was a decline in overall lung volume over the 4 weeks. However, there was no significant change in FEV1 (3.98 ± 0.58 vs 3.78 ± 0.56 L) suggesting not a result of respiratory obstruction. Further, there was no significant difference between fire instructors and control group for any of the respiratory variables. While the controls did not change the four weeks (Table 4).

	Pre 4 weeks Instruction		Post 4 weeks Instruction		
Variable	Fire Instructors	Control	Fire Instructors	Control	
FVC (L)	4.73 ± 0.7	5.11 ± 0.68	4.16 ± 0.65	4.98 ± 0.69	
FEV ⁻¹ (L)	3.98 ± 0.58	4.31 ± 0.65	3.78 ± 0.56	4.18 ± 0.69	
PEF (L)	643 ± 106	680 ± 127	633 ± 119	660 ± 151	

Table 4: Physiological changes over the 4 weeks for fire instructors and controls

Cardiovascular Fitness Assessment

There were no significant changes in cardiovascular fitness over the 4 weeks when comparing the fire instructors as a whole group (Figure 3). However fire instructors demonstrated a 7% decline over 4 weeks, which represents a meaningful yet not statistically significant change.



Figure 3: Changes in maximal oxygen uptake over the 4 week fire instruction.

Although no significant change in VO₂max was found, two of the six fire instructors demonstrated declines in VO₂max of 10ml.kg⁻¹.min⁻¹ and 15ml.kg⁻¹.min⁻¹ over the 4 weeks, illustrated in Figure 4. These declines equate to percentage declines of 25 and 26%. These were found to be true VO₂max values (plateauing heart rate & VO₂). Declines of this magnitude demonstrate a meaningful change as these were greater than the possible technical level of error ~5%. This finding suggests a significant decline in cardiovascular function in some instructors but not others. This warrants further investigation in a larger cohort.



Figure 4: Changes in VO₂max over the 4 weeks in all individuals. Dashed lines denote the control group.

A reason for this decline is difficult to ascertain. A small yet significant reduction in RPE level reached during VO₂max test in fire service instructors over the 4 weeks (Pre 19 \pm 1; Post 18 \pm 1), suggests underlying motivational fatigue. While the sample size it too small to relate inflammatory changes of individuals to the declines found here.

Another possible reason for this difference is that the two individuals with greatest decline in VO₂max also noted a severe decline in FVC (17 and 18%) while the other instructors demonstrated lesser declines (7, 8 and 8%). The only other individual to see large declines in FVC (22%), reported injury in the first VO₂max and subsequently saw marginal improvements in the post instruction VO₂max trial. Interestingly this individual did not meet the minimum cardiovascular fitness requirement in either trial (42ml.kg⁻¹.min⁻¹). Further, the average cardiovascular fitness of the instructors at baseline (49.1 \pm 9.2 ml.kg⁻¹.min⁻¹) was not far above that of the minimum fitness requirement, especially considering the decline to 46.3 \pm 4.9 ml.kg⁻¹.min⁻¹ over the 4 weeks. Indeed, the university lecturing staff demonstrated significantly greater VO₂max (54.4 \pm 8.1 ml.kg⁻¹.min⁻¹), yet were group matched for age, height and weight, this is illustrated in Figure 3.

General Discussion

Cardiorespiratory function may be reduced in some instructors. Data suggests this is as a result of physical fatigue and not underlying cardiac changes.

This is also supported by psychological assessment demonstrating significant increases in fatigue.

Decline in respiratory function (FVC) may also cause decline in cardiorespiratory function over 4 weeks.

- A single exposure induces a significant acute inflammation, which is coped with acutely.
- Evidence suggests immune function is influenced over longer term
 - 'Worst' values pre wash out.
- Time away from heat instruction could reduce inflammatory and immune function issues to near baseline as found over 7 week washout.

Study Limitations

The study was limited by the low subject number. This made comparison across instructors difficult as individual variation played a significant role in the evaluation of the data. However, this individual variation could have been due to the natural changes in immune function. Other authors have suggested that individuals may be tolerant or intolerant to heat exposure, thus causing this dichotomous relationship, as found across the six instructors.

The study evaluated a relatively short four week fire instruction period. This timeframe may not have been sufficient to fully demonstrate the impact the

workload may have on each individual. Likewise there was limited control of the fire instructor workloads although most completed between 13 and 15 heat wears over four weeks. However, there was no control over the roles undertaken during these heat wears. Some individuals may have experienced a significantly greater the heat workload over the four weeks.

Conclusion

This pilot study demonstrates that the fire instruction induces fatigue, inflammation and decline in immune function over four weeks. While periods of no exposure allow the instructors values of inflammation and immune function to return to the 'normal' range.

Methods should be evaluated for integration into working rotas to reduce the length of heat based cycles and to allow recovery periods, thus reducing long term inflammation and immunosuppression for instructors' long term physical and mental welfare.

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