EF2000 Interim AEA Chest Counter-Pressure Garment and Thermal Strain: Effects of Reduced Bladder Coverage

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INTRODUCTION

An enhanced G protection system has been developed to reduce the effort required by aircrew to tolerate the sustained, high levels of +G acceleration that may be encountered when flying the Eurofighter 2000 (EF2000) aircraft. The clothing consists of increased coverage anti-G trousers and positive pressure breathing with chest counter-pressure (CCP), which results in a greater level of insulation in comparison with the standard anti-G aircrew equipment assembly[1]. As the main fabric of these garments is impermeable, the question arose whether some modification of the CCP garment could be made which would result in a reduction in the overall thermal strain. The present study assessed the thermal strain associated with wearing CCP garments in which the bladder coverage had been reduced.

METHODS

Subjects were 3 males, aged 29, 36 and 42. Core temperature was measured using a rectal probe and skin temperature was measured at eight body sites. Heart rate was measured using a 3-lead configuration. Subjects were weighed nude and after donning the EF2000 interim summer clothing assembly, except that for each of the 3 experimental occasions a different CCP garment was worn, being either the current EF2000 CCP garment with full bladder coverage ("full"), a garment with bladder coverage absent over the back area ("backless") and a garment in which bladder coverage was reduced over the whole garment by means of holes ("perforated").

Automatic logging of body temperature, at 1 min intervals, was started while the subject remained seated for 15 min after which he entered the hot chamber environment (dry bulb temperature, 35±1°C; globe temperature, 45°C; relative humidity, 10%; air movement 1m s^{-1}). The subject sat quietly for 15 min, after which he exercised for 5 min by pushing the lower legs against a 10 kg load. At the end of exercise the subject rested for 10 min. The sequence of 5 min work followed by 10 min rest was repeated a further 6 times during 2h exposure to the hot environment. At 15 min intervals the subject indicated his thermal comfort on a 4-point scale. At the end of the 2h exposure the subject was re-weighed, the differences before and after exposure for nude weight indicating the amount of sweat secreted and the difference for clothed weight indicating the amount of sweat evaporated.

Means over 10 mins for core temperature, skin temperatures and heart rate were analysed using repeated measures analyses of variance in which the 2 repeated factors were time (10 min blocks; the first block being the pre-exposure baseline control) and garment ("full", "backless", "perforated"). Data for body and clothing weights were analysed using repeated measures (pre/post-exposure and garment) analyses of variance.

RESULTS

Rectal temperature - There were no effects with respect to CCP garment. After an initial fall from baseline level, mean rectal temperature in the heat rose gradually and was 0.81°C above baseline control at the end of 2h exposure to heat.

Skin temperatures - All skin temperatures rose during heating but there were no differences with respect to CCP garment for temperatures of the biceps, forearm, thigh, calf, upper back, lower back and chest. For the abdomen temperature, a lower temperature was observed with the "perforated" garment than with the

"backless" and "full" ($p<0.01$), which did not differ from one another. The Ramanathan mean skin temperature[2], the mean temperature of the 4 torso sites and the means of the 2 arm and 2 leg sites did not show any differences with respect to CCP garment.

Heart rate - There were no differences in heart rate with respect to CCP garment. Mean heart rate increased from 68 beats/min in the 10 min period preceding exposure to 111 beats/min at the end of 2h exposure to heat.

Weighings - Nude weight before exposure was greater than after ($p<0.05$), indicating significant loss of body weight through sweating, while clothed weight was greater before exposure than after ($p<0.01$), indicating significant evaporative sweat loss. There were no differences in the nude or clothed weights, or in the fraction of sweat evaporated, with respect to CCP garment worn.

Thermal comfort assessments - No effects were observed.

DISCUSSION

In the present study, rectal and skin temperatures, together with heart rate, rose in response to the thermal stress imposed. Normal thermoregulatory responses were evident as significant sweat loss and evaporation, with the mean rectal temperature rise within 1°C of baseline. However, there were no differences in these measures with respect to the CCP garment worn, except in the skin temperature of the abdomen which demonstrated a lower temperature when the "perforated" garment was worn, compared with the other two garments.

A lower abdomen temperature while wearing the "perforated" garment may have been a consequence of a greater flow of air through the garment front than would be the case with the impermeable fronts of the "full" and "backless" garments, particularly as the subject faced into the flow of air. Similarly, there was a tendency for the chest temperature also to be lower with the "perforated" garment, while the skin temperatures of the back showed no difference between garments as airflow over the subject's back was likely to be limited to some extent by the back of the seat.

There was also no indication from clothing weights of any differential sweat loss from the upper and lower halves of the body when wearing the different CCP garments. Equally, there was no evidence that the more permeable garments improved "sweating efficiency" as the percentage of sweat evaporated did not differ between CCP garments. Thus it would appear that reduction of bladder coverage over the back area of the CCP garment did not confer any advantage over the current full coverage garment in terms of the reduction in thermal strain.

The advantage of reduced skin temperatures at the front of the torso with the "perforated" garment was, however, small and would constitute insufficient evidence to recommend modification of the current CCP garment, particularly in the absence of any indication of a reduced rise, or rate of rise, in core temperature, or of any reduction in sweat loss.

REFERENCES

1. Sowood P.J. and O'Connor E.M. 1993, Warm weather flight trial of prototype EFA interim AEA, Royal Air Force Institute of Aviation Medicine, AEA Report No 624.

2. Ramanathan N.L. 1964, A new weighting system for mean surface temperature of the human body, J. Appl. Physiol 19, 531-533.