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Influence of Wet Cooling Vest on Firefighters' Protective Clothing*

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Abstract

Firefighters' Protective Clothing (FPC) is essential for protection against thermal and physical threats. FPC must be comfortable, enable heat transfer from the wearer to the environment and should not restrict motion of body parts. The application of a cooling vest under protective clothing may prevent overheating by cooling at the microenvironment level while working in a hot environment during firefighting. In this study, the effect of using a passive system, in the form of a nonwoven fleece material, was investigated. This system was distributed across the surface of a vest on the upper front chest and back. In this passive system, hydro-crystals swell on contact with cold water, lowering body temperature or holding the body temperature at a normal level. The thermal insulation of the wet and dry cooling vest was tested using a thermal manikin. Results showed that the thermal resistance of the system dropped significantly due to replacement of dry air with moist air with higher thermal conductivity. This reduction was proportional to the amount of moisture present within the system.

Keywords: Cooling Vest; Firefighters' Protective Clothing; Thermal Manikin; Hydro-crystals

1 Introduction

Firefighters' Protective Clothing (FPC) must comply with the standards such as BS EN 469 and AS 4967-2009 to assure their protective properties against life threating risks and skin burns. FPC is usually a multilayer construction (three or four layers) of different fabrics to provide essential protection [1-3]. However, this multi-layered fabric system makes heat exchange between the human body and the environment difficult, due to the presence of a semi-permeable or impermeable moisture barrier. The restriction of metabolic heat exchange with the environment may lead to heat stress for the firefighters. As a consequence, it may result in accumulation of sweat

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under the clothing next to the skin. This in turn may lead to a reduction in comfort, reducing performance and even becoming life threatening in an extreme hot environment [1, 2].

Several researchers, Havenith and Heus [4], Groeller and Taylor [5], Raimundo and Figueiredo [6], have studied the influence of FPC on fire safety improvement and optimization, heat production and injury prevention. These studies focus on the environmental working conditions to which firefighters are exposed, on simulations of thermoregulatory responses and on parameters of firefighter's clothing. FPC properties have to be investigated in details as accumulation of heat in the human body and sweat in the microenvironment of clothing mostly depend on the garment characteristics. Generally, metabolic heat and generated sweat are captured between the human skin and the outer shell of FPC, due to the structure of this type of protective clothing which includes an impermeable or semi-permeable layer to prevent chemical slippage into the system. Such a layer reduces the breathability of the FPC, while restricting heat and moisture transfer from inside the system to the environment. It is clear that this impacts on the physiological and behavioral reactions of firefighters' and may cause significant undesired reactions, namely introversion (violent sweating, loss of judgment, amnesia), superficial skin damage (pain and first degree burns), heat stroke (fainting, cessation of sweating, central nervous system alteration) and permanent injuries (greater than first degree burn, brain damage or, in more serious cases, death) [4-6]. A variety of systems are used for cooling firefighters during work out as shown in Fig. 1.

(a) (b) (c) (d) (e)

Fig. 1: Systems for cooling firefighters: (a) Drager, (b) Arctic Heat, (c) Cool Comfort, (d) Flexi Ice Vest [7, 8, 9, 10] and (e) Cooling vest [11]

Each system differs in performance over time and functionality. The focus of this paper is on the passive cooling system using a cooling vest. The passive system, in the form of a nonwoven fleece material, was distributed across the surface of a vest on the upper chest and back. A nonwoven fleece with hydro-crystals swells on contact with cold water and, in turn, cools the wearer or keeps their skin temperature at normal levels. The lower part of the vest was made of a polyester air-netted material. We hypothesize that this cooling vest can decrease the thermal insulation of firefighters' clothing. The cooling vest may be used while performing high intensity work, such as firefighting, and can be used as standalone product or in combination with other breathable or non-breathable clothing [11]. Furthermore, it may be used as a pre-cooling system prior to activity, as inter-cooling during activity and as post- cooling after high intensity work.

In this study, the effect of presence of a cooling vest on the thermo-physiological comfort of firefighters was investigated. It was hypothesized that the cooling vest would help to maintain a low skin temperature, due to the water evaporation from the cooling vest and higher thermal conductivity of the moist air in comparison with the dry air [11]. Experiments were performed using a thermal manikin with a dry and wet cooling vest worn under the FPC and covered with an impermeable PVC membrane to prevent heat loss by evaporation and mass transfer.