Journal of Thermal Biology 58 (2016) 106–114

Contents lists available at ScienceDirect

Journal of Thermal Biology

journal homepage: www.elsevier.com/locate/jtherbio

Physiological and psychological responses in Fire Instructors to heat exposures

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ARTICLE INFO

Article history:
Received 3 February 2016
Received in revised form
15 April 2016
Accepted 20 April 2016
Available online 22 April 2016

Keywords:
Immune function
Inflammation, Fire service
Heat exposure
Overtraining

ABSTRACT

Aim: Fire Service Instructors (FSI) are exposed to many repeated periods of high environmental temperatures when training firefighters. Such repeated exposures will impose significant strains on the function of instructors. We aimed to measure the effects of a training programme including repeated exposures to heat, termed "Wears" in the fire service, on the physiological, psychological some immunological markers of Fire Service Instructors.
Methods: Six FSI and six physiologically matched controls completed blood and cardiovascular tests pre and post a 4 wk heat instruction training block, controls completed the tests only. FSI were given a 7 wk period of no heat exposure prior to starting the training. Physiological and perceptual measures were taken pre and post the first and last Wear of the 4 wk training protocol.
Results: There were acute effects of a Wear on core temperature and physiological strain index, as well as measures of fatigue. The acute exposure to heat during a Wear led to a consistent decrease in CRP (−10% to −40%), increased IL6 concentrations 33–45%) as well as increased RPE and TSS. Over the training programme significantly lower quantities of white cells, particularly neutrophils, leukocytes and monocytes were found in the FSI group. Between the start and the end of the 4 week training programme the FSI showed a significantly greater physiological strain index (PSI) to the Wears, which nearly doubled from 2.5 to 4.7 ($p < 0.05$).
Conclusion: Physiological and psychological measures indicate that FSI may be experiencing symptoms and changes to their health consistent with an overtraining type condition.

1. Introduction

Training new recruits for the fire service entails exposure of the trainees and their trainers to uncompensable heat stress (Montain et al., 1994), on successive days throughout an intense training programme, which can often last 4–6 weeks before receiving a break. Simulated firefighting exercises occur in uncompensable heat stress conditions, with reported environmental temperatures ranging 67–190 °C (Eglin et al., 2004; Eglin, 2007). The physiological strain experienced during such exposures is indicated by increased rectal temperatures (38.0–39.0 °C), near maximal heart rates (119–189 b min^{-1}), exaggerated levels of sweat loss (0.5–2.0 L h^{-1}) and high rates of energy expenditure (oxygen consumption 2.3–3.55 L min^{-1}) (Eglin, 2007). Fire service instructors (FSI) are further affected by reduced heat dissipation from limited vapour permeability and restricted bodily movement while wearing protective clothing (Selkirk and McLellan, 2004). Diminished work capacity and decrements in heart function have been measured in firefighters as a result of working in the heat during firefighting situations (Fernhall et al., 2012). Investigations by Williams et al. (1996) on cardiovascular responses in FSI showed near maximal heart rate values which were higher than their trainee firefighters. More recently, Eglin et al. (2004) reported that FSI experienced severe physiological strain, arising from the

Abbreviations: Δ, Change; ANOVA, Analysis of variance; BP, Blood pressure; CO, Carbon monoxide; CON, Control; C-RP, C-reactive protein; Crt, Cortisol; FEV_1, Forced expiratory volume at 1 s; FSI, Fire service instructors; FVC, Forced vital capacity; Hb, Haemoglobin; Hct, Haematocrit; HR, Heart rate; IgG, Immunoglobulin G; IL-6, Interleukin-6; IQR, Interquartile range; MFSI-SF, Multidimensional Fatigue Symptom Inventory-Short Form; NBM, Nude body mass; PEF, Peak expiratory flow; PSI, Physiological strain index; RPE, Rating of perceived exertion; SCBA, Self-contained breathing apparatus; SD, Standard deviation; T_{re}, Rectal temperature; TSS, Thermal sensation scale; U_{col}, Urine colour; U_{osm}, Urine osmolality; U_{sg}, Urine specific gravity; $\dot{V}O_{2max}$, Maximal oxygen uptake; WBC, White blood cells; wk, Week

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http://dx.doi.org/10.1016/j.jtherbio.2016.04.008
0306-4565/

strenuous duties and prolonged duration of heat stress and this was shown to compromise their ability to perform instructional tasks. A variety of perceptions of psychological function in such studies may reflect differences in external heat loads and work duties (Eglin et al., 2004) as well as the personnel investigated. When measured FSI report increased anxiety, mostly through increased feelings of apprehension and nervousness (Eglin, 2007), which may impede mental performance, cognitive function (Smith et al., 1996) and result in injury through inappropriate decision making, which worsens with repeated or prolonged exposures (Smith et al., 1996, 1997).

The effects of simulated acute heat exposures may reduce immune function, in the short term, (Sheppard et al., 1986; Smith et al., 2005) and it is likely to have longer term consequences, especially if there is insufficient time for recovery between bouts of heat exposure. As well as this firefighting personnel appear to be at greater risk of respiratory (Sheppard et al., 1986) and cardiovascular diseases (Fernhall et al., 2012), although nothing is known about the incidence in FSI. Measurement of immune function and markers of systemic inflammation, following acute heat exposure, have shown alterations indicative of infection or inflammatory process (Smith et al., 2005; Huang et al., 2010). Elevated concentrations of cortisol and interleukin-6 (IL-6) support the suggestion that fire service personal may be at a greater risk of health complications due to repeatedly undertaking demanding thermal exposures when training and throughout their career (Sheppard et al., 1986; Fernhall et al., 2012).

