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ARMSTRONG LABORATORY

THERMAL STRESS IN U.S. AIR FORCE OPERATIONS

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The voluntary, fully informed consent of the subjects used in this research was obtained as required by AFR 169-3.

The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

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THERMAL STRESS IN U.S. AIR FORCE OPERATIONS

Issues Raised by Deployment to the Persian Gulf

Activities related to Desert Shield and Desert Storm produced a high level of interest in heat stress and heat injury to personnel in U.S. Air Force (USAF) operations. Queries focused on required water intake, the possible need for electrolyte supplementation, and the use of work-rest cycles to prevent heat casualties. Advice on prevention of heat casualties was formulated as a "lesson plan" for Physiological Training Officers and was then revised and forwarded to the USAF Surgeon General's office for issue to flight surgeons. These documents were then modified in the light of operational experience and served as the basis for Air Standardization Coordinating Committee Working Party 61 Proposed Advisory Publication 61/114L, Prevention of Heat Casualties during Air Operations in Hot Weather.

A detailed review of climatic data for the Persian Gulf was undertaken to insure that aeromedical guidance was appropriate to actual climatic conditions. Meteorological data were requested from the USAF Environmental Technical Applications Center (ETAC), Scott AFB, Illinois. ETAC provided Operational Climatic Data Summaries for sites as follows: Iraq (6), Israel (4), Jordan (4), Saudi Arabia (10), other locations along the Persian Gulf (8), and one on the Indian Ocean. Special summaries were extracted from the ETAC data base for the following places: Baghdad, Iraq; Riyadh, Saudi Arabia; Kuwait; Dhahran, Saudi Arabia; Sharjah, Oman; and Salalah, Oman. The following variables were analyzed for the six sites: Heat and humidity; Wet Bulb Globe Temperature (WBGT); nightly minimum dry bulb temperature (Tdb); cumulative heat stress (mean degree-hours above 20 °C). The data showed that heat poses potentially serious problems for flying operations for half the year (May through October), and the nature of the heat stress varies widely from extreme, dry heat (>110 °F, 10 % relative humidity (RH)) at Riyadh to more moderate but humid heat (88 °F, 70% RH) at Salalah. Detailed results were formulated as a technical note, Climatic Heat Stress in the Persian Gulf.

Aircrew Heat Stress

Preliminary data were obtained regarding the cooling capacity of the air-ventilated head and vest units of the Tactical Life Support System (TLSS). This ensemble includes chemical protection, extended-coverage G-trousers, and assisted pressure breathing for protection from altitude and acceleration. The original design included a

liquid-cooled garment, which has now been replaced with an air distribution vest worn between the undershirt and the flight suit. Environmental conditions in our experiments were Tdb=28 °C and black globe temperature=35 °C. The subject wore thermistors on the thigh, torso, head and forehead. He walked on a level treadmill for 10 min, then sat for 20 min, repeating the cycle three times. The first 30-min cycle was used to equilibrate the subject to the warm conditions, following which the ventilating air flow was turned on. The following configurations were tested: 1) Control (demist air only), 2) TLSS head ventilation (no vest), and 3) TLSS Head-Vest with vest flow set to 8 or 15 cfm. Thermal comfort data were collected at the end of each 30-min period during the experiment. Results indicated that ventilation with ambient air provides some relief from moderate heat stress, but that higher air flow is not helpful if the blower system raises inlet temperature.

Aircrew Heat Stress Guidance

Experience with the Fighter Index of Thermal Stress (FITS) indicated the need for a more comprehensive index of heat stress for a wide range of aviation scenarios. The general concept is for an open-ended, semi-quantitative scale which can be used to assess the cumulative effects of heat stress over a series of missions. Due to current emphasis on chemical defense scenarios, the initial version was developed for chemical defense clothing and is documented under Work Unit 2729 04 04.

Real-time Heat Stress Monitors

During the summer of 1990, our laboratory conducted informal trials of two noninvasive systems for monitoring heat stress responses. One was a commercially available radio pill with associated antenna and digital recorder; the system was found to have problems with quality control and signal acquisition that rendered it unsatisfactory for either laboratory or field use at this time. The other product used a single chest strap which incorporated electrocardiogram leads and an insulated skin thermistor (estimated core), and required input of subject age group and clothing type. Signals were recorded on a belt-mounted unit which set off "warning" and "cease work" alarms at limits. Comparison with classical measurements of heart rate and rectal temperature (Tre) in nude and heavily clothed working subjects showed that the estimated core temperature varied with external conditions.

Clothing Effects on Human Thermoregulation

It has been stated that personnel working in impermeable protective clothing will have to stop when skin temperature equals or exceeds Tre because this

"convergence" implies that physical collapse is imminent. The available data base included 42 experiments in hot environments (Tdb= 29-35 °C) which produced convergence. Subjects continued work for up to 45 min after Tsk ≥ Tre, and 29 subjects (70 %) continued work to classical limits (Tre=39 °C and/or HR=HRmax). We conclude that convergence is not an adequate indicator of heat tolerance limits.

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