Motorcycle protective clothing: physiological and perceptual barriers to its summer use

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Abstract

Despite strong evidence of protective benefits, thermal discomfort is a key disincentive to motorcyclists wearing protective clothing in hot conditions. This paper presents some findings from our studies concerning the thermal management properties of motorcycle protective clothing and their physiological impact in hot conditions.

The thermal and vapour permeability and abrasion resistance properties of motorcycle protective clothing were investigated in laboratory tests. The physiological and cognitive impact on humans was investigated using objective and subjective measures under controlled climate conditions and in a real-world riding trial. The aims were to determine: (i) if associations existed between thermal management and the abrasion-resistance properties of a range of commonly available, all-season motorcycle protective suits, (ii) the extent of the thermal load imposed by motorcycle clothing worn in average Australian summer conditions, and (iii) the impact of that thermal burden on psychophysical function.

The results demonstrated significant physiological strain for motorcyclists wearing protective clothing in hot conditions. Wide variations in the thermal characteristics and abrasion resistance properties of the suits tested were identified. Ongoing work is investigating the impact that elevated thermal discomfort and physiological thermal strain can have on riding performance and the potential for clothing features, such as ventilation ports to reduce thermal discomfort. These results will determine thresholds for the thermal qualities of motorcycle clothing required for an acceptable compromise between user comfort and injury protection. The outcome will inform industry and consumer information programs about the performance required of motorcycle protective clothing suitable for use in hot conditions.

Introduction

Protective clothing can induce heat strain by trapping metabolic heat with potentially severe consequences for physiological and cognitive function (Faerevik and Reinertsen 2003, Caldwell et al. 2006). Thermal discomfort has also been identified as a key disincentive and potential risk for motorcyclists wearing protective clothing in hot conditions (EEVC 1993, de Rome et al. 2011a, de Rome et al. 2011b). This paper presents a summary of findings from a series of three studies into the thermal management properties of motorcycle protective clothing and their physiological impact in hot conditions.

Method

The first study explored the thermal comfort properties of motorcycle clothing commonly worn in Australia and investigated the association between the thermal and abrasion resistance properties. The second investigated the physiological and cognitive impact on humans wearing motorcycle clothing under controlled climate conditions (de Rome *et al.* (in press)). Thirdly we examined the impact of motorcycle clothing under different riding conditions in a real-world riding trial.

Study 1. Ten sets of all-season motorcycle protective jackets and pants were selected to represent a range of those most commonly worn in Australia. Their thermal properties were tested using a thermal, sweating manikin in a climate controlled chamber. Thermal resistance (I_T) was tested at ambient temperature 30°C (45% relative humidity), vapour resistance (R_{eT}) was tested at 35°C(40%) (ASTM F1291-10 2010). Ensembles were tested with optional winter liners removed but ventilation ports closed. The results were used to calculate the relative vapour permeability indices (I_m) of these ensembles ($I_m = K.I_T / R_{eT,}$), where K is a constant (60.6515 Pa/K). A low permeability score indicates a garment is more likely to induce physiologically significant heat strain when worn in hot conditions. The ensemble with the lowest permeability score (I_m=0.09) was selected for use in Study 2. The ensembles were also tested for impact abrasion resistance, measured as time in seconds to hole, using a moving abrasive belt calibrated to the specifications of the European Standard for motorcycle protective clothing (CEN 2002). Results are reported descriptively. Scores for impact abrasion and vapour permeability were graphed to identify any trends in association between protective performance and thermal comfort.

Study 2. Human trials were conducted in a controlled climate (chamber) to simulate motorcycle riding in an Australian summer. Ambient temperature was *based on the range from 14th to 86th percentile average summer temperatures in Australia's seven largest cities.(BOM 2014) Temperatures were* set at 25°C (Trials A, B), 30°C Trial C and 35°C Trial D(BOM 2014). Relative humidity was 40% for all trials. Radiant heat was provided by three 500-W infra-red lamps suspended above the participant. Wind speed was simulated by a fan with velocity 30 km.h^{-1}. This study used a repeated measures design with the 12 participants acting as their own controls. They each completed four 90-min trials over four weeks, comprising one control trial (A) and three experimental trials (B, C, D). Participants were dressed identically to the manikin using the ensemble selected from Study 1 in the three experimental trials, and street clothes (jeans, long-sleeved t-shirt) in the control state. In all conditions they wore helmet, gloves and boots. The ventilation ports in the experimental garments were closed to ensure participants were tested under conditions where motorcycle clothing was most likely to disturb thermal homoeostasis. Heart rate, deep-body temperature (auditory canal) and skin temperature were continuously monitored. Self-reports of thermal and skin wetness sensation and discomfort were collected at regular intervals. Sweat rates, clothing moisture retention and evaporation rates were determined by weighing all garments before and after each trial. Results in the full paper are presented as descriptive parameters and comparisons conducted using paired t-tests and two-way ANOVA.(de Rome *et al.* 2015)