FSI are likely to experience larger number of heat exposures, combined with physical exertion, compared to standard fire service personnel and are therefore likely to be at greater risk of the consequences of accumulated heat stresses. However, repeated exposure to heat and exercise may be beneficial in some circumstances. Given suitable preparation and safeguard exercise in the heat on repeated occasions may lead to improved performance, a process termed acclimation (Gibson et al., 2015). The aim of the study was to see whether the FSI were affected by the training programme and to quantify the physiological strain, perceptual stress and markers of inflammation and immune function in a cross-section of FSI and provide data on their changes during their typical working routines. A further aim was to measure FSI experiences of the repeated heat exposures and their effects on fatigue perception. The study examined the effects of a rest period before return to training. In particular we were interested in the acute response to a single bout of severe heat exposure, known by the Fire Service as a 'Wear', and the response to a 4 wk fire instruction course. It was hypothesised there would be significant differences in acute and chronic responses to the heat exposure for FSI and that FSI would show physiological, immunological and psychological characteristics different to a non-heat exposed group of matched individuals. We also hypothesised that due to the process of heat acclimation the FSI would experience lower stress due to the heat exposure at the end of the training period.

2. Methods

2.1. Participants

Six male FSI from the Fire Service College (Moreton-in-Marsh, England, UK) and six non-firefighter control (CON) participants volunteered after providing written informed consent to participate (Table 1). The study was approved by the Institution Ethics Committee and conducted in accordance with the Declaration of Helsinki (revised 2008). FSI had a range of service history (2–10 years), while CON participants had not been exposed to ambient temperatures >25 °C in the previous 4 months to any measures taken.

2.2. Experimental design

Initial physiological, perceptual, inflammatory and immunological measures, were taken at the end of a previous instruction course, the control group were measured at the same time of the year. The measures were repeated after 7 wks of no-heat exposure for the FSI, all volunteers maintained normal exercise routines. This was followed by a 4 wk breathing apparatus fire instruction course that included fifteen Wears per instructor. At the end of the course FSI were re-measured. The control group were re-measured at a similar time of the year to the FSI to avoid any seasonal influences on the variables measured and the activities in Wear 1 and Wear 2 were matched as closely as possible. (Fig. 1). For measuring the acute response to heat, Wear 1 and Wear 2 were used and matched for working conditions as much as was possible, in terms of exposure time and thermal environment.

2.3. Experimental procedures

2.3.1. Fire instruction drills

The fire instruction drills included fire behaviour, fire attack and, search and rescue. FSI wore their fire protective clothing during the Wears; including jacket (Bellyclare Special Products Ltd.), trousers (Bellyclare Special Products Ltd.), boots (9005 GA, Jolly Scarpe, USA), flash hood (MSA Gallet, Bellshill UK), helmet (FISF, MSA Gallet, Bellshill, UK), gloves (Firemaster 3, Southcombe Brothers Ltd, Somerset, UK) personal undergarment and self-contained breathing apparatus (SCBA), weighing ~21 kg in total. Wears lasted 37 ± 19 min (range 15–120 min), temperature in-Wear averaged 174.0 ± 83.9 °C and were typically conducted 1 or 2 times per day over 4 consecutive days, followed by 3 days without exposure. On one occasion a FSI had three Wears in 1 day. Work rotas determined the role of the FSI during the Wear and therefore the duration and thermal stress experienced. Although FSI do not undertake firefighting duties, they continually assess and monitor trainees, set and stoke fires, carry dummy casualties and climb stairs. FSI roles are intermittently changed between instructors, as some are situated within direct heat exposure, while others observe from a distance.

2.4. Physiological measures

Heart rate (HR) was measured continuously using telemetric monitors (Accurex+, Polar Electro, Oy, Kempele, Finland). Rectal temperature (T_{re}) was measured pre and post Wears using a single use probe (449H, Henleys Medical, Hertfordshire, UK), placed

Table 1
Physiological and perceptual changes over the 4 weeks of the fire instruction course for Fire Service Instructors (FSI) and controls (CON) (mean ± SD).

	First assessment		Final assessment	
	FSI	CON	FSI	CON
Age (years)	41 ± 4	40 ± 3	–	–
Stature (cm)	178 ± 1	178 ± 2	–	–
NBM (kg)	83.3 ± 11.4	78.1 ± 8.1	83.1 ± 11.2	78.1 ± 6.9
FVC (L)	4.73 ± 0.70	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
FEV_1/FVC (%)	84 ± 6	84 ± 9	91 ± 6	86 ± 8
PEF (L)	643 ± 106	680 ± 127	633 ± 119	660 ± 151
CO (ppm)	5 ± 8	2 ± 3	5 ± 5	2 ± 0
Systolic BP (mmHg)	134 ± 16	143 ± 22	138 ± 12	140 ± 8
Diastolic BP (mmHg)	81 ± 9	87 ± 9	8 ± 7	86 ± 8
$\dot{V}O_{2max}$ (ml kg^{-1} min^{-1})	49.4 ± 9.1	51.5 ± 5.9	46.4 ± 4.9	54.3 ± 8.9

* Denotes significant difference from pre to post 4 weeks of the fire instruction ($p < 0.05$).