Thermal Strain in F-18 Pilots During Sustained Chemical Defence Operations

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INTRODUCTION

Chemical defence (CD) operations generally require aircrew to wear specialised individual protective equipment (IPE). For Canadian Forces F-18 pilots, the CD-IPE includes extra layers of clothing as well as a fully encapsulating rubber hood (AR-5 respirator) over the head. The addition of these clothing elements to the standard flight ensemble increases the insulation over the body and interferes with heat dissipation.

When operations are conducted in hot climates, high ambient temperatures and humidity make it more difficult for the body to dissipate internally generated heat. Conditions inside the cockpit can at times be so extreme that the surroundings actually become sources of heat to the body. The combination of external environmental stress, internal heat production, and increased clothing insulation could lead to unacceptable levels of thermal strain in aircrew.

The present study was undertaken to evaluate thermal physiological strain in F-18 pilots wearing full IPE during sustained CD operations in warm weather.

METHODS

The study was conducted at Canadian Forces Base (CFB) Baden in Germany during the period 22 May – 4 June, 1988. All flights were carried out using dual-seat F-18 aircraft modified to accept the front-seat pilot wearing the full CD-IPE and the back-seat safety pilot wearing normal flight clothing and equipment. The protocol involved six pilots flying seven missions over a three-day period in full IPE. During the first week, three pilots acted as IPE pilots while the remaining three acted as daytime safety pilots (a different safety pilot flew back-seat during the evening missions). During the second week, IPE and safety pilots reversed roles.

For two consecutive days, IPE pilots flew two back-to-back missions over an eight-hour period followed by a night mission in full IPE. Pilots remained encapsulated in IPE for the full eight-hour period of the two daytime missions but undressed and re-dressed in IPE prior to the evening flight. The third day involved only a single morning mission. All IPE dressing and undressing procedures were performed in the bunker as if there were a true CD hazard, and pilots slept in the bunker for three nights beginning with the night prior to the first flight. Thus, over the two weeks of the study, six pilots conducted 42 missions in full IPE under realistic sustained CD conditions and extended duty periods (approximately 16 hours/day).

Thermal strain was assessed by measurements of rectal temperature (Tre), heart rate, and dehydration. Data were collected for both IPE and safety pilots, treating the latter as reasonable physiological control subjects even though their daily schedules and duties were slightly less demanding than those of the IPE pilots. Body temperatures and an electrocardiogram were collected continuously throughout the day using 8-channel Oxford 9000 Medilog ambulatory recorders. Dehydration during each encapsulation period was calculated from nude weights obtained before dressing and after undressing in the flight ensembles (corrected for fluid consumed and urine expelled).