Study 3. Volunteer riders (N=22) wearing their own motorcycle protective clothing, were randomly assigned to one of two routes devised to represent 90-min. urban commuter rides or recreational rural rides in March 2015. Riders' reports of thermal and skin wetness sensation and discomfort (Gagge *et al.* 1967) were recorded at two pre-determined 5-minute rest stops. Skin temperature and humidity inside clothing was monitored continuously throughout the rides using sensors attached to the skin. Computer-based cognitive tests of reaction-time and executive function, measures of workload -Raw Task Load Index –(RTLX) (Byers J.C. *et al.* 1989)) and mood -Visual Analogue Mood Scale (VAMS)(Bond and Lader 1974) were conducted pre- and/ or post-ride. Results were analysed using SAS Mixed procedure for repeated measures.

Results

Study 1. Thermal (I_T) resistance averaged 0.36(SD:0.05) and vapour resistance (R_{eT}) averaged 140.7(SD:68.3), with only a moderate correlation between the two measures (r=0.53). The ensemble with the lowest vapour permeability (I_m=0.09) was then tested in Study 2. Eight of the ten suits failed to achieve the minimum impact abrasion resistance (4 sec.) in Zones 1 and 2 as required by the European Standard (CEN 2002). Comparison of abrasion resistance and vapour permeability index scores showed no clear pattern for jackets, but the pants with the highest abrasion resistance were also those with highest vapour permeability.

Study 2. Trials A and B were conducted at 25ºC. While body core temperature remained stable, heart rate, skin temperature and sweat production all increased significantly. In trial B, participants reported feeling hotter, more sweaty and less comfortable than in Trial A (<0.05). In fact, sweat production had doubled and whereas all sweat had evaporated in Trial A, only 60% evaporated in Trial B, leaving 40% of trapped with the clothing. The substantial physiological differences between Trial A and B are attributable to the difference between street clothes and motorcycle clothes.

There were also significant increases in physiological measures between each of the experimental trials (B-D) and the control trial. Heart rate and skin temperature increased significantly (P<0.05) from trials B to D. As the ambient temperature approached core body temperature, dry heat loss from the skin was reduced and body-body temperature increased.

Study 3. The average ambient temperature during the road trial was unexpectedly cool, 21ºC with 37% relative humidity. Those riding the urban route were slightly warmer (25.7ºC versus 25.5ºC, P=0.005) and wetter (42.4% versus 40.9% P=0.06) than those on the rural route. Subjective ratings of thermal sensation were consistent with measured skin temperature (P=0.004) but ratings of thermal discomfort were not (P=0.76). Subjective ratings of wetness sensation (P=0.001) and wetness discomfort (P=0.04) were consistent with humidity measured within the clothing.

Compared to rural riders, urban riders experienced greater workload (3.5 versus 2.4, P<.0001), felt less alert (37.4 versus 26.0, P<0.05) and less contented (19.3 versus 13.8, P<0.05) on completion of the ride. .

Discussion

These studies provide the first objective measures of the thermoregulatory performance of the protective clothing worn by a high proportion of Australian riders. The results have demonstrated significant potential for physiological strain for motorcyclists wearing protective clothing in hot conditions. The critical threshold occurs when the air temperature exceeds skin temperature thereby preventing dry heat losses. Beyond that point, riders must rely wholly upon evaporative cooling which may be restricted by clothing.

The on-road trial demonstrated the importance of vapour permeability even in cool weather. In addition to the differences in thermal comfort observed between urban and rural riders, the differences in workload and mood is also of interest. Those routes were selected primarily in order to explore differences in wind cooling effects between low and higher speed riding. These results suggest that the complexity of urban riding may place higher physiological demands on riders than less complex but higher speed rural roads. Further work is required to investigate the features of urban versus rural riding environments and their impact of rider fatigue and mood as a potential factor in crashes.

The results also suggest that subjective ratings of thermal and wetness sensation, if not comfort, may be valid and less costly instruments for assessing thermal comfort for studies where more precise instruments are not viable. The wide variation in thermoregulatory performance between garments suggests that thermal comfort can be improved. Comparison of the results for vapour permeability and the abrasion resistance of the pants tested also indicate that improvements in thermal comfort need not be at the expense of safety.

Ongoing work aims to establish the effectiveness of clothing features such as ventilation ports on thermal discomfort. The next stage will investigate the impact that thermal discomfort and thermal strain may have on riding performance. The results will determine thresholds for the thermal qualities of motorcycle clothing required for an acceptable compromise between user comfort and injury protection. The outcome will inform industry and consumer information programs about the performance required of motorcycle protective clothing suitable for use in hot conditions.

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