DISTRIBUTION OF CORE, MUSCLE, SUBCUTANEOUS AND SKIN TEMPERATURES IN COMFORT, WARM AND COLD

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INTRODUCTION

Some years ago I became intrigued with Aschoff's (1) hypothesis that the body had a thermally invariant core and a shell of lower temperature, and that the shell expanded during cold exposure to preserve the temperature of the shell, which shrank in size. Was skeletal muscle part of the core, or the shell or a separate compartment altogether? It also seemed interesting to test Kerslake's (2) idea that "deep skin temperature" controlled sweating. My laboratory developed several special thermistor probes, and, after some pilot runs, the men of the laboratory staff were willing to undertake the following rather uncomfortable experiments.

Data were logged by hand and on a strip chart recorder, producing a difficult mass of numbers. This 1972 data has recently been read into a computer and this report comes from a first look at the graphed data.

METHOD

Four men served as subjects. They were 29 (22-40) years old (mean and range), 1.78 m tall (1.73-1.79), weighed 69.5 kg (67-72) and were healthy, physically active people. Each man sat nude and instrumented in an environmental chamber for a 6-hr session, which included 1 hr or more of thermal comfort and 2 hrs or more of heat and cold. They were encouraged to drink water but did not eat.

Chamber air temperatures were 27 C (comfort), 45 C and 15 C; vapor pressure was between 10 and 14 mm Hg (1.3 - 1.9 kPa) and air movement was less than 0.1 m/sec. Exposure times were long enough that body temperatures stabilized and there was heavy sweating in heat and strong shivering in cold. The times of onset for sweating and shivering were recorded. Two of the men went from comfort to hot to cold; the other two went from comfort to cold to hot.

Body temperatures in the core were measured in the esophagus, rectum and auditory canal. Skin temperatures were measured at 16 sites. Six subcutaneous temperatures (T_{sq}) were measured on the forearm, over the triceps, on the chest, back, thigh and calf. Muscle temperatures were measured in the anterior thigh and in the back in the midlumbar region. Standard Yellow Springs Instrument Co. thermistors were used for rectal and skin temperatures. The special T_{ac} probe was held an individually molded rubber plug and further insulated externally. T_{es} was measured with a Konigsberg Instrument Co. radio pill suspended at the level of the cardiac atria on a string anchored to a tooth, the proper length having been determined fluoroscopically for each man. T_{sq} was measured with short needle probes resembling thumb tacks; the depth was adjusted using spacers under the caps so that the probe reached to 1/2 the skinfold thickness at each site. Two muscle temperature sensors were mounted in Teflon catheters, so that T_{mu} was read at depths of 2 and 4 cm.

Because of the many needle probes and because of the awkward amount of cabling for 28 pairs of thermistor leads, no exercise was attempted.

Skin temperatures, T_{ac}, T_{re} and chamber temperatures were printed every two minutes on a strip chart recorder. The remaining temperatures were read on a digital ohmmeter and then converted by hand to temperature from calibration data unique to each probe. These were tabulated every 10 min.

RESULTS

Inspection of the newly-generated graphic records of these data leads to the following observations, most of them unsurprising. The spread between high and low temperatures in any compartment (core, muscle, subcutaneous and skin) was least in the heat and greatest in cold. Subcutaneous temperatures were higher than those on the skin, and muscle temperatures higher yet -- but there was overlapping. Core temperatures were highest except in heat, when some skin, subcutaneous and muscle temperatures were higher. Heat and cold caused exponential changes toward new steady state temperature levels that were generally reached more slowly as depth from the surface was greater.

Sweating began much earlier in the two men who went from comfort to hot than in the two who went from cold to hot, confirming that precooling delays the effects of heat (3). By contrast, shivering began after nearly the same delay whether the subject had started from comfort or heat, but those who started from heat shivered at higher levels of T_{co}, T_{sk}, T_{sq} and T_{mu}.

The core-shell concept could not be evaluated because sampling at depth was insufficient. The (resting) muscle temperatures seemed to be independent of the core and other compartments. There was so much variation of T_{sq} from site to site that it seemed unlikely that there was a deep skin temperature that controlled shivering and sweating. However, deep-to-shallow temperature gradients in the skin were consistent with the notion that thermal gradients could be sensed as heat flow.

Sweat onset and shivering onset occurred at several levels of temperature in the core, muscle, subcutaneous and skin compartments, depending on the pre-existing ambient condition. Further analysis might reveal combinations of temperature which could predict thermoregulatory response.

CONCLUSIONS

This unusually complete set of body temperature records shows how heat and cold exposure at rest develop new temperature distributions in major body compartments. The data may be useful to those who work with biothermal models. The data arrays are available to others on floppy disk, with a BASIC program for initial handling.

REFERENCES

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3. Veghte, J.H. and Webb, P. Body cooling and response to heat. J. Appl. Physiol. 16: 235-238, 1961.