Effect of base layer materials on physiological and perceptual responses to exercise in personal protective equipment

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ABSTRACT
Ten men (non-firefighters) completed a 110 min walking/recovery protocol (three 20-min exercise bouts, with recovery periods of 10, 20, and 20 min following successive bouts) in a thermoneutral laboratory while wearing firefighting personal protective equipment over one of four base layers: cotton, mod- acrylic, wool, and phase change material. There were no significant differences in changes in heart rate, core temperature, rating of perceived exertion, thermal discomfort, and thermal strain among base layers. Sticking to skin, coolness/hotness, and clothing humidity sensation were more favorable (p < 0.05) for wool compared with cotton; no significant differences were identified for the other 7 clothing sensations assessed. Separate materials performance testing of the individual base layers and firefighting ensembles (base layer + turnout gear) indicated differences in thermal protective performance and total heat loss among the base layers and among ensembles; however, differences in heat dissipation did not correspond with physiological responses during exercise or recovery.

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1. Introduction

The personal protective equipment (PPE) worn by firefighters is designed to protect against thermal injuries, products of combustion, scrapes and abrasions and falling objects. The personal protective clothing (PPC), or turnout (TO) gear, is specifically designed to protect against thermal injury and includes a thermal layer and a moisture barrier layer to prevent hot water passing through the material to the firefighter. The turnout gear that firefighters wear is typically manufactured to meet specific industry standards (NFPA, 2006) for thermal protection and evaporative heat transfer. Paradoxically, the equipment designed to afford protection also contributes to the physiological and perceptual strain experienced by the firefighter. The increased physiological strain associated with working in PPE is well documented (Cheung et al., 2010; Duncan et al., 1979; Nunneley, 1989; Sköldström, 1987; Smith and Petruzzello, 1998; Smith et al., 1995), with both the added mass of the gear, and the gear’s insulating and encapsulating properties, and the positioning of the added mass contributing to the strain (Haisman, 1988).

Current standards for thermal protection and moisture transfer of firefighting clothing only apply to the turnout gear worn by the firefighters. However, the entire clothing ensemble, including the base layer or undergarment, would be expected to influence both thermal protection afforded and the transfer of moisture through the garment. Furthermore, some newly developed technical textiles are designed to wick moisture away from the skin and enhance evaporative cooling, whereas others may attenuate increases in temperature through the absorption of heat using phase change materials (Mondal, 2008). In addition to physiological and perceptual benefits, it is possible that different base layer textiles may be sensed as being more comfortable than standard fabrics.

The performance of different base layers under protective gear has been examined by several researchers. Wickwire et al. (2007) determined that a snug-fitting synthetic shirt with moisture-wicking properties worn under a bulletproof vest did not enhance cooling compared with a 100% cotton shirt. Similarly, van den Heuvel et al. (2010) observed no differences in measures of physiological or perceived strain among five different base layer configurations when worn under a standard combat uniform and body armor. Under a combat uniform alone, Fogarty et al. (2009) detected no differences in core temperature (T core), skin temperature (T sk), heart rate (HR) or psychophysical variables between a 100% cotton t-shirt and polyester shirt.

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