Advances in Forest Fire Research 2018

EDITED BY
DOMINGOS XAVIER VIEGAS
ADAI/CEIF, UNIVERSITY OF COIMBRA, PORTUGAL

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Assessment of a human body thermoregulation software to predict the thermophysiological response of firefighters

António M. Raimundo; A. Virgilio M. Oliveira; Divo A. Quintela

ADAI-LAETA, Department of Mechanical Engineering, Faculty of Sciences and Technology of the University of Coimbra, Portugal. {antonio.raimundo@dem.uc.pt}

2 Department of Mechanical Engineering, Coimbra Institute of Engineering of Polytechnic Institute of Coimbra, Portugal, {avfmo@mail.isec.pt}

Abstract

Firefighting requires hard work in very hot environments that often lead to a continuous increase of the heat stored in the human body, promoting heat stress and heat-related illnesses. Due to safety reasons of the individuals involved, a complete characterization of the evolution of the thermal stress state of firefighters is only possible through numerical simulations of the thermophysiological behavior of the human body.

The present work has two main objectives: (i) the assessment of the effectiveness of some body cooling techniques capable to mitigate the risk of hyperthermic stress; and (ii) the evaluation, test and validation of the ability of a human body thermoregulation software to predict in detail the thermophysiological response of firefighters.

The software under evaluation, the HuTheReg program, was developed by the authors. This tool is composed by several modules, namely for the calculation of the human body thermophysiological response, the heat and water transport through clothing, the heat and mass exchange between the external surface of clothing (or skin) and the environment, the start and evolution of skin injuries (pain and burn) and the detection of specific incidents.

In the field of body cooling methodologies, the cases selected embrace 3 different classes of scenarios: (i) body cooling during both exercise and recovery phases (by use of an ice jacket, by intake of very cold water or ice slurry, by both); (ii) body cooling only during the exercise phases (by use of an ice jacket, by intake of very cold water or ice slurry, by both); and (iii) body cooling only during the recovery phases by exposure to a cold environment (passive exposure, with hands and forearms immersion in cold water, with forced air movement using fans, with the use of an ice jacket, with the intake of very cold water or ice slurry, with a combination of these cooling methodologies).

The comparison between the experimental and the predicted values shows a good prediction ability of the HuTheReg program, which is a good indication of its capability to reproduce the human body thermoregulatory responses over the range of climatic conditions investigated. Although with very different effectiveness, all body cooling techniques considered proved to be capable to mitigate the level of hyperthermic stress of firefighters engaged in characteristic activities.

Keywords: Safety firefighting; Human thermoregulation modelling; Software validation; Body cooling techniques

1. Introduction

Firefighting requires long periods of hard work in very hot environments which often lead to a continuous increase of the heat stored in the human body, promoting heat stress and heat-related illnesses [Raimundo and Figueiredo 2009; Barr et al. 2010].

Firefighting may lead to increases in deep body temperature to values higher than 39°C which may have serious consequences or be even fatal [Carter et al. 1999; Raimundo and Figueiredo 2009]. Temperatures above 39°C represent acute hyperthermic stress. When attained, the person physical and...