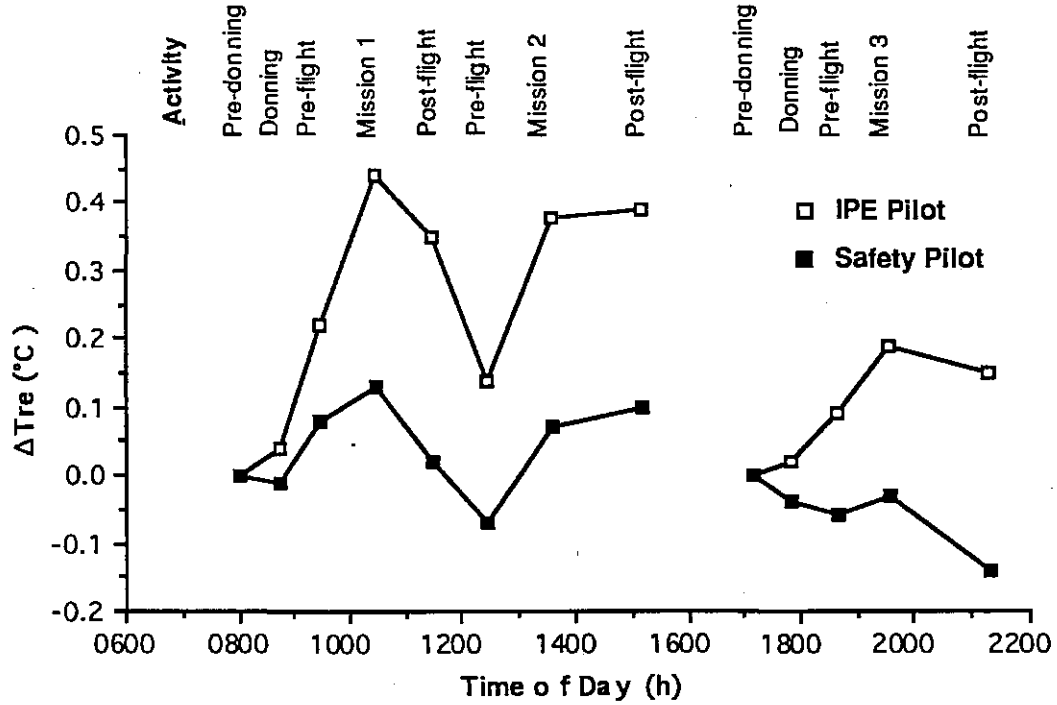
Environmental conditions in the cockpit were recorded at one-minute intervals using a data-logging WBGT meter (Reuter Stokes WIBGET Model RSS217). Conditions on the ground were recorded by a similar meter carried by an observer who followed the subjects throughout the day. The merged WBGT data provided comprehensive records of the environmental conditions experienced by the pilots.

RESULTS

Daily high temperatures on the ground were, on average, about 9°C warmer during the first week of the

trial compared to the second week (27°C vs. 18°C). While this was undesirable from an experimental design perspective, it did provide for interesting comparisons of stress vs. strain. Cockpit temperatures during the first week sometimes exceeded 40°C dry bulb temperature, they averaged >30°C dry bulb during the afternoon missions of the first week, and were always the hottest environmental temperatures to which pilots were exposed throughout a day. Note that cockpit air conditioning was used during flight, but was ineffective in providing a comfortable environment for the pilots during the hottest periods.

Despite the differences in environmental conditions between weeks, Tre values in both IPE and safety pilots were only slightly (but insignificantly) lower during the second week of the study. This allowed data for both weeks of the study to be combined into average daily responses for IPE and safety pilots. The graph below presents these data as change in Tre (after insertion of the probe) against time of day, with the various daily activities listed across the top of the graph. All temperatures other than those at the morning pre-donning and at the evening pre-donning and donning time points were significantly different between pilot types (Student's t-test; $p<0.05$). IPE pilots clearly showed higher levels of thermal strain than the safety pilots. A more detailed activity/time analysis indicated that Tre increases were generally associated with pilot activities involving physical exertion.



Heart rates in IPE pilots were significantly elevated throughout the day compared to safety pilots, running 15–20 beats per minute higher and averaging about 90 beats per minute. Average sweat production per mission in IPE pilots was almost 70% higher in IPE pilots compared to safety pilots, although it depended heavily on environmental conditions. The highest level of dehydration observed in a single subject was 2.2% while the average for IPE pilots was 1.2% over the first (hotter) week.

CONCLUSIONS

Thermal strain was significantly greater in IPE pilots compared to safety pilots wearing standard flight clothing. Despite this, all IPE pilots were able to complete all missions, although some commented that they would not have flown the third mission on some days without a safety pilot. Overall, the stresses observed in this study were tolerable, but this might not be the case when ambient conditions are more severe and/or true combat conditions exist. The major problem appears to be difficulty with dissipation of internally generated metabolic heat, and the multiple layers of clothing tend to attenuate the benefits of cockpit air conditioning. Consideration should be given to providing personal cooling garments to aircrew to alleviate thermal strain and ensure maximum effectiveness in the performance of duty.