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The influence of a menthol and ethanol soaked garment on human temperature regulation and perception during exercise and rest in warm, humid conditions

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ABSTRACT

This study assessed whether donning a garment saturated with menthol and ethanol (M/E) can improve evaporative cooling and thermal perceptions versus water (W) or nothing (CON) during low intensity exercise and rest in warm, humid conditions often encountered in recreational/occupational settings. It was hypothesised there would be no difference in rectal (Tre) and skin (Tsk) temperature, infra-red thermal imagery of the chest/back, thermal comfort (TC) and rating of perceived exertion (RPE) between M/E, W and CON, but participants would feel cooler in M/E versus W or CON.

Methods: Six volunteers (mean [SD] 22 [4] years, 72.4 [7.4] kg and 173.6 [3.7] cm) completed (separate days) three, 60-min tests in 30 °C, 70%rh, in a balanced order. After 15-min of seated rest participants donned a dry (CON) or 80 mL soaked (M/E, W) long sleeve shirt appropriate to their intervention. They then undertook 30-min of low intensity stepping at a rate of 12 steps/min on a 22.5 cm box, followed by 15-min of seated rest. Measurements included heart rate (HR), Tre, Tsk (chest/back/forearm), thermal imaging (back/chest), thermal sensation (TS), TC and RPE. Data were reported every fifth minute as they changed from baseline and the area under the curves were compared by condition using one-way repeated measures ANOVA, with an alpha level of 0.05.

Results: Tre differed by condition, with the largest heat storage response observed in M/E ($p < 0.05$). Skin temperature at the chest/back/forearm, and thermal imaging of the chest all differed by condition, with the greatest rate of heat loss observed in W and M/E respectively ($p < 0.01$). Thermal sensation differed by condition, with the coolest sensations observed in M/E ($p < 0.001$). No other differences were observed.

Conclusions: Both M/E and W enhanced evaporative cooling compared CON, but M/E causes cooler sensations and a heat storage response, both of which are likely mediated by menthol.

1. Introduction

In warm, humid conditions, the thermal gradient between the skin and environment is reduced, along with the capacity for both dry and evaporative heat loss. These factors, along with an elevation in metabolic heat production from exercise, have long been known to reduce work capacity (Rowell et al., 1966). Thermoreceptors located within the body convey information about the accumulation of thermal energy to higher brain structures, and when mean body temperature rises uncontrollably, the cumulative neuronal input is thought to contribute to an inhibitory signal that lowers power output to protect the organism from heat injury (Nybo, 2010). Lessening the inhibitory signal during exercise in the heat may enhance, or help to maintain work. Given the inhibitory signal seems to be accentuated by warm thermoreceptor activation (Tucker et al., 2006; Schlader et al., 2011a, 2011b), it might be attenuated by the cold receptor activation that follows chemical or thermal stimulation. The purpose of this study was to assess whether donning a garment saturated with menthol and ethanol (M/E) can improve evaporative cooling and thermal perceptions versus water (W) or nothing (CON) during low intensity exercise and rest in warm, humid conditions that may be encountered in a recreational or occupational setting.

There is a broad literature assessing the effectiveness of various cooling interventions (ice vests, water immersion) during exercise

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in the heat, many of which are impractical during an actual sporting or working scenario (Barwood et al., 2009; Cheung, 2010; Duffield, 2008). Wetting the skin with water is a simple cooling strategy that can enhance evaporative heat loss and lower skin temperature during exercise in warm, humid conditions (Bassett et al., 1987), and it may also reduce perceptions of heat stress and the requirement for sweat production. In an effort to enhance evaporative heat loss and lessen warm sensations in the heat, some commercial companies have added menthol and ethanol to their water-based skin cooling products. Menthol is a chemical compound that activates the cold receptor TRPM8 (McKemy et al., 2002; Peier et al., 2002) and elicits cool sensations when applied to the skin of heat stressed humans (Barwood et al., 2012, 2014, 2015; Gillis et al., 2010, 2015; Lee et al., 2012). But menthol also induces a heat storage response that is in part mediated by a reduction in cutaneous skin blood flow (Gillis et al., 2015) and possibly a withdrawal of sudomotor function i.e. a delay in the onset of sweating, or a reduction in sweat rate. (Kounalakis et al., 2010). Ethanol, on the other hand is an alcohol that vaporises more quickly than water or sweat, and has the potential to increase the rate of evaporative heat loss from the skin (Godts et al., 2005).

The benefit of wetting the skin with a water-based solution containing ethanol and/or menthol compared to water alone, or nothing at all, is not clear. Mujika et al., (2010) provided highly trained rowers with forearm sweatbands soaked in either a cooling solution containing ethanol, menthol and water, or water alone (no Control condition), during an indoor 2000 m self-paced time trial. The authors observed no significant difference in perceived exertion, time to finish, or pacing strategy between the interventions. The evaporative cooling capacity of this intervention was perhaps limited because the surface area exposed to the solution was small (forearms only) and the sweat bands created an additional barrier to evaporative heat loss between the skin and the environment. Also, the possible negative influence of the ethanol/menthol solution on thermoregulation could not be assessed because the self-paced study design did not control for metabolic heat production. The question raised herein could be answered by applying an ethanol/menthol solution over a larger surface area to allow for greater heat exchange. Replacing the cotton sweat band with a lightweight breathable fabric garment may also improve the vapour pressure gradient between the skin and the air and increase evaporative heat loss. The thermoregulatory and perceptual influence of this intervention should be assessed during fixed work-rate exercise to control metabolic heat production. Given the dearth of research assessing the influence of an ethanol and menthol-based solution in humans, initial research should induce a light to moderate cardiovascular and thermoregulatory challenge to ensure participant safety.

In addition to the evaporative cooling potential attributed to ethanol, menthol, which is also contained within some cooling solutions, '*elicits cold sensations at otherwise indifferent skin temperatures*' (Hensel, 1981, p.32), but also give rise to heat storage due in part to a reduction in skin blood flow (Gillis et al., 2015) and possibly a withdrawal of sudomotor function (Kounalakis et al., 2010). It is difficult to predict whether the theoretical improvement in evaporative cooling imparted by ethanol will outweigh the potential heat storage induced by menthol, and whether thermal perception will improve, or be impaired as a result. It remains unclear whether wetting the skin with a menthol/ethanol/water-based cooling solution absorbed into breathable garments may provide effective short and long term improvements in evaporative cooling and thermal perceptions.

The primary aim of this study was to assess whether donning a shirt soaked with a water-based solution containing menthol and ethanol could improve evaporative cooling and thermal perceptions compared to a water-only soaked shirt, or nothing at all, during rest and exercise in a warm, humid environment. It was hypothesised that there would be no difference (null hypothesis) in deep body temperature, thermal comfort and rating of perceived exertion between the menthol/ethanol skin wetting (M/E), water skin wetting (W), and a dry condition (CON) during rest or exercise, but participants would feel cooler in M/E compared to either W or CON (alternative hypothesis).

2. Methods

2.1. Participants

This experiment received ethical approval from the BioSciences Research Ethics Committee at the University of Portsmouth. Six volunteer participants took part in this within-participant repeated-measures study design, with a mean (SD) age, mass and height of 22 (4) years, 72.4 (7.4) kg and 173.6 (3.7) cm respectively.

2.2. Experimental protocol

Participants completed three, 60-min tests in warm, humid conditions (30 °C, 70% rh). In order to safely assess the effectiveness of the ethanol/menthol solution in humans, a light to moderate cardiorespiratory and thermoregulatory challenge was chosen. Such activity may be comparable to that undertaken by recreational gym users, or those undertaking walking/hiking exercise for extended periods in warm, humid conditions. From an occupational perspective those working underground (i.e. mining) may also be exposed to warm conditions whilst completing moderate exercise for the duration of a shift. Each test began with 15-minutes of seated rest followed by a 30-min period when participants engaged in low intensity stepping exercise at a rate of 12 steps per minute onto a 22.5 cm box, and ending with another 15-minutes of seated rest.

During each test participants were assigned in a balanced order to one of three different conditions consisting of long sleeve sports shirts (breathable 100% polyester) soaked with either 80 mL of 0.2% menthol +20% ethanol (M/E), 80 mL of water alone (W) or an un-soaked dry shirt serving as a Control (CON); otherwise participants wore shorts and trainers.

2.3. Measurements

Participants arrived at the laboratory, were weighed naked and equipped with a heart rate (HR) monitor (Team System Polar, UK). They then self-inserted a calibrated rectal thermistor (Grant Instruments, Cambridge Ltd., Royston, UK) 15 cm beyond their anal sphincter. Three calibrated skin thermistors (Grant Instruments, Cambridge, UK) were secured by single pieces of adhesive tape (Tegaderm™ Film, 3M, UK) at the right chest, left scapula and right forearm. An estimation of upper body mean skin temperature was obtained using a thermographic camera, which captured images of the back and upper torso/chest. The thermal imaging camera (A320 series, ThermaCAM™, FLIR systems, Kent, UK) captured images of shirtless participants in the infra-red spectral range of 7.5 μm–13 μm, with a temperature range from minus 20 °C to 120 °C and an accuracy of 2%. At 25 °C the camera had a sensitivity of 0.07 °C, and a focal plane array containing 320 × 240 pixels. Thermal images were analysed using proprietary software (Researcher 2.9, FLIR systems, Kent, UK), which allowed the user to select a region of interest *i.e.* chest/front torso (from the nipple line to the umbilicus), or back (from the shoulders to the height of the umbilicus), and obtain a mean surface temperature from that region. Skin and rectal temperatures were recorded on an electronic data logger (Squirrel 1000/1250 series, Grant Instruments,